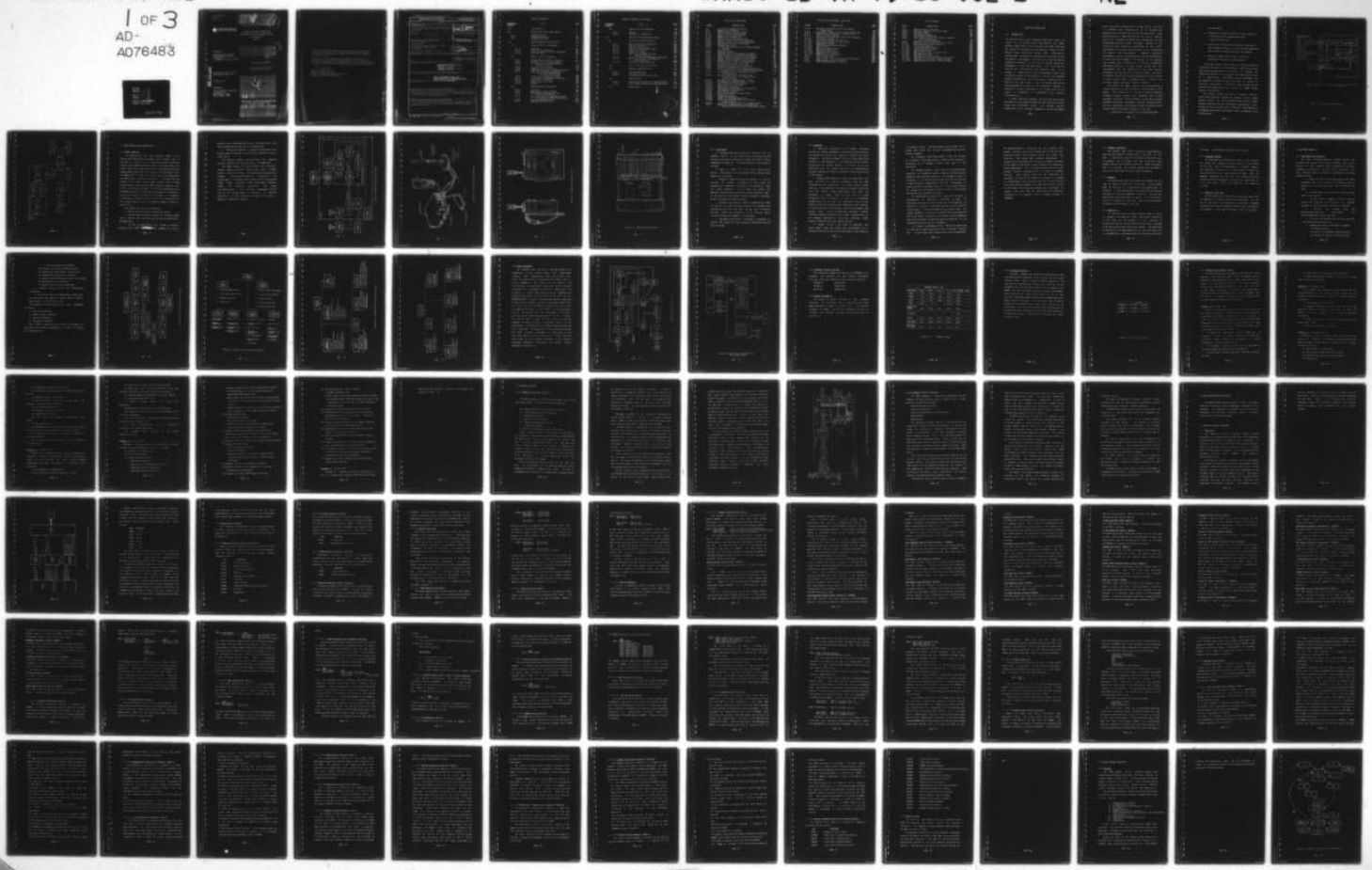
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AIR FORCE REPORT
SD TR-79-13
VOLUME II

AD A076483

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MANPACK/VEHICULAR USER EQUIPMENT (MVUE)
SET DESCRIPTION
VOLUME II

Prepared for:

DEPARTMENT OF THE AIR FORCE
Space and Missile Systems
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Los Angeles, California 90009

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INCORPORATED

This final report was submitted by Texas Instruments Inc, Dallas, Texas, under Contract F04701-75-C-0181, with the Space and Missile Systems Organization, Air Force Systems Command, Los Angeles Air Force Station, Los Angeles, California.

This report has been reviewed by the Information Office (OIS) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations. This technical report has been reviewed and is approved for publication.

JOSEPH A. STRADA, LCDR, USN
Director of Navigation Equipment & Avionics
Navstar Global Positioning System

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This volume describes the design of the MVUE set as implemented in Phase I of GPS, to include set description, software overview; and software/hardware subsystem descriptions.

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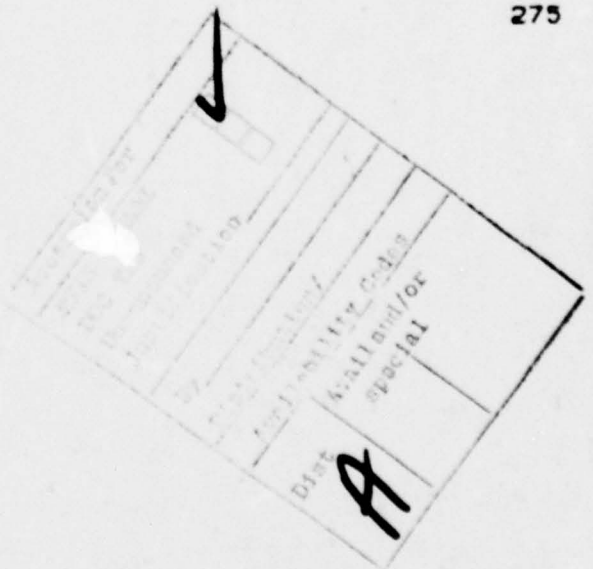
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MVUE SET DESCRIPTION

1.0 INTRODUCTION

This section of the Texas Instruments MVUE Final Report as called out in Contract Data Requirements List (CDRL) sequence number A003 on contract F04701-75-C-0181 describes the design of the MVUE set as implemented in Phase I of the Navstar Global Positioning System (GPS). Historically, sophisticated equipment was designed and fabricated to meet its specific requirements. Although such an approach may be simplest to undertake, it provides only minimum production advantages to each user application. Life- cycle cost and risk for each configuration are typically high. In an attempt to offset some of these disadvantages, there is an inclination toward the development of three or four standard system configurations, one of which may be selected for a specific user application. Such an approach does afford some advantages as a result of the potential increase in production of each configuration, but in most cases it will result in compromise of performance and physical characteristics.

A more effective approach for achieving utility and affordability can present perhaps the more difficult initial design and development issues. This approach requires establishing user equipment commonality, not at the system

level, but at the subsystem level so that similar functions in different user configurations can be isolated and generalized to use identical circuits or subroutines. These building blocks or common modules can be used to satisfy every user equipment requirement and consequently, provide the maximum production volume advantage. Because of the flexibility and commonality established at this level, performance and physical characteristics are not compromised for specific user requirements. Component technology improvements can be incorporated with minimum perturbations to other functional elements. The results is an approach that permits the concentration of efforts in subsequent development phases to be aimed toward product and cost improvements that are beneficial to all users and not encumbered with the difficulties of the "slight" variations of system characteristics and performance that often result in major system level incompatibilities, forcing the evolution toward uniqueness, rework or redesign.

The design of common modules must be preceded by a careful definition of the functions to be performed by each module. This definition is evolved through an iterative elevation process centered upon variables such as QPS equipment functions to be performed, current and projected component technology, performance, physical characteristics, and cost. Basically, this process follows the general steps listed below (illustrated in Figure 1-1 and 1-2):

1. Definition of functions to be performed by QPS

user equipment

2. Separation of these functions into two catagories:
   - Those sensitive to applications and
   - Those not sensitive.

3. Subdivision of application-insensitive functions into elements grouped to provide maximum commonality over the span of identified user requirements.

4. Design of common modules that provide the performance required of these elements.

The design of each common module was guided by imposing constraints defined by the requirements containing the worst case condition applicable to the module. For example, the design requirement for size, weight, and power may be driven by a man-portable requirement while performance and environmental constraints may be driven by missile or satellite requirements. In addition, other constraints and controls were established that guided the common module design to cost efforts.

The system concept and design resulting from this effort permit maximum commonality between various system designs through the use of different quantities of common modules to satisfy specific performance requirements. Also, because of the functional nature of modules, improvements to accommodate performance requirements were incorporated with minimum impact.

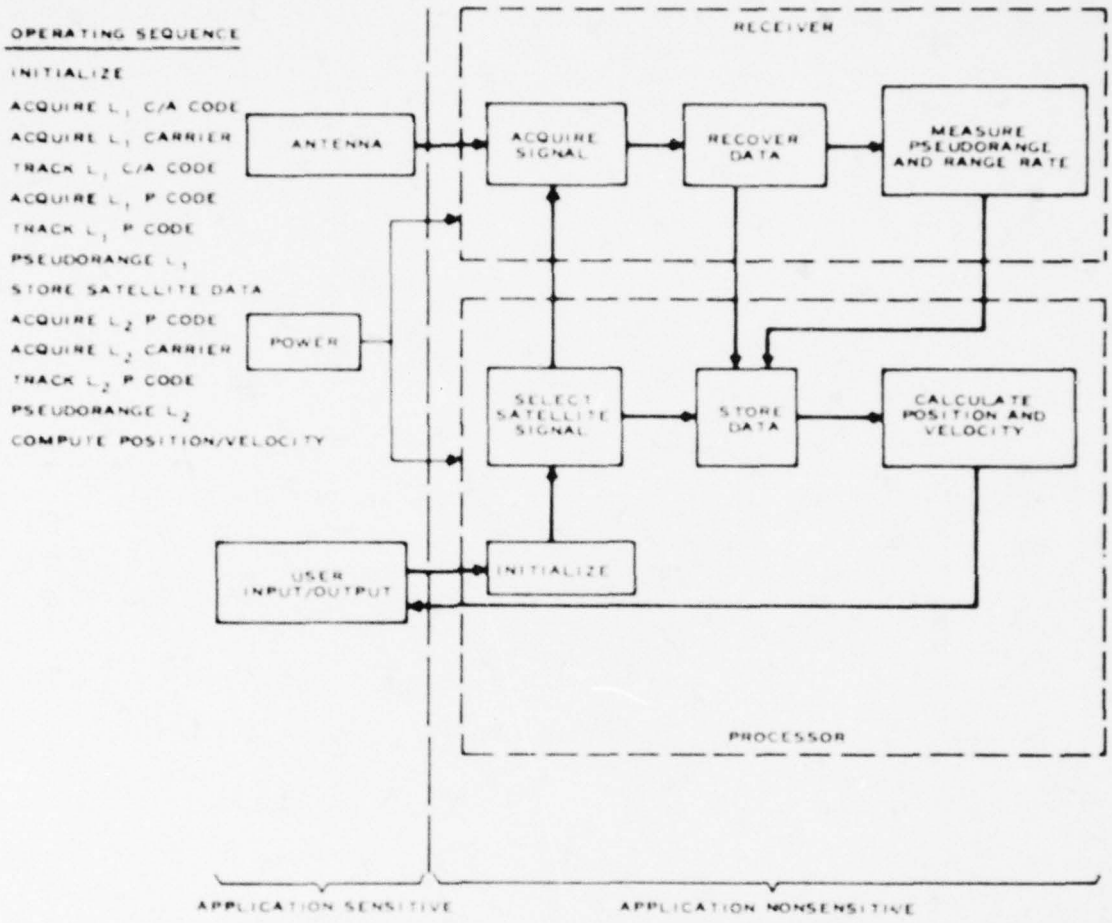


Figure 1-1. Functional Systems Operation

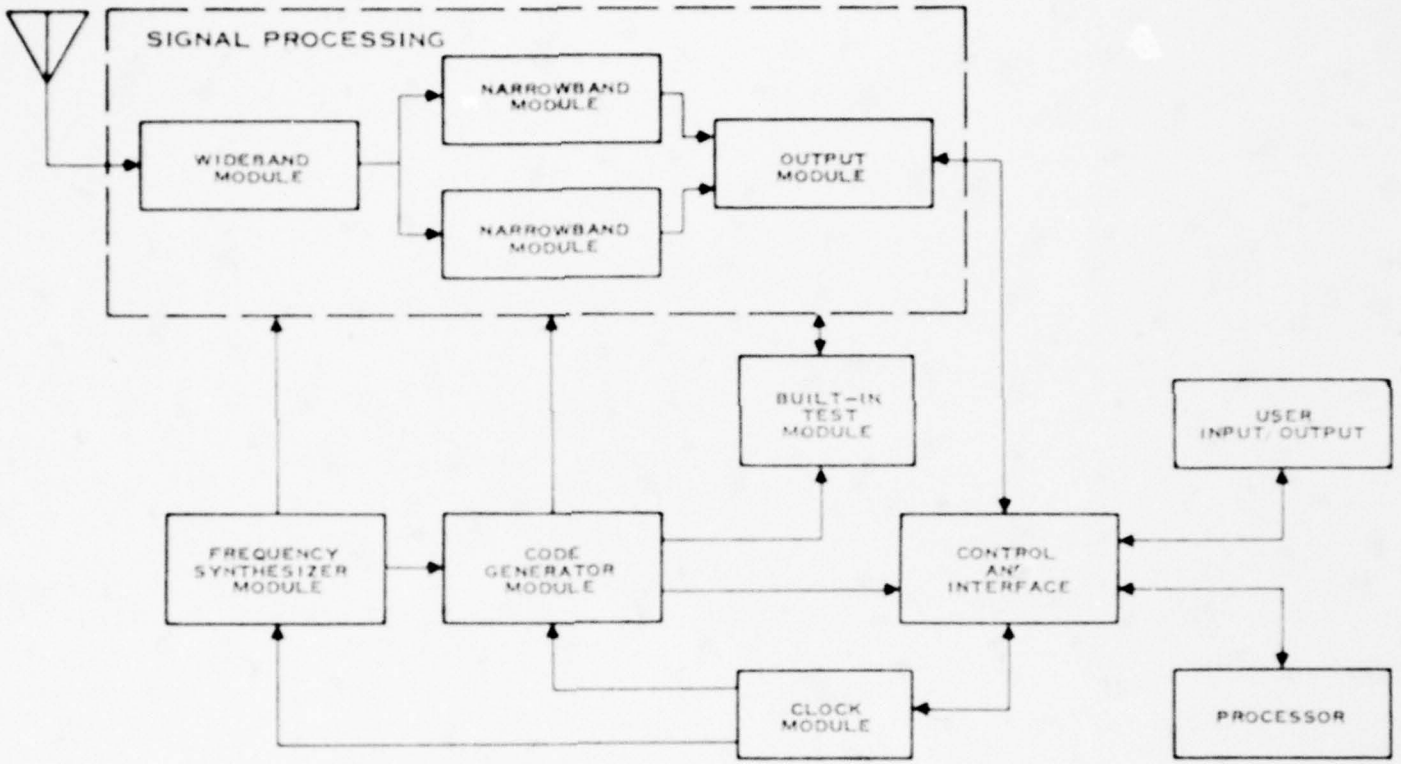


Figure 1-2. General Block Diagram

2.0 MVUE SYSTEM LEVEL DESCRIPTION

2.1 SYSTEM OVERVIEW

The Manpack/Vehicular User Equipment (MVUE) is the appropriate combination of hardware and software that is required to receive and process the available navigation signals into useable navigation data in accordance with the Prime Item Product Specification for the Global Positioning System Manpack/Vehicular Positioning and Navigation Set, CID-ADUE-101A, 3 June 1975. A functional block diagram of the MVUE system is shown in Figure 2.1-1. The heart of the system is a single channel GPS receiver and a TI 9900 microprocessor configured with 48K of memory organized into a 8K root and two 16K pages. A pictorial representation of the MVUE components included when the system is installed in a vehicle is shown in Figure 2.1-2. The MVUE in a manpack configuration is shown in Figure 2.1-3. The configuration of the system modules within the MVUE encasement is shown in Figure 2.1-4.

The primary functions of the MVUE are:

a. Select and acquire GPS transmitter signals.

b. Process GPS transmitter signals and estimate MVUE user's position and time with an accuracy as specified in CID-ADUE-101A.

c. Provide interface with user through a Control Display Unit (CDU), [redacted] on command the user's

position, time, range and bearing to a rendezvous point, and other system outputs specified in CID-ADUE-101A.

d. Provide for operation in manpack configuration with battery power or mounted in a vehicle and powered by vehicle power source.

The detailed system specifications and required physical characteristics are provided in CID-ADUE-101A.

The MVUE system has 8 major modes: off, cold start, operate, almanac collection, standby, warm start, software restart, and built-in-test. The operate mode has two major submodes: initialization/satellite acquisition and steady-state. The steady-state submode has five operational states: normal, ionospheric delay measurement, ephemeris update, new satellite acquisition, and signal loss/reacquisition. The following paragraphs briefly describe the system modes of operation. (A detailed description of user operating procedures is given in Appendix A, MVUE User's Manual.)

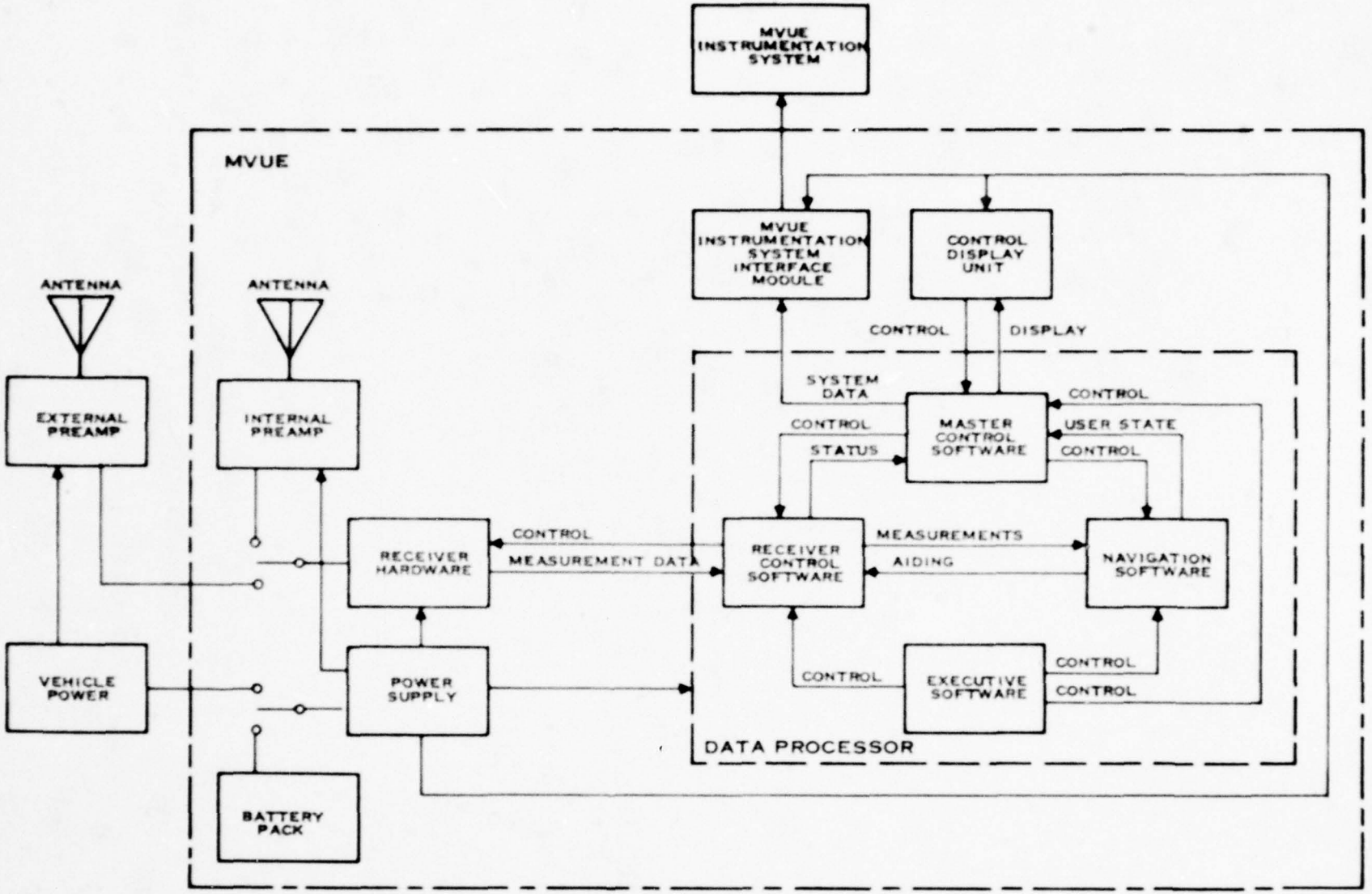


Figure 2.1-1. MVUE Functional Block Diagram

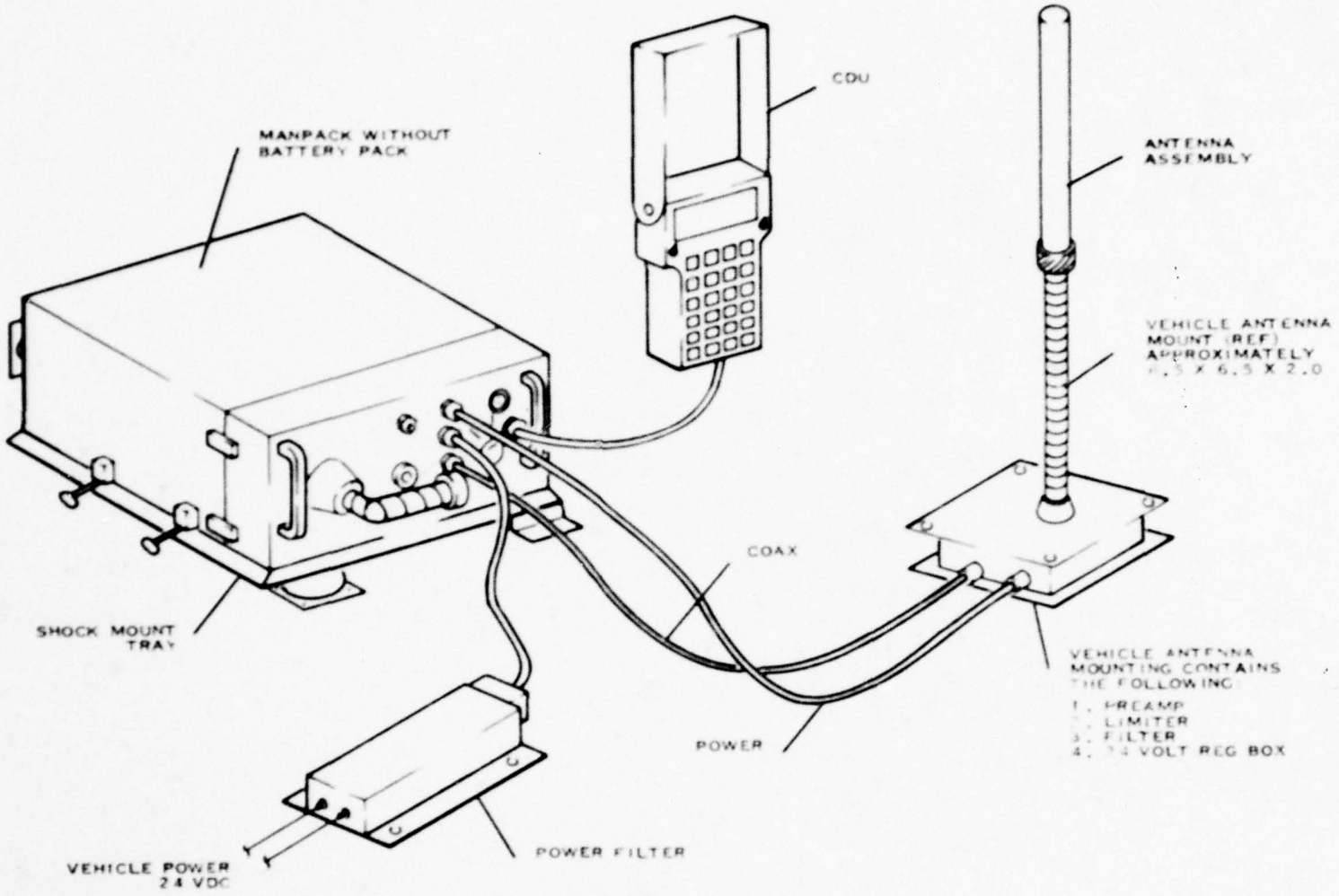


Figure 2.1-2. Overall Vehicle Installation

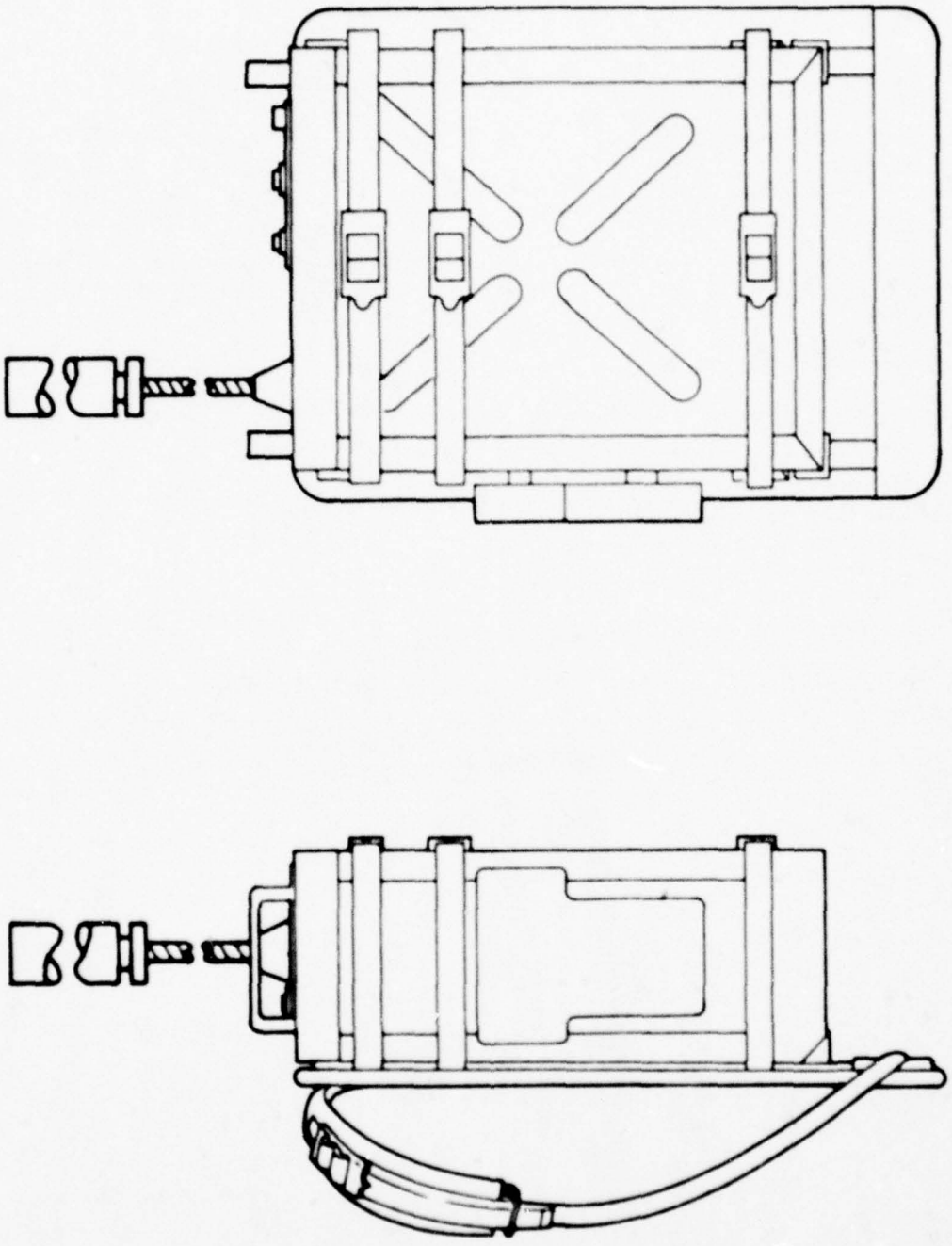


Figure 2.1-3. Manpack on Fieldpack Carrier

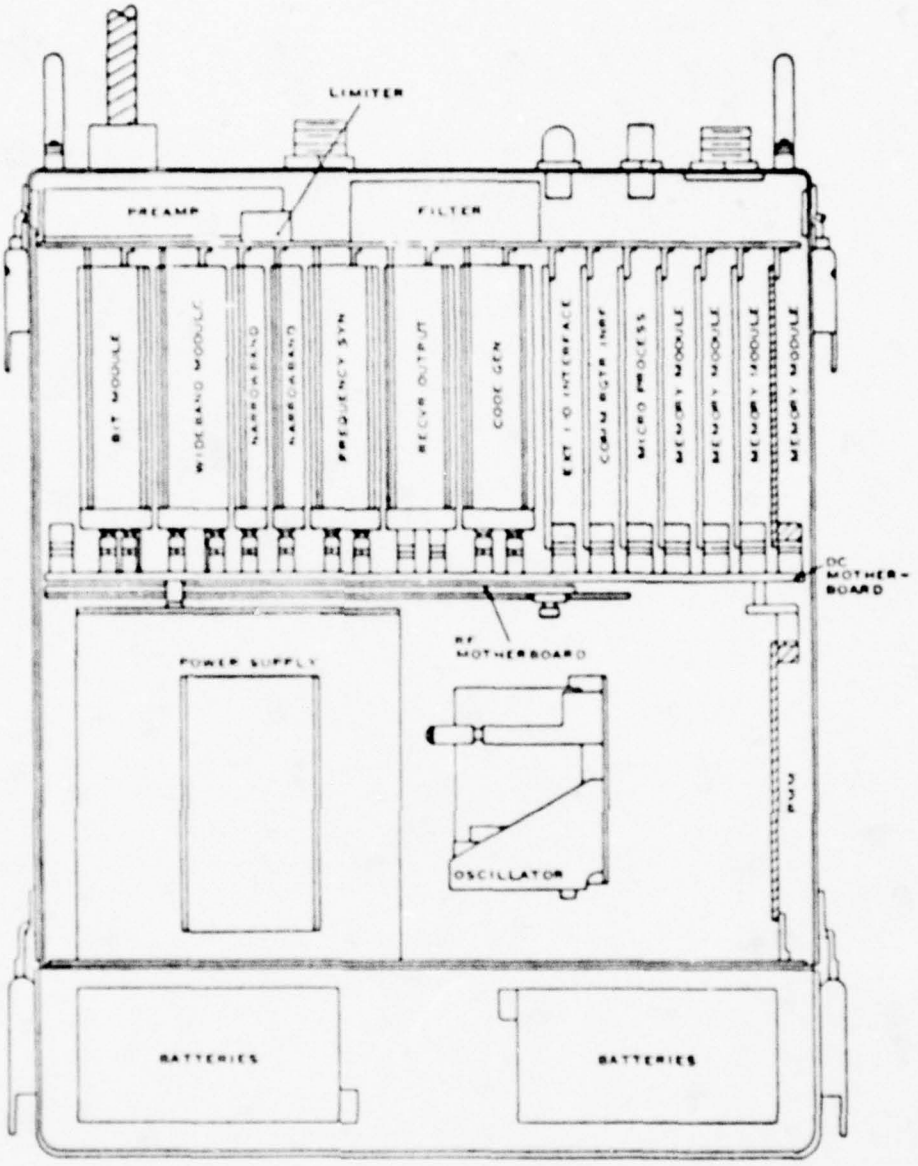


Figure 2.1-4. MVUE Final Configuration

2.1.1 Cold Start

a. Equipment Stabilization Period - At first turn on operator control via the CDU will be prohibited for 13.5 minutes to allow the reference oscillator and other critical components to stabilize. A manual override of this delay is provided.

b. Power Up - After the 13.5 minute stabilization period, the processor will be powered and all random access memory will be zeroed.

c. GO/NO GO - Before alowing the operator to further activate the system, a sequence of self tests are automatically commanded to determine if the system is ready for normal operation. If all tests are passed, the operator's inputs are processed and normal operation begun. If all tests are not passed, a warning message is displayed before proceding to normal operation.

d. System Initialization - Before commanding the MVUE to acquire the satellites and navigate, the operator must initialize his position and time. He may also initialize altitude, select the satellites to be acquired, and/or initialize rendezvous (waypoint) coordinates.

e. Navigation Activation - The system is commanded to acquire the satellites and navigate by depressing the FIX key on the CDU.

2.1.2 Operate

a. Satellite Acquisition - The software subsystem initializes system parameters and then provides aiding to the receiver to acquire the satellite signals and begin navigation. The system attempts to acquire those satellites selected by the operator or, if the operator did not select any sources, the system attempts to acquire up to six satellites with the largest elevation as determined by software computations based on satellite orbital data stored in the almanac.

b. Steady State Operation - After the satellites have been acquired and satellite ephemeris data has been collected from the satellites, the system begins normal tracking of the satellites by sequencing between satellites every two seconds. Range measurements are made and navigation is begun. After a short delay to allow navigation filter convergence, a user fix is displayed automatically on the CDU, and additional fixes or other system outputs are displayed when commanded by the operator or once per minute if the operator chooses the automatic CDU display mode. During steady-state operation, several different states of operation are invoked automatically by the software depending on particular conditions. These states of operation are described as follows:

(1) Normal - In the normal mode of operation, the system makes range and range rate measurements for a different satellite every two seconds based on the satellite

L1 frequency signals. The measurements are processed by a Kalman data filter and the user's estimated position and time are updated.

(2) Ionospheric Delay Measurement - Every 24 seconds an ionospheric delay measurement is made by the receiver by processing an L2 frequency signal from one of the satellites.

(3) Ephemeris Update - Once every hour of steady-state operation, an ephemeris update is made by collecting fresh ephemeris data from each satellite. The ephemeris data is collected in six second blocks and during each six seconds of data collection, measurements are not incorporated to update the user's estimated position. The six second blocks are spread out over several minutes in order to not degrade appreciably the navigation accuracy.

(4) New Satellite Acquisition - Every two minutes, a determination of satellite visibility is made. As satellites rise and set over the horizon, the system may be required to acquire a new satellite that is not currently being tracked. In the new satellite acquisition mode, the system attempts to acquire the signal from a new satellite and if the signal is acquired, the system collects ephemeris data from the satellite and then adds the satellite to the constellation being used for navigation.

(5) Signal Loss/Reacquisition - Satellite signals may be lost due to signal masking by trees, buildings, terrain, etc. In the signal loss/ reacquisition state of operation,

the system attempts to reacquire the lost signals using special receiver reacquisition modes and if less than four satellite signals are available during the signal loss condition, the system must navigate suboptimally. If signals from three satellites are being processed, the range to the center of the earth is held constant and treated as a fourth measurement. This is called altitude hold, since the system is forced to navigate along a surface of constant altitude. When signals from only two satellites are available, the range to the center of the earth is treated as a measurement, and in addition the user's clock bias and clock bias rate are assumed to be known and are not updated by the Kalman filter when measurements are incorporated. If signals from less than two satellites are available, navigation is not possible, and a software restart is commanded.

2.1.3 Almanac Collection

The operator may choose to acquire a new almanac by selecting the almanac collection mode via the CDU. In this mode, a satellite is acquired by searching the entire sky, if necessary, for the signal, and then collecting fresh almanac data for all operable satellites. After the almanac data is collected, the system automatically attempts to acquire the satellites and begin normal navigation.

2.1.4 Standby

The operator may place the system into standby at any time by manually switching to this mode. In the standby mode, the processor is not powered and less system power is consumed. In the standby mode, the system does not process any data and cannot be commanded via the CDU. The last user state before entering standby is stored in a non-volatile portion of memory for later use. Time is also maintained. No outputs are available in this mode.

2.1.5 Warm Start

The transition back to normal operation after a period of standby is the warm start mode. This mode is similar to a cold start but the operator is not required to reinitialize and the initial position of the user is assumed to be the position when standby was invoked. The satellites are acquired in the same manner as in a cold start and a fix is automatically displayed after the navigation filter has

converged. The GO/NO GO self tests are included.

2.1.6 Software Restart

This mode may be invoked at any time by the operator and causes the software to be recycled as if a cold start was occuring. Most of the RAM memory is zeroed; however, the operator's previous CDU initialization is saved, and reinitialization is not required but is allowed. When the operator depresses the FIX key, the system initializes system variables and attempts to acquire the satellites as in a cold start. Also, the GO/NO GO self tests are included.

2.1.7 Built In Test (BIT)

The BIT mode may be selected by the operator and causes the system to go through a sequence of self tests. At the end of each test, if an abnormality is observed, a message identifying the area of hardware containing the abnormality is displayed. If all tests are passed, an OK is displayed.

2.2 SOFTWARE OVERVIEW

2.2.1 Functions and Structure

The data processor/computer software accepts and processes the outputs of the receiver assembly and control display unit and performs those computations and tasks necessary to support the required system operation. The data processor/computer software is allocated the following system functions:

a. Select the set of GPS transmitters from those available that will provide the necessary inputs to compute on a continual basis the user's position and time.

b. Provide signal acquisition and tracking aiding data to the receiver.

c. Accept control commands from the CDU and provide for altering the processing of computer programs or other equipment functions as required.

d. Convert the system data and pseudo-range/range-rate measurements into three-dimensional position and time.

e. Provide for GO/NO GO and self-test functions to the maximum extent practical.

f. Compute and output to the CDU on command:

(1) Present position

(2) Position of selected rendezvous point

(3) Azimuth to selected rendezvous point

with reference to grid-North

(4) Distance to selected rendezvous point

(5) Time-of-day (day-of-week, hour-min-sec)

(6) Estimate of uncertainty in position

(7) Number of GPS transmitters used by the system

(8) Altitude of user's position

(9) System condition warning messages

g. Provide receiver control and measurement processing

h. Provide all required system service tasks such as precision time keeping, system start-up control, mode control, error monitoring, etc.

The software is structured into four major subsystems as follows:

a. Executive Subsystem

b. Master Control Subsystem

c. Receiver Subsystem

d. Navigation Subsystem

The system functions are further subdivided and allocated to the software subsystems as shown in Figures 2.2-1 through 2.2-4.

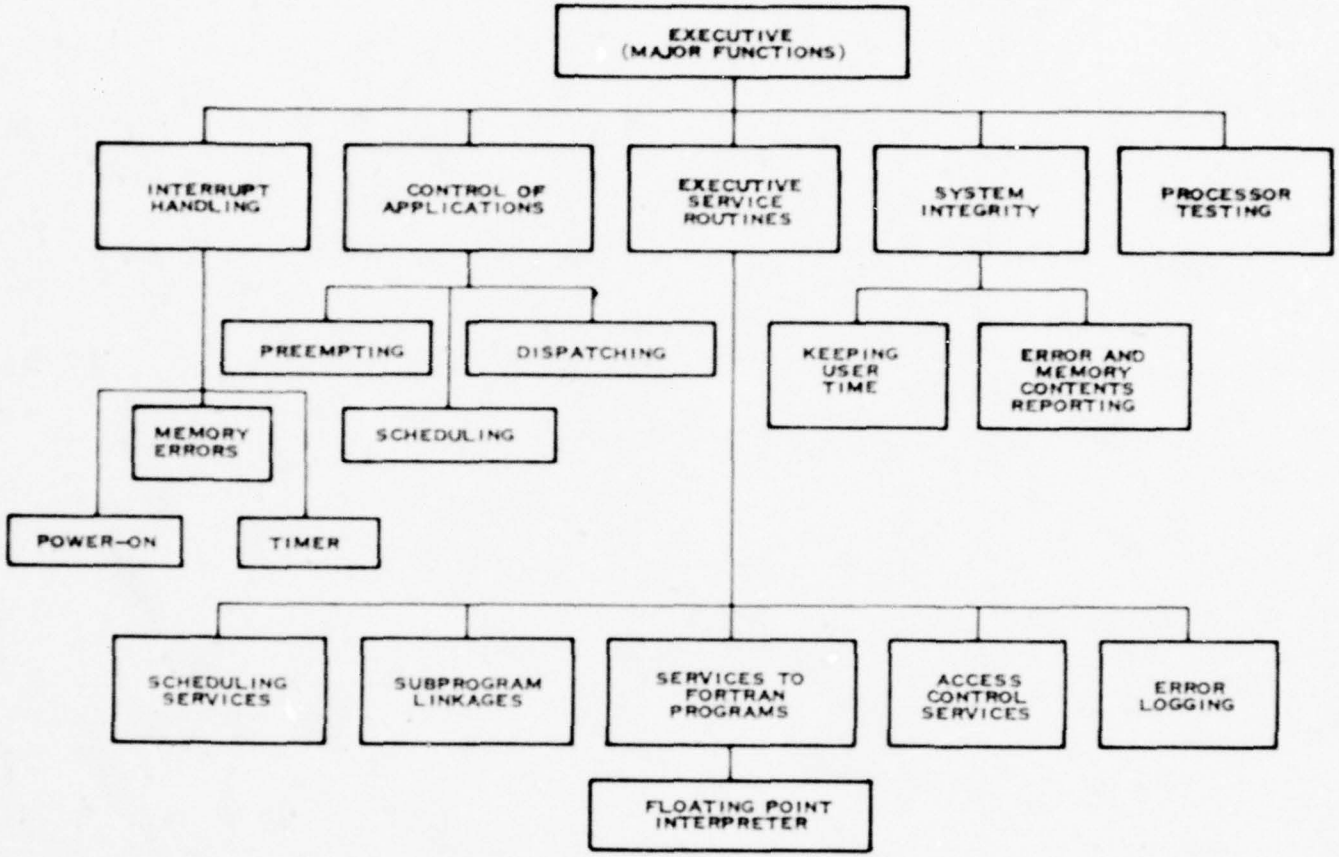


Figure 2.2-1. Executive Functional Subsystem

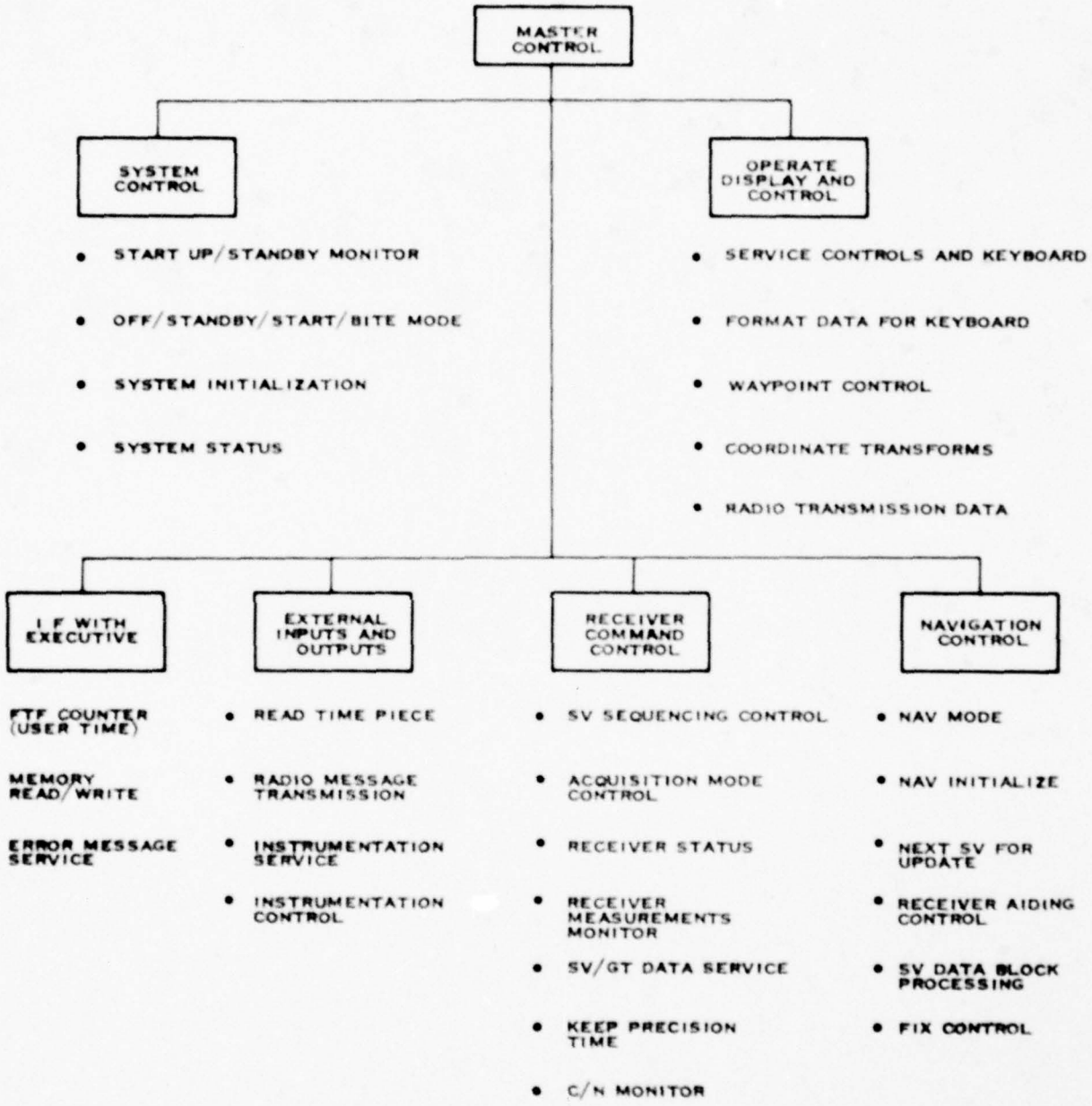


Figure 2.2-2. Master Control Functional Subsystem

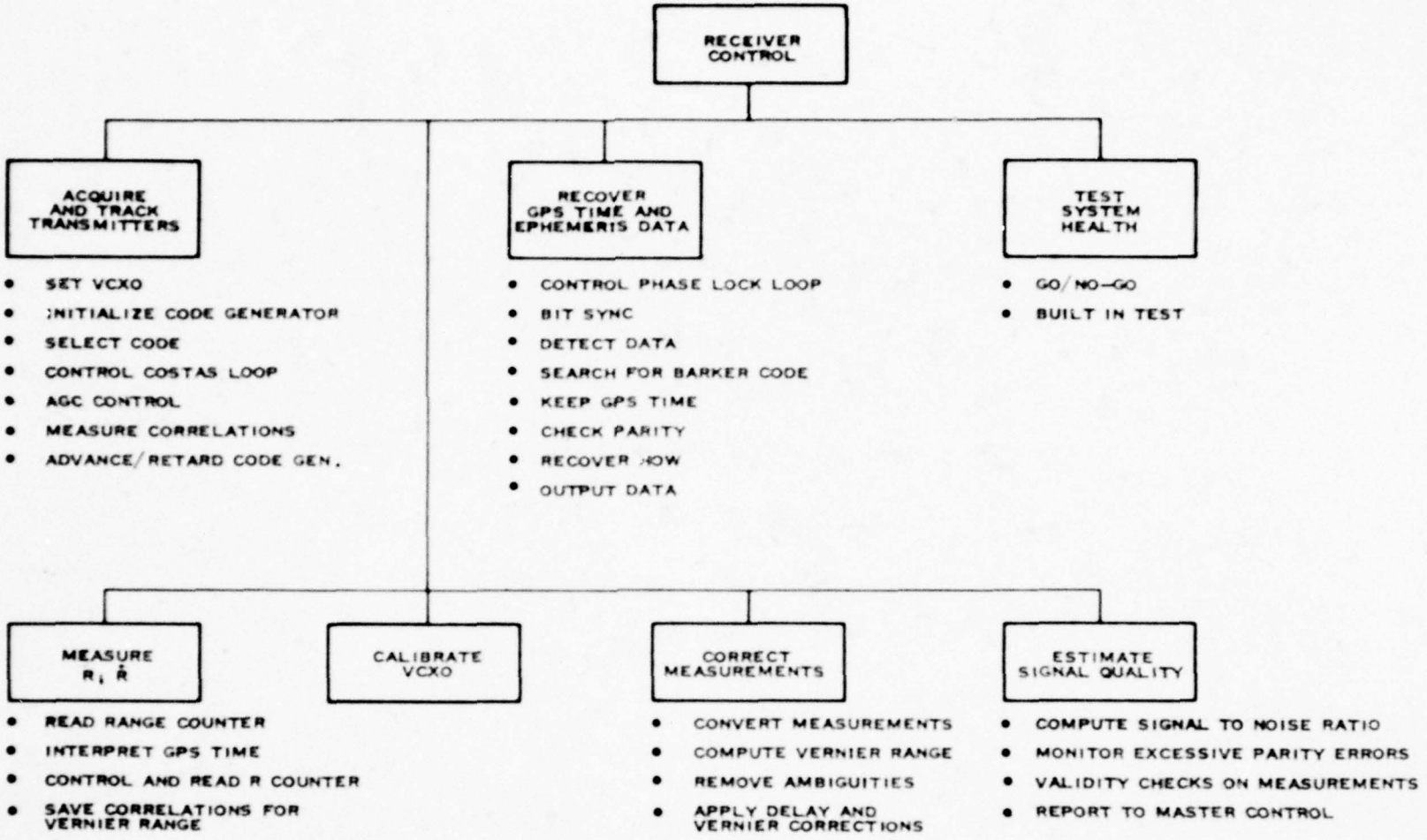


Figure 2.2-3. Receiver Control Functional Subsystem

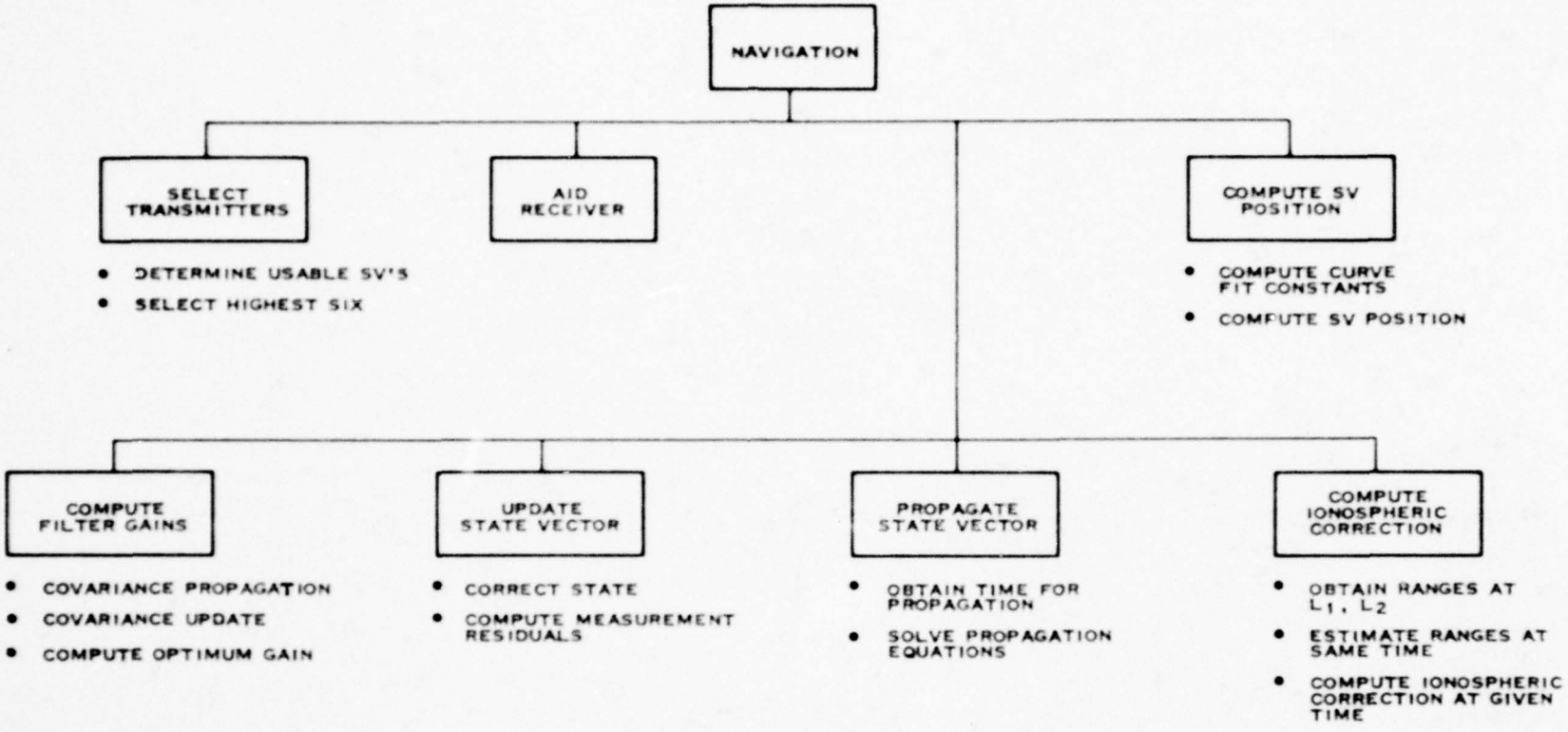


Figure 2.2-4. Navigation Functional Subsystem

2.2.2 Data Interface

The computer data utilized in the MVUE system can be categorized in four areas - signal data, measurement (ranging) data, computational data, and control data. First, the signal data is transmitted from either SV's or ground tramsmitter, and received by the receiver. The received data, recovered after complicated receiver hardware procedures, is l rearranged to store in a data base. This procedure is called data block processing. Regarding the detailed signal data interface, refer to the ICD, Doc No. MH08-00002-400 E. Second, the measurement data is generated by the reciever hardware using the signal data stream (P and C/A code) which is considered as a measuring rule. Third, the computational data is the output of the navigation process coordinating with the measurement. This data is also the system output and displayed on the CDU. Finally, the control data is used for the control of receiver assembly, navigation process or the master control of the MVUE system. In Figure 2.2-5, the MVUE software system data flow is depicted. The data/control flow interfacing between the MVUE software subsystems is partitioned to the functional level as shown in Figure 2.2-6. These interface data bases will be further specified in the Receiver subsystem, Navigation subsystem, and Master Control subsystem in Section 3.0.

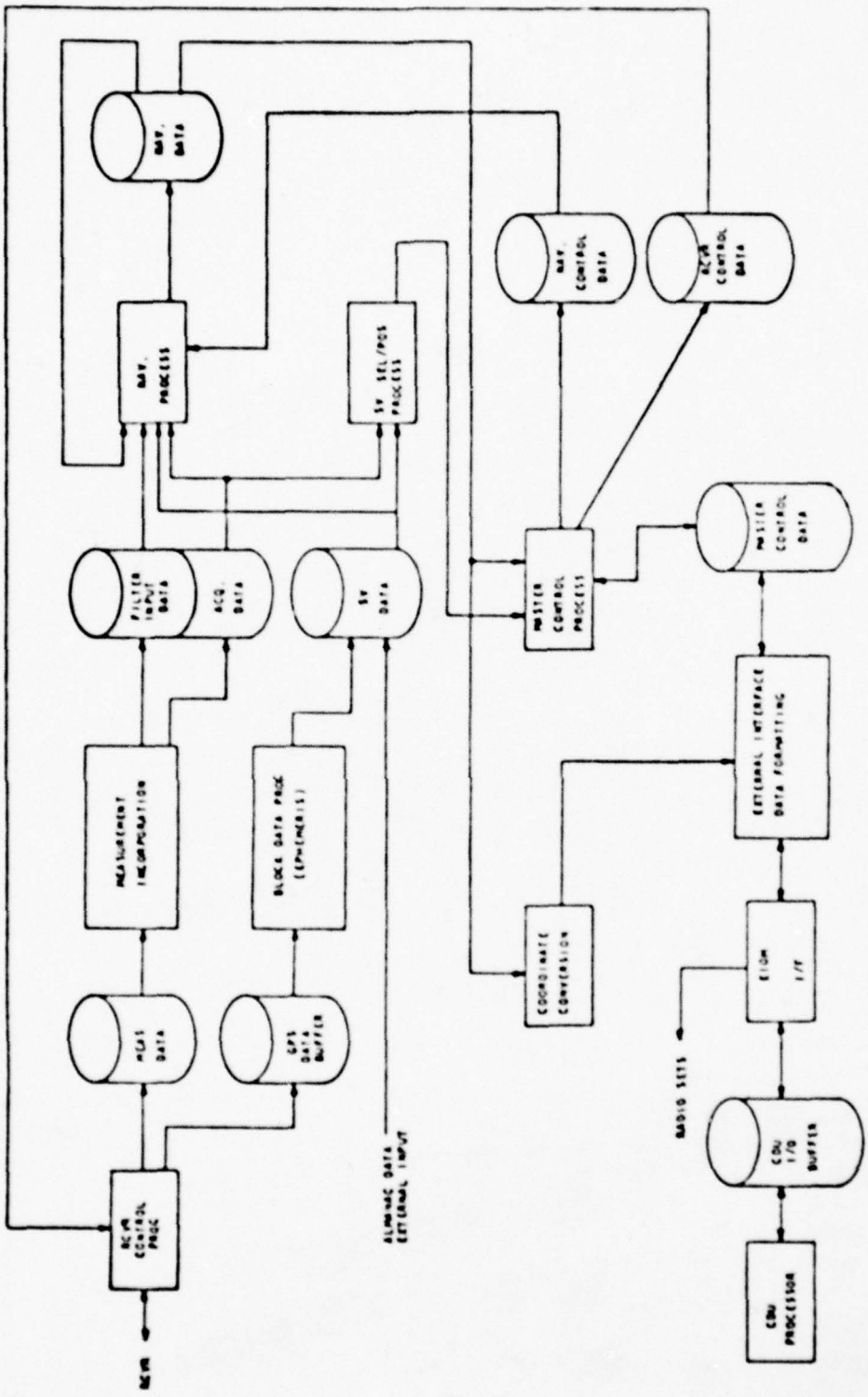


Figure 2.2-5. Program Data Flow

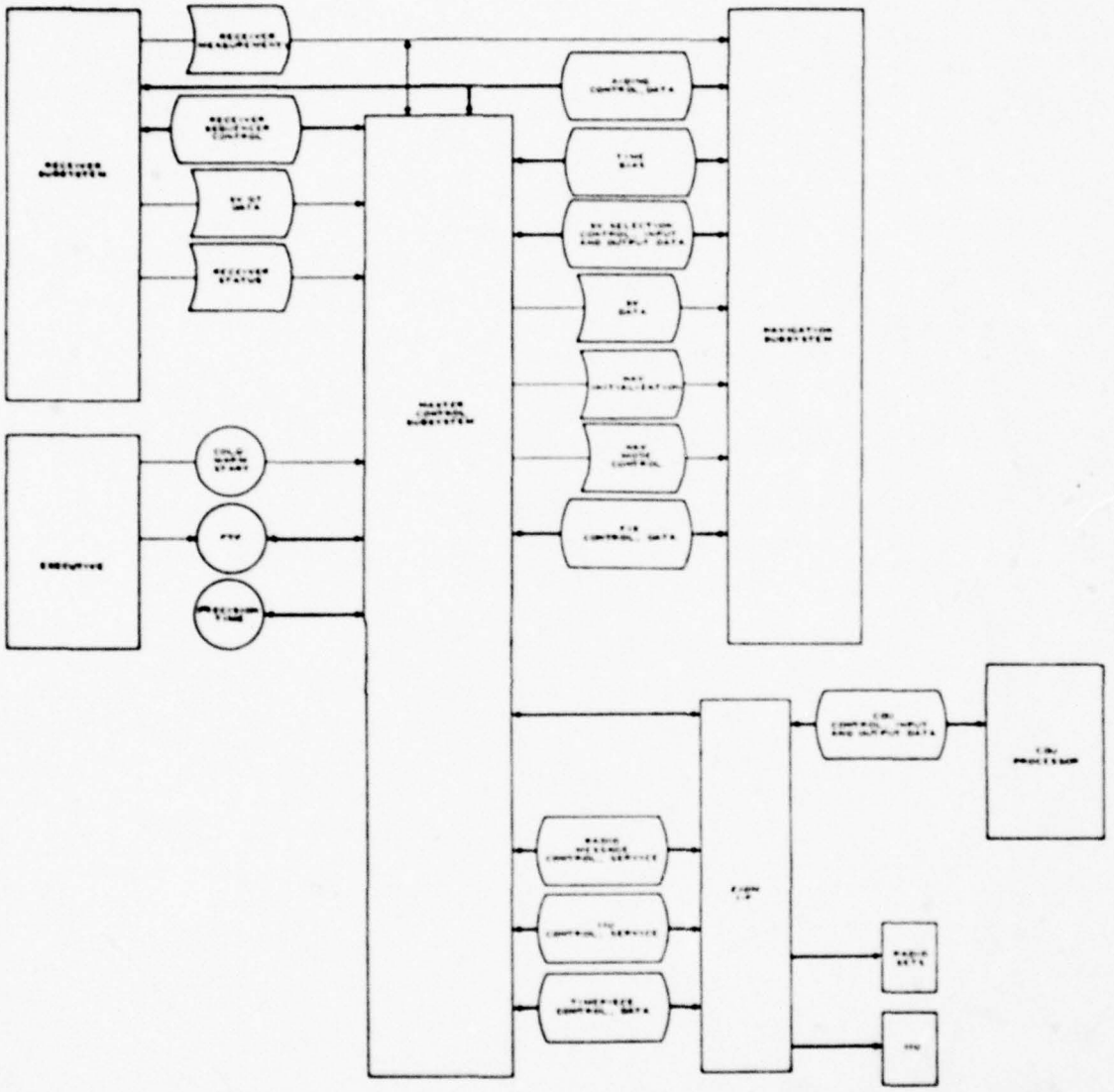


Figure 2.2-6. Control/Data Interface of the MVUE Software System

2.2.3 Computer Program Language

The installed programs are compiled with FORTRAN IV and Assembler and supported with the software development utilities, which are referred to the following references:

FORTRAN IV	945411-9701
Assembler	943441-9701
Utilities	945256-9701

2.2.4 Memory Allocation

The amount of memory required by each software subsystem, its allocation, and a comparison with total memory available is shown in Figure 2.2-7. The further breakdown of memory required by subsystem function is included in the software subsystem description given in section 3.0.

	PROGRAM MEMORY (ROM)				
SUBSYSTEM	PAGE 0	PAGE 1	PAGE 2	TOTAL	DATA MEMORY (RAM)
RCSS	209	6501	746	7456	762
MCSS	611	7654	9899	18164	1602
NSS	1637	1651	5586	8874	1548
EXEC	4479	23		4502	1181
SUBSYSTEM TOTAL	6936	15829	16231	38996	5093
I/F DATA					941
TOTAL	6936	15829	16231	38996	6034
AVAILABLE	8192	16384	16384	40960	6400
PER CENT UTILIZED	84.7	96.6	99.1	95.2	94.3

FIGURE 2.2-7 MEMORY SIZING

2.2.5 Processor Loading

Processor loading was studied by determining the peak time required for completion of two second and 24 second priority tasks under a variety of system conditions. The peak time was determined by calling the Executive routine X3TIMM at the end of the two second priority navigation task N1MMIT and the 24 second priority navigation task N1MNFL. Since these are the final system tasks to run in each priority, these measurements characterize system loading for these system priorities. The Executive task X3TIMM is called with an argument equal to the task priority in 20 millisecond units and returns the number of 20 millisecond periods that have transpired since the task was scheduled at its priority boundary. The results of the study are given in Figure 2.2-8.

PRIORITY	LOADING	
	TYPICAL	MAXIMUM
2 SEC	0 4 SEC	1 2 SEC
24 SEC	1 6 SEC	3 5 SEC

Figure 2 2-8 Processor Loading

2.2.6 Software Development History

The MVUE software was developed and delivered for field testing in four distinct phases. Each new software version contained significant additional system capabilities with respect to the previous version. The basic software versions were defined as Releases 2.0, 3.0, 4.0, and 5.0. In two cases, additional sub-releases were delivered to correct problems or add capabilities; these releases were 2.1 and 5.1. The date of delivery and list of capabilities for each software release are given below.

Release 2.0 - October 1978

The first release delivered to the field was known as the "Basic Navigation" release because it was designed to provide basic navigation capabilities with no frills in order to check out basic design issues and determine MVUE compatibility with the field test instrumentation and data collection/reduction facilities. The basic software system level capabilities were as follows:

(1) Basic CDU operations including capability to initialize position in WGS-72 latitude and longitude, initialize time, select GPS satellites or ground transmitters, and initialize altitude.

(2) Navigation with four, five, or six signal sources including satellites and/or ground transmitters.

(3) CDU output of WGS-72 latitude, longitude, altitude, and time.

(4) CDU output of most system warning messages.

(5) MVUE Instrumentation System interface and system data collection and output.

Release 2.1 - October 1978

This release was delivered at approximately the same time as Release 2.0. Two capabilities were added and one software correction was made. Release 2.1 capabilities were as follows:

(1) All Release 2.0 capabilities.

(2) Waypoint operations including input of up to eight waypoints in WGS-72 coordinates, CDU output of range and bearing to each waypoint, and display of waypoint coordinates.

(3) Manual altitude hold, enabling navigation with only three signal sources.

(4) Time initialization correction.

Release 3.0 - 18 December 1978

Release 3.0 software primarily added those additional capabilities necessary for successful Operational Test and Evaluation Agency (OTEA) testing. Capabilities of release 3.0 were as follows:

(1) All Release 2.1 capabilities.

(2) CDU display of mean sea level altitude.

(3) Military Grid coordinate transformation.

(4) C/NO monitor.

(5) Excessive oscillator bias warning.

(6) Automatic satellite selection (table look-up of SV 4, 6, 7, 8).

(7) Ephemeris update (once per hour).

(8) New satellite acquisition search mode and transition of new SV into navigation.

(9) Partial GO/NO GO self test.

(10) Automatic altitude hold mode.

(11) Stationary user mode.

(12) CDU output of estimated uncertainty in user state.

(13) Radio/DMD output.

(14) Degraded mode navigation with three or two signal sources using altitude hold and clock bias rate freeze.

(15) Correction to prohibit ionospheric correction for ground transmitters.

(16) Exponential filter smoothing of ionospheric correction data.

Release 4.0 - 18 April 1979

Release 4.0 software added all remaining capabilities required to satisfy CID-ADUE-101A system specifications except for Built-in-Test (BIT). Also, several system enhancements were made. The release 4.0 capabilities were as follows:

(1) All Release 3.0 capabilities.

(2) Full satellite selection/replacement logic.

(3) User position smoothing for stationary user.

(4) Mean sea level altitude correction for all data using the Molodensky coordinate conversion technique.

(5) Improved system performance for receiver jamming.

(6) Complete GO/NO GO self test.

(7) Warning message display for illegal CDU keystrokes.

(8) Satellite acquisition with old almanac data.

(9) Computation of precision time using ephemeris clock correction parameters.

(10) Correct setting of measurement validity flag when receiver failure status is set.

(11) Data reasonableness check of ionospheric correction L1/L2 measurement data.

(12) Expanded search interval in lost signal reacquisition mode.

Release 5.0 - 5 June 1979

Release 5.0 software added Built-In-Test and a number of major system enhancements. They are as follows:

(1) All Rel. 4.0 capabilities

(2) Built-In-Test (BIT)

(3) Almanac Acquisition Mode

- Selected by operator
- Acquires up to 9 almanacs from one SV
- Searches sky until SV found
- Searches for SVs with IDs 1-9

- Operator selects SVs or SVs automatically selected by system based on visibility and elevation as determined PROM almanac data
- When system selects SVs it searches for SVs declared non-visible if unsuccessfull in finding SVs declared visible
- System automatically aquires SVs for normal navigation after completion of the Almanac Acquisition Mode

(4) Software Restart Mode

- Selectable by operator
- All previous CDU inputs saved
- Reinitialization not required but operator may reinitialize any parameters if desired

(5) System invokes Software Restart anytime normal sequencing is not possible (failure to acquire enough SVs, loss of all signals for four minutes, etc.)

(6) Operator input of altitude during steady state operation

(7) Display of system status

- For all acquisition modes
- Every 30 seconds
- Displays number of visible SVs, number of SVs acquired, and ID of SV that is currently being processed

(8) Operator inhibit of ionosphere correction

(9) Operator inhibit of all atmospheric corrections (ionosphere and troposphere)

(10) Operator setting of RAM almanac save flag

(11) CDU prompting major level 5 changes

* Changed from DHO to OP2
* Minor levels include ALM (Almanac Acquisition Mode), RST (Restart Mode), RAM (RAM almanac save flag), ION (ionosphere correction flag), and ATM (atmosphere correction flag)

(12) Acquisition activated by depressing FIX button

(13) GO/NO GO self test mode modified to allow normal system operation even if test fails. (Flashing R will still be displayed)

(14) Precision time calculated using ephemeris data for all SV position and time computations

(15) Subsequent SV acquisition mode searches over two doppler bins (previously one bin)

(16) User time updated from instant entered in CDU by operator

(17) Proper reinitialization of user velocity states and the covariance matrix during warm start

(18) Increased accuracy for receiver self aiding via the incorporation of range acceleration term when extrapolating previous measurement

(19) Capability to enter standby mode from any other system mode except OFF

Release 5.1 - 2 July 1979

Release 5.1 software corrected a timing error in Rel 5.0 software that caused an EIOM test failure when

Running the BIT sequence. Otherwise, this release was identical to Rel. 5.0.

2.3 HARDWARE OVERVIEW

2.3.1 HARDWARE FUNCTIONAL OVERVIEW

The MVUE hardware is functionally designed to perform seven major tasks. The tasks include the following:

a) Satellite Vehicle (SV) Signal Processing

b) Control Display Unit Interfacing

c) Radio/DMD Interfacing

d) Built-In-Test Processing

e) Internal System Power Control

f) System Time Keeping

g) MVUE Instrumentation Systen Interfacing

Under software control the hardware is controlled in such a manner to acquire and decode the signals generated by the various SV's. This includes capability to acquire the SV's in their appropriate doppler bin, C/A-code, and P-code. Fifty-Hz data is also decoded to perform the handover from C/A to P-code. When each SV is acquired in P-code the hardware is utilized to measure P-code position which translates to a range measurement within the navigation subsystem of software.

Once the system has determined position and time for user. The information can be made available in various formats on the Control Display Unit (CDU). The CDU is implemented with two rows of 10 alphanumeric display devices

to display the various system information. The CDU is responsive to formatted messages from the system which define characters to be displayed as well as the location of the characters within the two rows. The system is also responsive to messages from the CDU which are initiated manually by a user. The user may thus exercise control over the system via the CDU.

Messages displayed on the CDU may be transmitted to either a radio (PRC-77 or PRC-25) or a digital message device (DMD) by means of a frequency shift keyed audio tone with a special data format compatible with the DMD.

The MVUE system is implemented with a Built-In-Test function which allows fault isolation of hardware failures. The task is accomplished via a hardware module dedicated to this function. The software system invokes the module which generates an L1 and L2 pseudo-replica (not complete L1 and L2 signals). Based on the results when acquiring the two signals, the system generates fault isolating information for display on the CDU.

Under software control the MVUE system may be set into two low power consuming modes refered to as standby, and or warm up. The modes are attained via the system power supply which inhibits power to those sections of hardware that do not require power during these modes.

During a warm-up mode (immediately after a cold start) and standby mode the hardware maintains a clock which is a record of time while in these modes. When turning on the

system from a cold start the hardware system will determine when 13.66 minutes have elapsed (time required to warm up Master Oscillator). At the end of this interval, all system power is enabled, provided the CDU STANDBY/ON switch is in the "ON" mode. If the switch is in standby, the system will be maintained in warm-up. If after having attained a normal navigating mode, the user may set the system to the standby mode to conserve battery life. While in this mode, the hardware timer will maintain time to a resolution of 20 ms. When the system is subsequently set to the "ON" mode, the timer clock information is loaded into the software system to aid in the reacquisition operation.

To help monitor the system the MVUE system provides an instrumentation interface. The MVUE Instrumentation System Interface accepts various analog test monitors to be converted to digital data. A port is included which allows the outputting of system scratchpad memory information for inspection and troubleshooting. The instrumentation interface is also capable of functioning as a CDU by having access to the CDU interface. An interface is included to intervene in Processor control via the Maintenance Panel Interface which allows a user to monitor processor registers, perform breakpoint operations, and other processor oriented functions.

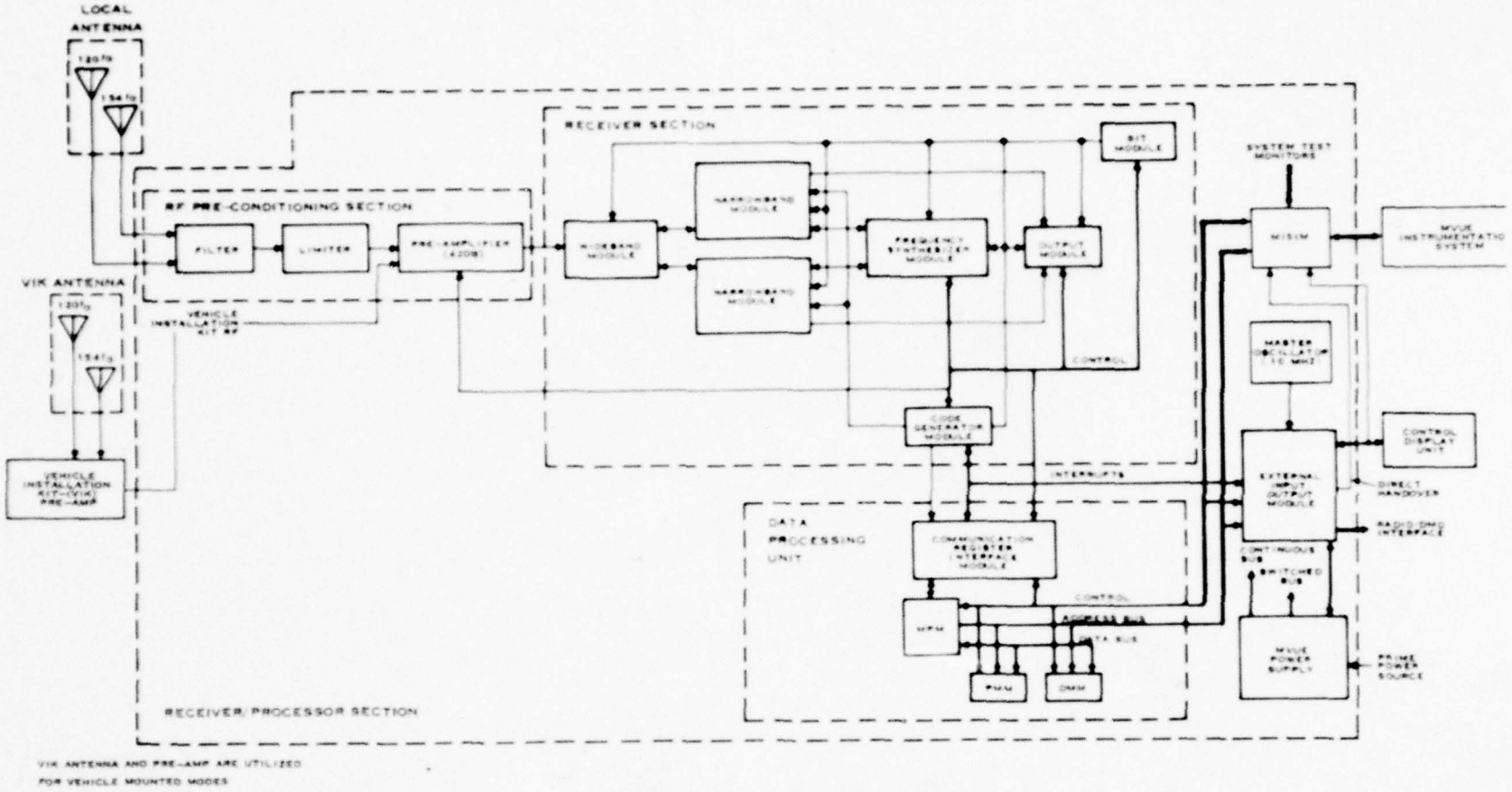


Figure 2.3-1. MVUE Hardware Functional Block Diagram

2.3.2 HARDWARE PHYSICAL OVERVIEW

The MVUE hardware is physically subdivided into the hardware funtional sections shown in Figure 2.3-1. These sections include the following:

Receiver/Processor Section

Control Display Unit

Vehicule Installation Kit Pre-Amplifier

MVUE Antenna

Battery Pack

The Receiver/Processor section is the portion of the system that contains all essential hardware to acquire SV signals and perform all necessary computations for the system. As can be seen in the MVUE Hardware Functional Block Diagram (Figure 2.3-1), the Receiver/Processor is subdivided into seven major areas. These include the RF Pre-Conditioning Section, Receiver Section, Data Processing Unit, External Input/Output Module, Master Oscillator, MVUE Instrumentation System Interface Module, and the MVUE Power Supply.

The RF Pre-Conditioning section merely prepares the RF carriers from the various antenna sources for input to the Receiver section. This section establishes the Noise Figure (5dB nominal) for the system and amplifies the signals to the appropriate level for proper Receiver operation. Some filtering is provided to limit interference from sources outside the system operating frequency range.

The Receiver section performs the function of frequency

down conversion and signal decoding under the control of the Data Processing Unit (DPU). The DPU will command the Receiver section to generate L.O. frequencies, C/A and P codes, and, will command the Receiver to assume various required settings to acquire the various SV's. The DPU can also invoke the Built-In-Test (BIT) module to generate internal test signals for fault isolation.

The Data Processing Unit (DPU) is the computer which drives the system. The operational software required to drive the system is stored within this section in the Program Memory Modules (PMM) while intermediate data is stored in scratchpad memory (Data Memory Modules). All control for the system emamates from the DPU. This control is exercised over the system via the CRU structure which is an I/O feature of the resident computer.

The External Input/Output Modules (EIOM) functions to provide the system with all external interfaces for the system. These include the Control Display Unit, MVUE Instrumentation System Interface (direct handover), and the Radio Interface. The EIOM also performs special internal system functions. These include power supply control while in standby or warm up modes, time keeping while in standby or warm up, Memory Paging Control, and Master Oscillator Clock, and Timing Distribution.

The Master Oscillator merely generates a 10 MHz clock reference for the system. This frequency standard is distributed within the system for various Receiver and

Processor functions.

The MVUE Instrumentation System Interface Module provides the user an instrumentation interface to monitor system status and intervene in system operation.

The MVUE Power Supply provides power to the system via continuous or switchable power busses when commanded to do so by the EIOM.

The Control Display Unit is the primary operator interface for the system. The operator is provided a visual interface (two rows of 10 alphanumeric LED displays) and a three level keyboard to enter commands to the system. The CDU is a light weight handheld unit to allow ease of operation.

The Vehicle Installation Kit (VIK) Pre Amplifier is functionally the same as the RF Pre-Conditioning section of the Receiver Processor. The difference being that it has a different mechanical form factor to be compatible with the various vehicles that the MVUE accomodates.

The MVUE Antenna is the signal reception element for the system which can be mounted on either the Receiver/Processor assembly for Manpack operation or on the VIK Pre-Amplifier.

The Battery Pack is the source of power for the MVUE in the Manpack configuration. Via the use of batteries a 24VDC power source is provided to the system.

3.0 MVUE SUBSYSTEM DESCRIPTIONS

The MVUE software system consists of four subsystems. These are the Receiver Control Subsystem, the Master Control Subsystem, the Navigation subsystem and the Executive Subsystem. The following sections contain functional descriptions of these subsystems.

3.1 RECEIVER CONTROL SUBSYSTEM

3.1.1 Overview

The Receiver Control subsystem (RCSS) provides measurments of pseudo-range and range rate to the Navigation subsystem and SV data to the Master Control subsystem. It provides control and monitoring of the receiver hardware. Data for acquisition aiding and precision time is received from the Navigation subsystem, while the Master Control subsystem provides mode commands and satellite identification data.

The Receiver Control Subsystem may be partitioned functionally into application functions and sequence control functions. Application functions are those which provide receiver oriented functions which are independent of the strategy chosen for receiver sequence control. Application functions may be further divided into receiver control interface functions, SV data recovery functions and measurement processing functions. The sequence control

function implements the selected control strategy and the acquisition, tracking and measurement strategy implemented for the MVUE. Figure 3.1-1 illustrates the principal interfaces among the functional elements of the Receiver Control subsystem, other subsystems and the receiver hardware.

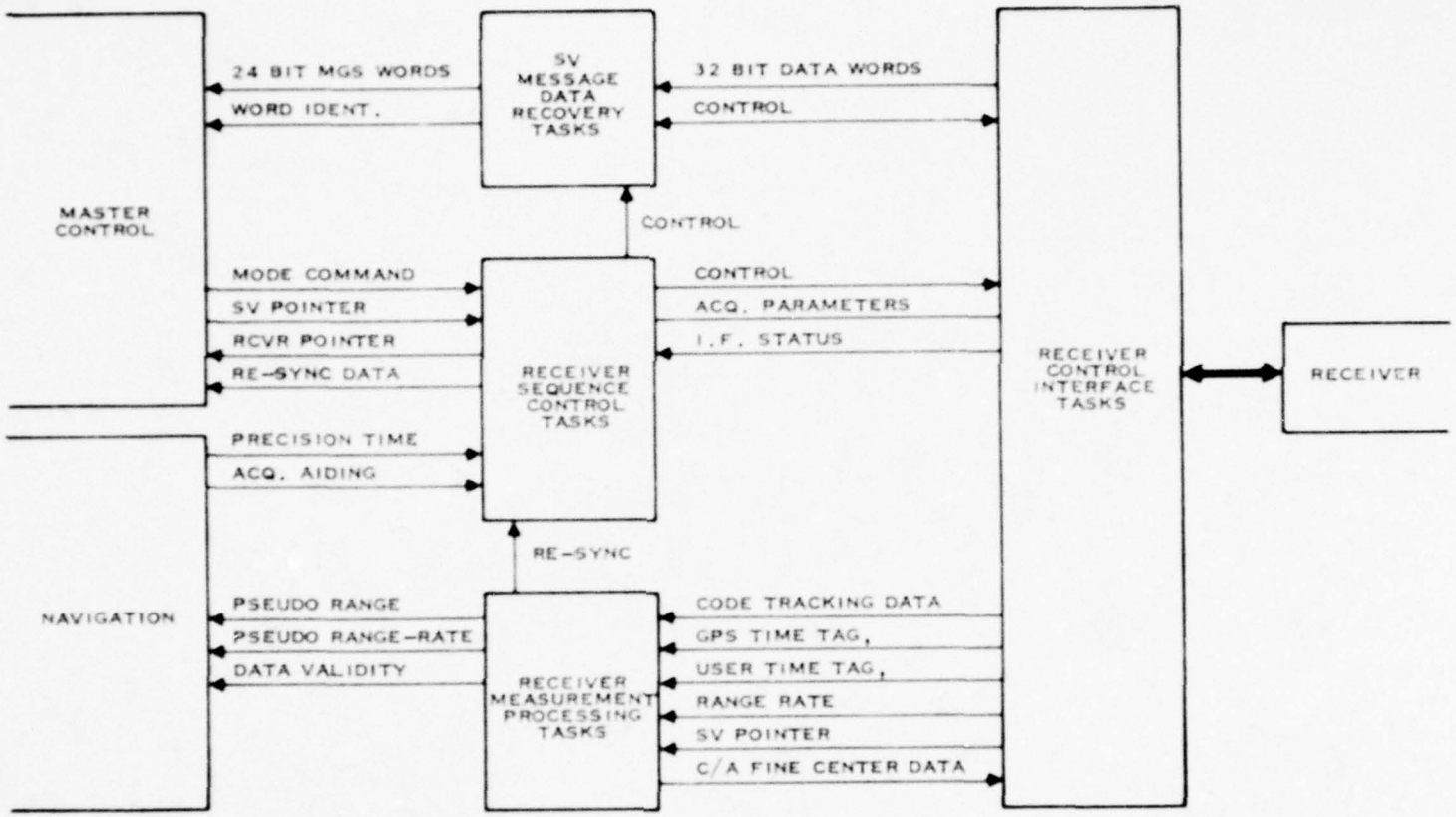


Figure 3.1-1. Receiver Control Subsystem Interfaces

Another partitioning of tasks is by whether invokation is performed by the executive or by the Receiver Sequence Controller (RSC). Those tasks which are executed at a rate of other than 5 milliseconds (except R1RSC) are invoked by the executive and are referred to as "global" tasks. These include:

Task	Priority
R1BSN	1 ms
R1DDT	10 ms
R1DSC	200 ms
R1REC	40 ms
R1RMO	2 sec
R1RSC	5 ms

All other tasks in the RCSS execute under control of the RSC and are refered to as "local" tasks. Their priority is 5 milliseconds. These tasks are responsible for maintaining any slower rate functions internally.

The general approach to Reciever Control is as follows: (1) a command is recieved from the Master Control subsystem, (2) aiding is received from the Navigation subsystem, (3) the sequence control function maps the command into a "Sequence Specification Table", which is a ROM data set providing pointers to subordinate data sets which describe the sequence of actions the Receiver Control subsystem is to perform in the commanded mode, (4) application functions, as commanded by the sequence control functions, acquire the desired signal and provide status, measurement and SV data

to the sequence control function as well as the other subsystems and (5) processing continues for the current mode until another mode command is received from Master Control.

3.1.2 Application Functions

The following subparagraphs describe the application functions included in the Receiver Control subsystem. For additional descriptions of the tasks described, refer to paragraph 5.2.

3.1.2.1 Receiver Control Interface Functions

Receiver Control interface functions are those which provide control and monitoring of the receiver hardware. They are comprised of the following computer program components (CPC's):

CPC	FUNCTION
R1CAL	VCXO Calibration
R1NSE	Noise Calibration
R1PIN	P-code Initialization
R1RNG	Ranging
R1SCH	Sequential Code Search
R1SET	VCXO Set
R1TRK	Code Tracking
R1RRM	Range Rate Measurement (BITE only)
R1BSN	Bit Sync
R1DDT	Data Detect

3.1.2.2 SV Data Recovery Functions

The SV data recovery functions provide validated SV data to the Master Control Subsystem. SV data is recovered by R1DDT and then buffered and validated by R2PCK. R1DSC provides timing and control for R2PCK and M2DBPR, which performs the data block processing for master control. The CPC's which comprise the SV data recovery functions are as follows:

CPC	FUNCTION
R2PCK	Parity Check
R1DSC	Data Sequence Control

3.1.2.3 Measurement Processing Functions

Measurement processing functions are those which validate and scale raw measurements of pseudo range and range rate and provide those measurements to the Navigation subsystem. They are comprised of the following CPC's:

CPC	FUNCTION
R1REG	Linear Regression
R1RMO	Range Measurement Output

3.1.3 Receiver Sequence Control Functions

The Receiver Sequence Controller (RSC) performs the top level control function for the RCSS. A group of control structures are defined which are processed by the modules included in the RSC to implement the control requirements of

the RCSS. The following subparagraphs describe (1) the control structures which are defined for the RSC, (2) the organization of control structures to implement the control of receiver sequences for each receiver mode and (3) the software modules which process the control structures.

3.1.3.1 Control Structures

The control structures defined for the RSC are linked together to form "task system descriptions". These describe the sequence of operations and the time dependent scheduling of events which are required for a particular reciever mode. In a sense, the RSC is a programmable entity, the programming of which, for each mode, is provided by a task system description, which is interpreted at execution time by the RSC.

The control structures implemented in the RSC are described in the following subparagraphs. The mnenomic names indicated are associated with the MVUE implementation of the RSC and are not critical to the operation of the RSC. Control structures of individual types have been grouped into data sets for ease of maintenance, but the grouping is also not required for RSC operation.

The task system descriptions in graphical form are included in Appendix D.

3.1.3.1.1 Mode/Sequence Association

The mode commands which the RCSS receives from Master Control are used to index into a Sequence Specification Linkage Table, REASSP. REASSP is constructed as follows:

```
REA001 DATA REBxxx      SST pointer
       DATA REBxxx      SST pointer
       DATA REBxxx      SST pointer

       DATA REBxxx      SST pointer
```

Each entry points to a Sequence Specification Table (SST) included in the data set REBSST. A zero entry results in the receiver being reset. An SST is a collection of pointers to Service Request Tables (SRT's). The SST's are constructed as follows:

```
REBxxx DATA RECxxx   SRT pointer
       DATA RECxxx   SRT pointer

       DATA RECxxx   SRT pointer
       DATA 0        end of table indicator
```

An SST, then, lists the SRT's which are to be processed by the RSC for a given mode. In some cases (e.g. First SV Acquisition mode, Subsequent SV Acquisition mode and Almanac Acquisition mode) the same SST is invoked for more than one commanded mode (refer to the data set REASSP).

The processing of the SST is first initiated by R1XCCP when a mode command is received from Master Control. Further processing of the SST occurs when an SST processing SRB is processed (c.f. paragraph 3.1.3.1.3.6).

3.1.3.1.2 Service Request Tables

The central structure through which the behavior of the RCSS is described is the Service Request Table (SRT). The SRT's are implemented in the data set RECSRT. RECSRT is

constructed as follows:

```
RECxxx DATA REDxxx    SRB pointer
       DATA REDxxx    SRB pointer

       DATA REDxxx    SRB pointer
       DATA 0         end of table indicator
```

An SRT, then, describes the Service Request Blocks (SRB's) which are to be invoked for a particular receiver function. SRT's are used in the construction of SST's and various other control structures, for example, the pre-activation SRT pointer which may be specified in the task activation SRB. This requires that SRT processing be recursive, since the processing of one SRT may result in the processing of another SRT. Recursion is supported to the depth specified in the data set REWCTB.

Certain function descriptions which are used in multiple sequences have been defined as "primitives". These primitives have SRT's which may be invoked in the Sequence Specification Tables of multiple modes as required. Examples of these functions include VCXO Calibration, Noise calibration, etc.

3.1.3.1.3 Service Requests

The basic programmable element available to task system descriptions is the Service Request Block (SRB). The following subparagraphs describe the SRB's for which service request processors have been provided.

3.1.3.1.3.1 Hardware Modification Service

The hardware modification service is provided by the module R2XHMP. This service allows the task system description to modify the state of the MVUE receiver. It processes a service request block of the following format:

```
REDxxx DATA R2XHMP        points to service request processor
       DATA REHxxx        points to Modification Control Record (MCR)
       DATA <address>     points to data to be output
```

The hardware modification service request invokes the MCR in order to output the data pointed to by the data output pointer to the hardware at a CRU address defined by the MCR. The MCR's are small sections of executable code included in the data set REHMCR. The data output is selected from the ROM constants in the data set RELTRL or from RAM variables as appropriate, e.g. SV code selections. The MCR's are described below.

Output Module Timing Control (REH001)

This MCR controls output module timing. One byte of data is output.

Bit 7 (MSB) controls switch H on the output module, selecting sample and hold input to the A/D converter. A one selects sample and hold 2 while a zero selects sample and hold 1. (Refer to the Interface Control Document, Texas Instruments drawing 2008917, for a description of switch functions.)

Bit 6 controls switch G on the output module, controlling the input to sample and hold 2. A one selects the data multiplexer selection, while a zero selects the

output of integrate and dump 2.

Bit 5 controls switch F on the output module, controlling the input to integrate and dump 2, the non-inverting argument of the difference amplifier, and one argument of the summing amplifier. A one selects narrowband channel 3 correlation while a zero selects narrowband channel 2 correlation.

Bit 4 controls switch E on the output module, controlling the input to the inverted argument of the difference amplifier, the second argument of the summing amplifier and the third input for integrate and dump 1. A one selects narrowband channel 2 correlation while a zero selects narrowband channel 1 correlation.

Bits 3 and 2 control the input to integrate and dump 1. a two selects the output of switch E, a one selects the output of the difference amplifier and a zero selects the output of the summing amplifier.

Bits 1 and 0 control the timing of the integrate and dump and the sample and hold circuits. A two selects 5 milliseconds, a one selects 20 milliseconds and a zero selects C/A epochs (1millisecond). The timing selected for the output module is also used to control the timing of the code generator advance/retard clock, which is controlled in the MVUE through the EIOM.

Code Generator Module Output Register 0 (REH002)

This MCR controls the code injection to the narrowband modules. Five bits of data are output from the byte passed

to REH002.

Bits 4, 3 and 0 (0 being the least significant bit) control code injection for narrowband channel 2. A zero selects C/A early, a one selects P early, a two selects C/A late, a three selects P late, a four or five selects C/A prompt, and a six or seven selects P prompt.

Bits 2, 1, and 0 control code injection for narrowband channel 1, with the selection codes corresponding to those for channel 2.

Code Generator Module Output Register 1 (REH003)

This MCR controls code injection to the narrowband modules. Bit selections are the same as for Register 0 (REH002). The two registers are alternately selected when code flop is enabled.

Narrowband 1 AGC Selection (REH004)

This MCR controls selection of the AGC time constant for narrowband channel 1. The least significant bit of the byte pointed to by the SRB is passed to the hardware; the other 7 bits are ignored. A zero in the LSB selects a 40 millisecond AGC time constant, while a one selects a 1 second time constant.

Narrowband 2 AGC Selection (REH005)

This MCR controls selection of the AGC time constant for narrowband channel 2. The least significant bit of the byte pointed to by the SRB is passed to the hardware; the other 7 bits are ignored. A zero in the LSB selects a 40 millisecond AGC time constant, while a one selects a 1 second time

constant.

Wideband AGC Selection (REH006)

This MCR controls the selection of the AGC time constant for the wideband module. Bits 1 and 0 are transmitted to the hardware; the other 6 bits are ignored. A one selects a 1 millisecond AGC time constant while a two selects a 2 second AGC time constant. This MCR assures that at least one time constant control line is always on (a make-before-break strategy)

Calibration Bit Control (REH007)

This MCR controls the Costas loop tracking. The least significant bit of the byte passed by the SRB is used; the other 7 are ignored. A value of one cause the loop to be in the calibrate mode, with the frequency synthesizer being controlled by the VCXO setting output by the processor. A value of zero closes the Costas loop, using error feedback from a narrowband module to control the frequency synthesizer.

Code Generator Reset (REH008)

This MCR causes a code generator reset. The data pointed to by the SRB is ignored.

Code Generator Start (REH009)

This MCR causes the code generator to start. The data pointed to by the SRB is ignored.

C/A Code Selection Loading (REH010)

This MCR outputs the 6 least significant bits of the byte passed by the SRB to the code generator to select the C/A

code for the desired SV. Refer to the data set REFCDE for the appropriate code for each SV.

P Code Generator Reset (REH011)

This MCR resets the P code generator. The data byte passed by the SRB is ignored.

P Code Selection Loading (REH012)

This MCR outputs the 6 least significant bits of the byte pointed to by the SRB to the P code generator to select the appropriate P code for the desired SV. Refer to the data set REFCDE for the data to be output for each sv.

3-State Bus Control (REH013)

This MCR is used to select the state of the 3-state bus. The least significant bit is used; the other 7 bits are ignored. A value of zero enables the bus, while a one disables it.

Output Module Data Selection Control (REH014)

This MCR selects the narrowband channel from which data is to be recovered. Bits 1 and 0 are used; the 6 most significant bits are ignored. A value of zero indicates channel 1 while a value of two indicates channel 2.

Code Flop Control (REH015)

This MCR is used to select the mode of code flopping. Bit 0 (LSB) is used; the other 7 bits are ignored. A value of zero stops code flop and causes the code generator to use register 0 to determine code outputs to the narrowband modules. A value of one enables code flop, causing the code generator to alternate between output registers 0 and 1.

Bandpass Filter Control (REH016)

This MCR is used to select the center frequency of the bandpass filter in the wideband module. Bit 0 (LSB) is used; the other 7 bits are ignored. A value of zero selects L1 while a value of one selects L2.

Built In Test Module Reset (REH017)

This MCR resets the Built In Test module. The data pointed to by the SRB is ignored.

Built In Test Module Injection Control (REH018)

This MCR is used to enable one of the two RF output signals available from the Built In Test module. The 2 least significant data bits are used, the 6 most significant bits are ignored. A value of zero selects no signal, a value of one selects the wideband module test signal and a value of three selects the narrowband test signal (18Fo). Note: the 230 kHz output to the range rate counter is enabled when either of the RF output signals is selected.

Built In Module Start (REH019)

This MCR starts the built in test module. The data pointed to by the SRB is ignored.

Q Switch Control, Narrowband 1 (REH020)

This MCR is used to control the Q switch for narrowband channel 1. The least significant bit is used; the other 7 bits are ignored. A value of zero closes the Q switch while a value of one opens it.

Q Switch Control, Narrowband 2 (REH021)

This MCR is used to control the Q switch for narrowband

channel 2. The least significant bit is used; the other 7 bits ignored. A value of zero closes the Q switch while a value of one opens it.

AGC Control Selection, Narrowband 1 (REH022)

This MCR controls whether the AGC control for narrowband channel 1 is external or internal. The least significant bit is used; the other 7 bits are ignored. A value of zero selects external while a value of one selects internal.

AGC Control Selection, Narrowband 2 (REH023)

This MCR controls whether the AGC control for narrowband channel 2 is external or internal. The least significant bit is used; the other 7 bits are ignored. A value of zero selects external while a value of one selects internal.

T Code Selection Control (REH024)

This MCR controls the T code. The least significant bit is used; the other 7 bits are ignored. A value of zero disables T code while a value of one enables it.

TRANSEC Selection Control (REH025)

This MCR controls the selection of TRANSEC. The least significant bit is used; the other 7 bits are ignored. A value of zero de-selects TRANSEC while a value of one selects it.

Range Rate Counter Input Selection (REH026)

This MCR selects the input signal to the range rate counter. The least significant bit is used; the other 7 bits are ignored. A value of zero selects the 230 kHz signal from the BITE module, while a value of one selects

the 230 kHz signal from the frequency synthesizer. The BITE module signal is used for R1RRM, while the frequency systnesizer signal is used at all other times.

Wideband Attenuator Control (REH027)

This MCR controls the selection of the wideband attenuator. The least significant bit is used, the other 7 bits are ignored. A value of zero selects 0 dB attenuation while a value of one selects 20 dB attenuation.

Frequency Synthesizer L1/L2 Control (REH028)

This MCR controls the basic frequency of the frequency synthesizer. The least significant bit is used, the other 7 bits are ignored. A value of zero selects L1 while a value of one selects L2.

X1 Code Selection (REH029)

This MCR controls the X1 code. The least significant is used, the other 7 bits are ignored. A value of one selects X1 code while a value of one deselects X1.

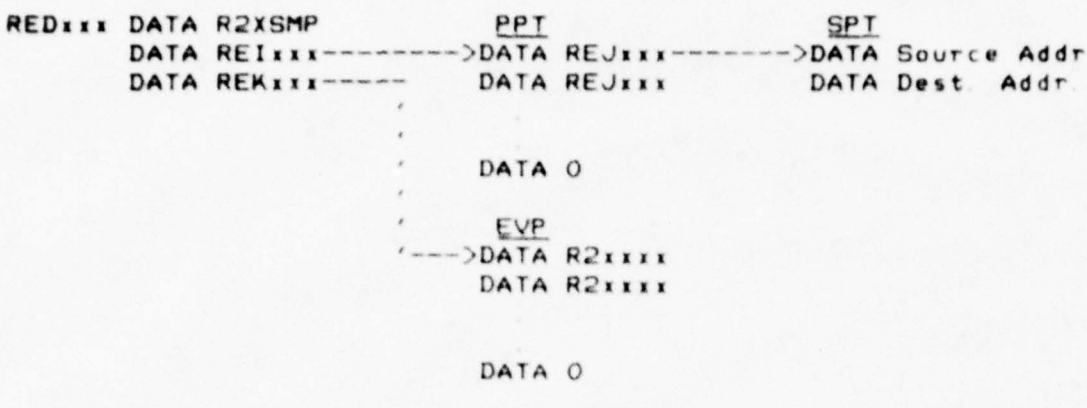
Reset Sample And Hold Circuit (REH030)

This MCR resets the sample and hold circuits in the output module. The data pointed to by the SRB is ignored.

3.1.3.1.3.2 Software Modification Service

The software modification service is provided by R2XSMP. It allows the task system description to transmit data from one location in memory to another, as well as permitting the calling of subroutines for those cases which require more complex or faster processing. The service

request block and the associated tables for software modification have the following format.



The software modification SRB points to two tables (either pointer may be null). The first table is the pair pointer table (PPT). It provides a list of pointers to transmission specification pair (SPT) pointer tables. Those tables, in turn, provide source and destination addresses. The second table is the entry vector pointer (EVP) table. It provides a list of entry points of subroutines which are to be invoked as a part of the software modification request. Note that the PPT and the EVP tables are of variable length and are terminated by a null pointer.

3.1.3.1.3.3 Task Activation Service

The task activation service is provided by R2XSAS. It allows a task system description to activate tasks which are either controller local or MVUE global tasks. The Service Request Block (SRB) and the associated table for task activation have the following format.

```
REDxxx DATA R2XSAS              ACB
       DATA REQxxx-------->DATA RECxxx     pre-act SRT pointer
                           DATA RENxxx     TAR pointer
                           DATA RECxxx     post-act SRT pointer
```

The task activation SRB points to an Activation Control Block (ACB). The first entry in the ACB is a pointer to a pre-activation Service Request Table (SRT) which provides a list of pointers to SRB's which are to be invoked prior to the activation of the task. The next entry is a pointer to a Task Attribute Record (TAR). Refer to paragraph 3.1.3.1.4.1 for a discussion of TAR'S. The final entry points to a post-termination SRT, which identifies services to be invoked after the task terminates. The pre-activation and post-termination SRT pointers may be null, in which case no action is taken.

3.1.3.1.3.4 Task Cancellation Service

The task cancellation service is provided by R2XSCS. It allows a task system description to cancel tasks which are either controller local or MVUE global tasks. The Service Request Block (SRB) for task cancellation has the following format:

```
       SRB
REDxxx DATA R2XSCS
       DATA RENxxx      TAR pointer
```

The task cancellation SRB points to an Task Attribute Record (TAR). Refer to paragraph 3.1.3.1.4.1 for a discussion of TAR'S. If the specified task is not active, no action is

taken.

3.1.3.1.3.5 Time Dependent Event Scheduling Service

The time dependent event scheduling service is provided by R2XTES. It allows a task system description to request the processing of a Service Request Table at some future time with respect to the clock of the RSC. The processing may either be scheduled to be synchronized with some event cycle (in 5 millisecond units) or to occur once at some time (in 5 millisecond units) from the current time. The SRB and the associated table have the following format:

```
        SRB
REDxxx  DATA R2XTES          SCB
        DATA REMSCB--------->DATA <event cycle time>
                             DATA <offset in 5 ms. units>
                             DATA RECxxx                  SRT pointer
```

The time dependent event scheduling SRB points to a Scheduling Control Block (SCB) which contains three parameters. The first parameter is the length of the event cycle (in 5 millisecond units) with which scheduling is to be synchronized. If the event is non-periodic, the contents of this word is 0. The second parameter is an offset in units of 5 milliseconds which is to be applied to the computed event time, allowing the relocation of an event with respect to its period. The last word points to an SRT which is to be invoked at the calculated event time. The SRT describes the event in terms of service requests.

The event times are calculated from the SCB data as

follows

(1) Cyclic Events

Te = (LI((Tc-K)/C)+1)*C+K where K<C and C<clock modulo

(2) Non-cyclic Events

Te = Tc+K where K>0

Definitions

C = Cycle period in 5 ms units

K = Offset in 5 ms units

Tc = Current time in 5 ms units

Te = Event time in 5 ms units

LI = Least integer function ie smallest integer <= argument

3.1.3.1.3.6 Sequence Specification Table Processing Service

The Sequence Specification Table (SRT) processing service is provided by R2XSSP. It allows a task system description to initiate processing of the next entry in the SST. Refer to paragraph 3.1.3.1.1 for a discussion of SST's. The SRB has the following format:

```
          SRB
RED:::  DATA R2XSSP
```

The SST processing service is typically invoked as part of a post termination SRT for a task which requires that it complete before processing continues.

3.1.3.1.3.7 No Operation Service

The no operation service is provided by R2XNOP. It

allows a task system description to issue a service request which result in no action being taken. It serves diagnostic purposes and is not used in the final software. The SRB has the following format:

```
          SRB
REDxxx DATA R2XNOP
```

3.1.3.1.3.8 Post-termination Processing Cancellation Service

The post termination cancelling service is provided by R2XCPP. It allows a task system description to cancel the post termination processing for a task which was started by an earlier task activation service request. The Service Request Block (SRB) for post termination processing cancellation has the following format:

```
          SRB
REDxxx DATA R2XCPP
       DATA RENxxx      TAR pointer
```

The task cancellation SRB points to a Task Attribute Record (TAR). Refer to paragraph 3.1.3.1.4.1 for a discussion of TAR'S. This service is typically used after a task terminates abnormally and processing of the post-termination Service Request Table is not appropriate.

3.1.3.1.3.9 X3ERRA Calling Service

The X3ERRA calling service is provided by R2XERR. It allows a task system description to invoke the executive error reporting routine. The Service Request Block (SRB)

for X3ERRA calling has the following format:

```
          SRB
RED###    DATA R2XERR
          BYTE <error code>
          BYTE <argument count>
          DATA <data address>     *optional*
          DATA <data address>     *optional*
          DATA <data address>     *optional*
          DATA <data address>     *optional*
          DATA <data address>     *optional*
          DATA <data address>     *optional*
          DATA <data address>     *optional*
```

The X3ERRA calling SRB points to arguments which are then passed to X3ERRA to report a processor error to the executive. The occurrence of this service request indicates an error condition which cannot be handled by the RCSS.

3.1.3.1.4 Task Attribute Structures

Each task which is controlled by the RSC is described in the task system descriptions through several structures. The following subparagraphs describe those structures.

3.1.3.1.4.1 Task Attribute Records

The Task Attribute Record (TAR) is used to describe the fundamental attributes of all tasks controlled by the RSC. More than one TAR may be provided for a particular task, since different invokations of a task may require different attributes, e.g., communication structures. TAR's are implemented in the ROM data set RENTAR. They are structured as follows:

```
RENxxx DATA <communication control block address>
       DATA <entry vector address>
       DATA <status block address>  (REXxxx)
       DATA <task attribute>
```

The first entry in the TAR is a pointer to a Communication Control Block (CCB). If the task is non-local or if no communication structure is required for the task, this entry is zero.

The second entry points to the task's entry vector. If the task is non-local, this entry is zero.

The third entry is a pointer to a status block for the task. It is provided for both local and global tasks.

The last entry is zero for local tasks, but for global tasks points to the task through the executive. The entry will be the mnemonic name of the task with the R1 replaced by R0, in order to provide proper communication with the executive subsystem.

3.1.3.1.4.2 Communication Structures

This facility is provided to allow local tasks to communicate with the RSC in order to indicate actions which are to be taken upon their termination or any other that they require communication services or need status messages to be transmitted to the Master Control Subsystem. A task initiates the communication with a call to R3COMM. Three structures are provided in the task system descriptions to support the communication. The first is the Communication Control Block (CCB). CCB's are provided in the ROM data set REPCCB. For applications which require multiple CCB's in

the same communication structure, the software modification service is used to move the CCB to the RAM data set RETSCM, which is then pointed to by that task's TAR. CCB's have the following format:

```
REPxxx DATA <message address>
       DATA <null message address in MLT>
```

The first entry in the CCB is a pointer to the message word which the task will use when it communicates. This address is that of the variable RCEMOD for most tasks but also takes on other values.

The second entry points to the null entry in a Message Control Linkage Table (MLT).

The MLT provides a list of addresses of Message Control Blocks (MCB's). Each MCB describes the action which the controller should take for a particular value of the message word. The MCB which is selected is determined by using the address of the null entry as a base address and the message code times 2 as a relative offset. MLT's are implemented in the ROM data set RERMLT. They have the following format:

```
       DATA RESxxx   <MCB for message value -n>
       DATA RESxxx   <MCB for message value -(n-1)>

RERxxx DATA RESxxx   <MCB for message value 0>

       DATA RESxxx   <MCB for message value m-1>
       DATA RESxxx   <MCB for message value m>
```

The MCB's specify the action to be taken by the controller when the task initiates a communication. MCB's are implemented in the ROM data set RESMCB. MCB's have the

following format:

```
RESxxx DATA <MCSS status message>
       DATA <SRT address>
       DATA <termination code>
```

The first entry in the MCB is the value which is to be passed to the Master Control Subsystem. The value is transferred through the data set REYRST to R1XCCP, which passes it on to Master Control. If no value is to be transmitted, this entry is zero.

The second entry points to an SRT which is to be invoked as a result of the communication. If no services are required, this entry is zero.

The third entry contains a termination code for the communication. A value of 0 causes the process waiting service to be invoked while a value of -1 causes the process stopping service to be invoked. Thus a call to R3COMM in a task with a 0 in this entry is equivalent to a call to R3WAIT, while a - in this entry would be equivalent to a call to R3STOP.

Since global tasks may not call R3COMM (they must use the executive's waiting and stopping services) special provisions must be made for communication with the RSC. This communication is implemented with an Interface Task Monitor which is the local task R1XITM. It is activated with a communication structure appropriate to the global task for which communication is desired. R1XITM then simply invokes R3COMM every 5 milliseconds so that any value placed in the tasks message word will cause the RSC to take

required action. Note that for this case the waiting/stopping selection affects R1XITM and not the task which is being monitored. If it is necessary to stop a task which is being monitored, the SRT which is part of the communication structure may include a task cancelling SRB.

3.1.3.1.4.3 Status Structure

For each task controlled by the RSC, a Task Status Table (TST) is allocated. The TST entries are defined in the RAM data set REXTST and are pointed to in the task's TAR. The format of the TST'S are as follows:

```
REXxxx BSS  2
       BSS  2
```

The first entry in the TST contains the activation status, 0 for not active and non zero for active. If the task is local the first word for an active tasks contains the address of the Task Descriptor Block (TDB).

The second entry contains the activity status, zero if the task is waiting to be readied and non-zero if the task is running.

3.1.3.1.4.4 Dynamic Task Control Structures

Memory for dynamic task control structures (task descriptor blocks, time event blocks and task status updates) is allocated in the RAM data set REUQLS. The amount of memory allocated is determined by assembly time constants contained in the data set REWCTB. Initialization

of this storage and the task status table described above is provided by R2XSIP, which uses parameters from the data set REETCP to identify areas of memory to be cleared or linked.

Task Descriptor Blocks have the following format:

```
<successor TDB address>
<predecessor TDB address>
<TDB status>
<WP>
<PC>
<ST>
<TAR address>
<post-termination SRT address>
```

The first and second entries in the TDB serve to link together TDB's for active tasks. The entries are zeroed when successor or predecessor tasks do not exist. The third entry inoicates whether the task is running (=1) or suspended (=0). The fourth, fifth and sixth entries describe the state vector of the task when it last yielded control of the processor. The seventh entry points to the Task Attribute Record. The eighth entry points to the post-termination SRT, if any.

Time Event Blocks have the following format:

```
<successor linkage>
<event time>
<event SRT pointer>
```

The first entry serves to link together time event blocks into a time event queue. R2XTES calculates the time at which a scheduled event is to occur and links it into one of two time event queues. If the calculated time is less than the local clock modulo (24000 five millisecond periods), the event is sorted into a pre-rollover queue. If the calculated time is greater than the local clock modulo,

it is sorted into a post-rollover queue. When the local clocks exceeds the local clock modulo (rolls over), the queues are swapped. The time event processor, R2XTEP, scans the time event queue each 5 milliseconds to determine whether it is time to process any events. If so, the respective SRT pointer is processed.

3.1.3.2 Sequence Descriptions

A receiver sequence is initiated when a command is received from the Master Control subsystem. The mode command causes the RSC to initiate processing of a Sequence Specification Table. The following subparagraphs describe the sequences which are executed by the RSC in response to various mode commands.

3.1.3.2.1 First SV Acquisition Sequence (Mode 2)

The first SV acquisition sequence is commanded by Master Control when precision time (relative time offset between GPS and User times) is not available. It consists of the following steps:

(1) A mode 2 command is received from Master Control.

(2) R1XCCP copies aiding data and initiates the processing of the sequence specification table REB005.

(3) The L1 frequency is selected.

(4) R1CAL is executed using the R1CAL primitive, REC060. This generates a linear approximation for the frequency vs. Voltage characteristic of the VCXO.

(5) R1SET is executed using the primitive REC064. This primitive causes the search parameter manager, R2XSPM, to be executed in order to provide range rate aiding for use by R1SET and search parameters for R1SCH.

(6) The C/A code generator is started using a non-correlating C/A code (SV "38").

(7) R1NSE is executed using the primitive REC068. This establishes an estimate of the noise level in the environment.

(8) R1SCH is executed using the R1SCH primitive, REC074. R1SCH uses the search parameters set by R2XSPM, which was executed by the R1SET primitive. Those parameters specify a full (1023 chip) C/A search, in steps of 16/17th's of a C/A chip. R1SCH moves the local code vs the satellite code until correlation is detected (1.35 times the noise estimate). If correlation is not detected, R2XSPM and R1SET are invoked again to initiate another full C/A search with Doppler offset of -20 meters per second from the aided value. A second search failure causes another full C/A search with a doppler offset of +20 m/s. Subsequent failures cause alternate Doppler bins to be selected until correlation is detected or a search timeout is declared by Master Control and another command is issued to the RCSS.

(9) R1TRK is activated using the primitive REC079, with FLL second order selected.

(10) R1BSN is activated using the primitive REC084. R1BSN resolves the ambiguity as to the C/A epoch which coincides

with the data bit transition, in order to be able to recover data.

(11) Data Recovery is initiated using the primitive REC103. After the barker code is found by R1DDT, R2PCK validates the barker code by: (1) checking parity of the following data word and (2) checking that the z-count recovered in the handover word matches the time entered by the operator within 4 minutes. R2PCK then passes data words and word identification to Master Control.

(12) Handover word data is passed to Master Control using the SRT REC104.

(13) Master Control commands an FTF resync to cause the local FTF to correspond with GPS time.

(14) Master Control commands handover to P code, by issuing a mode 10 command, which causes the RCSS to process the Sequence Specification Table REB006.

(15) R1DDT is commanded to save data for handover.

(16) R1RNG is activated in order to provide range measurements.

(17) R1PIN is activated using the primitive REC094. R1PIN initializes the P code to a state to correspond to the data in the handover word received from the SV.

(18) Handover is enabled by the SRT REC036.

(19) Handover is commanded by R1TRK at the start of a TLM word in order to minimize the useful data lost in the transition between codes.

(20) The receiver continues to recover data, execute range

measurements and perform P code tracking until another command is received from Master Control.

3.1.3.2.2 Subsequent SV Acquisition Sequence (Mode 3)

A subsequent SV acquisition is commanded by Master Control for initial C/A acquisition after the handover word has been acquired using a First SV Acquisition sequence (Mode 2). The same Sequence Specification Tables (REB005 and REB006) are used as for First SV Acquisition, with the differences being coded into the RCSS tasks. Subsequent SV Acquisition is initiated by a mode 3 command from the Master Control Subsystem. The differences between first and subsequent SV acquisition are as follows:

(1) The command to handover is issued by R1XCCP instead of MCSS.

(2) The validation of the barker code by R2PCK uses the local FTF to compare against the received z-count instead of user input time, since the local FTF has been synchronized with respect to GPS time during a Mode 2 acquisition.

3.1.3.2.3 C/A Reacquisition Sequence (Mode 4)

C/A reacquisition is commanded by MCSS after the SV's have been initially acquired and their ephemeris data has been recovered. It is used to acquire in C/A code using a short C/A code peak search and obtain range and range measurements, as a preliminary to p reacquisition. It is a "sequencing" mode in that the entire sequence executes

within 2 seconds. The C/A reacquisition sequence is initiates by a mode 4 command from MCSS. The following steps make up the sequence:

(1) The L1 frequency is selected.

(2) R2XSPM and R1SET are executed using the primitive REC064. No offset is applied to the range rate aiding received from Nav.

(3) R1PIN is executed with the REC094 primitive. This sets the C/A code to the code phase calculated from the aiding and precision time information provided by nav.

(4) R1TRK is activated using the primitive REC079. R1TRK executes a code peak search, the length of which is defined by R2XSPM (20 steps of 16/17th's of a C/A chip each). THE code is then positioned at the code phase where maximum correlation was detected. R1TRK then performs a coarse centering operation and transitions to a steady state tracking mode.

(5) R1RNG is scheduled using the primitive REC113. The actual range measurement takes place near the end of the 2 second interval during which this mode is active.

(5) R1REG accumulates discriminator data from R1TRK for use in the next 2 seconds by R1RMD for it's vernier range computation.

(6) During the 2 second interval, if a range measurement was taken during the previous 2 seconds, it is processed, validated and made avaliable to Nav by R1RMD.

3.1.3.2.4 P Reacquisition Sequence (Mode 5)

The P Reacquisition Sequence is the normal range measurement sequence during the steady state operation of the MVUE. The sequence is the same as for mode 4 (C/A Reacquisition) except that P code is selected and the code peak search length is 18 steps of 16/17th's of a chip with nav aiding and 22 steps with self aiding (mode 4 uses a constant 20 step search).

3.1.3.2.5 P Reacquisition Sequence-L2 (Mode 6)

The P Reacquisition Sequence-L2 is commanded in order to obtain a range measurement at L2 which is used by the Navigation subsystem to calculate ionospheric delay. The sequence is the same as for mode 5 (P reacquisition) except that L2 is selected and the RIRMO stores measurement data in the data set RNIONS instead of RNMEAS.

3.1.3.2.6 Ephemeris Update Sequence (Mode 7)

The Ephemeris Update Sequence is commanded in order to recover a subframes worth of data during steady state operation of the MVUE. The acquisition sequence is the same as for mode 5 (P reacquisition). The difference is that data recovery is initiated after the signal is acquired. The timing of the command is such that the sequence begins 2 seconds before the start of the subframe from which data is to be recovered. Data is recovered for the subframe (6 seconds) and then another command is received from Master

Control. The timing relationships are established by Master Control and are transparent to RCSS.

3.1.3.2.7 New SV Acquisition Sequence (Mode 8)

The new SV acquisition sequence is used to acquire SV's during steady state using a sequential P code search. It is used because the range to the SV is not known with sufficient accuracy to acquire with mode 4 or mode 5. The p code is initialized to a point with the code phase advanced 1.5 times the standard deviation of the error in range (-1.5 sigma). R1SCH then searches for correlation. The critical requirement for this mode is that the search must allow for being interrupted after two seconds and being resumed at some time later. If the search is interrupted, it resumes at a point 15 steps (16/17 of a chip apart) overlapped with the prior two seconds (to allow for SV motion affecting the code phase). If the search exhausts 813 steps (to +3.0 sigma) it is reset to -3.0 sigma and the search is resumed. If correlation is detected, R1TRK and R1RNG are scheduled to run 1195 milliseconds before the end of the 2 second interval. If the time at which the scheduling occurs is after 1195 milliseconds, no range measurement will be performed and Master Control will not recognize that acquisition occurred. Another mode 8 command will be received for the SV at which time the 15 point overlap should cause acquisition very early in the 2 second interval, providing time for the range measurement to

occur. This strategy allows sufficient regression points to be taken to provide a valid vernier range correction to the measurement.

The initial 2 second mode 8 interval includes a noise calibration which is skipped in subsequent intervals, with RINSE substituting a 100 millisecond delay to allow AGC settling.

A mode 8 command on an SV causes R1RMD to indicate no measurements for that SV. This forces the Navigation subsystem to supply navigation aiding (as opposed to receiver self aiding), which is more accurate when the signal has not been acquired for some time. Mode 8's are used both for new SV'S and reacquiring SV's which have not provided a good measurement for more than 4 minutes.

3.1.3.2.8 Sequential P Reacquisition Sequence (Mode 24)

The Sequential P Reacquisition sequence is used when measurements are being missed on an SV and the code peak search is indicating no signal present. It uses the same sequence specification table (REB014) as is used by mode 8, with the differences being defined by R2XSPM.

The differences include: (1) the search interval is 150 steps on each side of the expected code phase and (2) the search starts at the fully advanced code phase.

The mode selection criteria (whether to use Mode 8 or Mode 24) is established by Master Control and is transparent to the RCSS.

3.1.3.2.9 Almanac Acquisition Sequence (Mode 25)

The almanac acquisition sequence is initiated by an operator through the Master Control Subsystem. The same sequence specification tables (REB005 and REB006) are used as for first SV acquisition, with the differences being implemented in R2XSPM. The differences between first SV acquisition and almanac acquisition are as follows:

(1) The search parameters generated by R2XSPM provide a full doppler search (covering the range +/- 780 meters per second. The search starts with the aided value of range rate and searches about it until the limits are encountered. If the aided value is outside the limits, the search starts at the closest limit and covers all doppler bins to the other limit. Doppler bin center frequencies are separated by 52 meters per second to correspond to the bandwidth of the narrowband amplifiers.

(2) The timeout interval allowed by Master Control is sufficient for the full search (8 minutes).

(3) If acquisition is declared but bit sync or data recovery fails, the search will resume at the last attempted doppler frequency.

3.1.3.2.10 Built In Test Sequence (Mode 1)

The built in test sequence is executed during power up and during warm start or restart. It consists of the

following steps:

(1) The local clock of the receiver is synchronized with the FTF count.

(2) The wideband and frequency synthesizer modules are set up for L1.

(3) R1CAL is executed using the primitive REC060 to calibrate the VCXO.

(4) The Wibeband Module test signal from the bite module is selected.

(5) R1RRM is executed to measure the relative range rate from the built in test module.

(6) The VCXO is set to correspond to the BITE module relative range rate, using the primitive REC064 to execute R1SET.

(7) The 3-state bus is enabled and the BITE module is started.

(8) The BITE mode for R1PIN is selected and the T code is disabled.

(9) The code generator is initialized to start the X1 code.

(10) Noise calibration is performed to determine the noise environment.

(11) The 3-state bus is enabled.

(12) R1SCH is executed using search parameters defined by R2XSPM, which cause a 512 chip search to be executed.

(13) R1TRK is executed using the primitive REC079.

(14) R1BSN is executed in the verify mode to establish

correct bit sync.

(15) Data recovery is initiated. The BITE module modulates its output with a continuous barker code, so data recovery only goes as far as barker code detection.

(16) When a good measurement is processed by R1RMO, a mode 21 command is generated in order to initiate an L2 BITE measurement.

(17) The L2 sequence is the same as the L1 sequence except for selection of L2, not performing VCXO calibrate and leaving the BITE code generator running as the gode generator module is started so as to align with the BITE code. When a good L2 measurement is processed by R1RMO, a mode 22 command is generated to cause the RCSS to report BITE successful. If R1RMO detects 5 bad measurements in either the L1 or L2 sequence, a mode 23 command is generated to cause the RCSS to report BITE failure.

3.1.3.3 Receiver Sequence Controller Software Modules

The modules which make up the Receiver Sequence Controller are as follows:

CPC	FUNCTION
R1RSC	Sequence Control Kernel
R3COMM	Local Task's Communication Server
R3WAIT	Local Task's Waiting Server
R3STOP	Local Task's Stopping Server
R3CANC	Local Task's Cancelling Server

R2XTEP	Time Event Processor
R2XSTD	Local Task Dispatcher
R2XERR	X3ERRA Calling Processor
R2XCPP	Post-termination Processing Cancellation Processor
R2XNOP	No Operation Processor
R2XHMP	Hardware Modification Processor
R2XSMP	Software Modification Processor
R2XSCS	Task Cancelling Processor
R2XSSP	Sequence Specification Table Processor
R2XTES	Time Event Scheduling Processor
R2XSAS	Task Activation Service Processor
R2XSRT	Service Request Table Processor
R2XSIP	System Initialization Processor
R2XSPM	Search Parameter Manager
R1XITM	Interface Task Monitor
R1XCCP	Command Communication Processor

3.1.4 Built In Test

The Built In Test (BITE) function is assigned to the RCSS but performs both Master Control and Receiver functions. The Computer Program Component which performs the BITE function is T1BITT.

The approach to BITE is to provide operator selectable tests of the master oscillator, EIOM, CDU, local oscillators and Receiver functions. The test of receiver function analyzes the results of the BITE sequence performed at power-up. Failures are reported to the operator through the

CDU

3.2 MASTER CONTROL SUBSYSTEM

3.2.0 General

The MVUE Master Control performs system state transitions according to the state transition diagram and criteria shown in Figure 3.2-1. It also executes the master control functions of Table 3.2-1. These functions may be assigned to one of five groups: System Control, Receiver Control, Navigation Control, CDU Control, and EIOM Control.

The following paragraphs further partition these groups into eleven functions from the software implementation point of view. They are:

1. System Start-up Control
2. SV Acquisition Control
3. SV Reacquisition and Navigation Control
4. Fix Control
5. Waypoint Control
6. C/No Monitoring and Filtering
7. MVUE Instrumentation System Control and System Status Monitoring
8. Data Block Processing
9. Coordinate Transformation Service
10. CDU Control
11. EIOM Control

Figure 3.2-2 shows the relationships among these functions. The functions communicate among each other using data sets. The details of the data sets are described in the following paragraphs.

Timing for each of the master control functions is important and is achieved by allocating the function to a software task having the desired scheduling. The software

modules, the scheduling of tasks, and the assignment of tasks to functions are listed in the paragraphs associated with each of these functions.

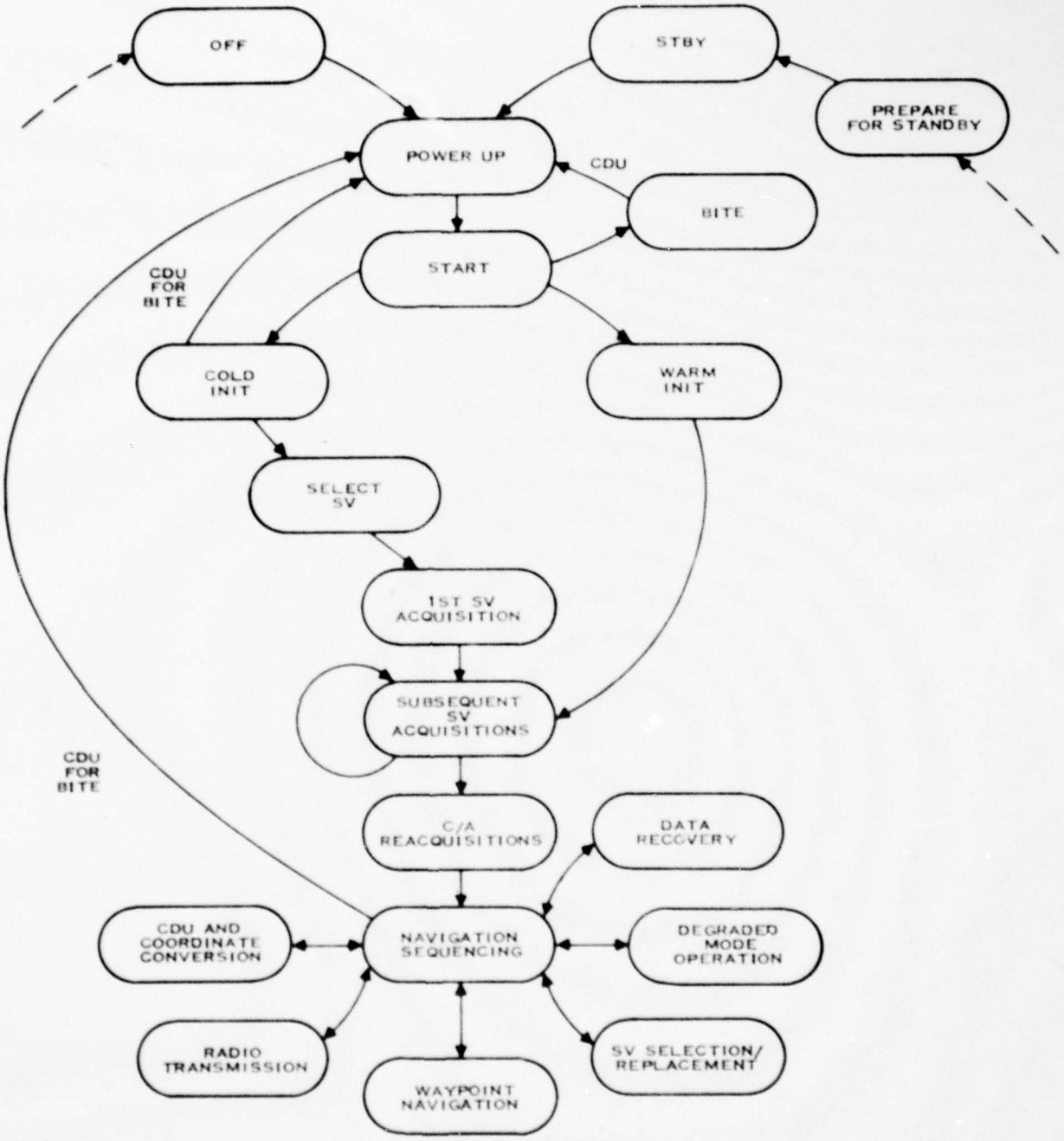
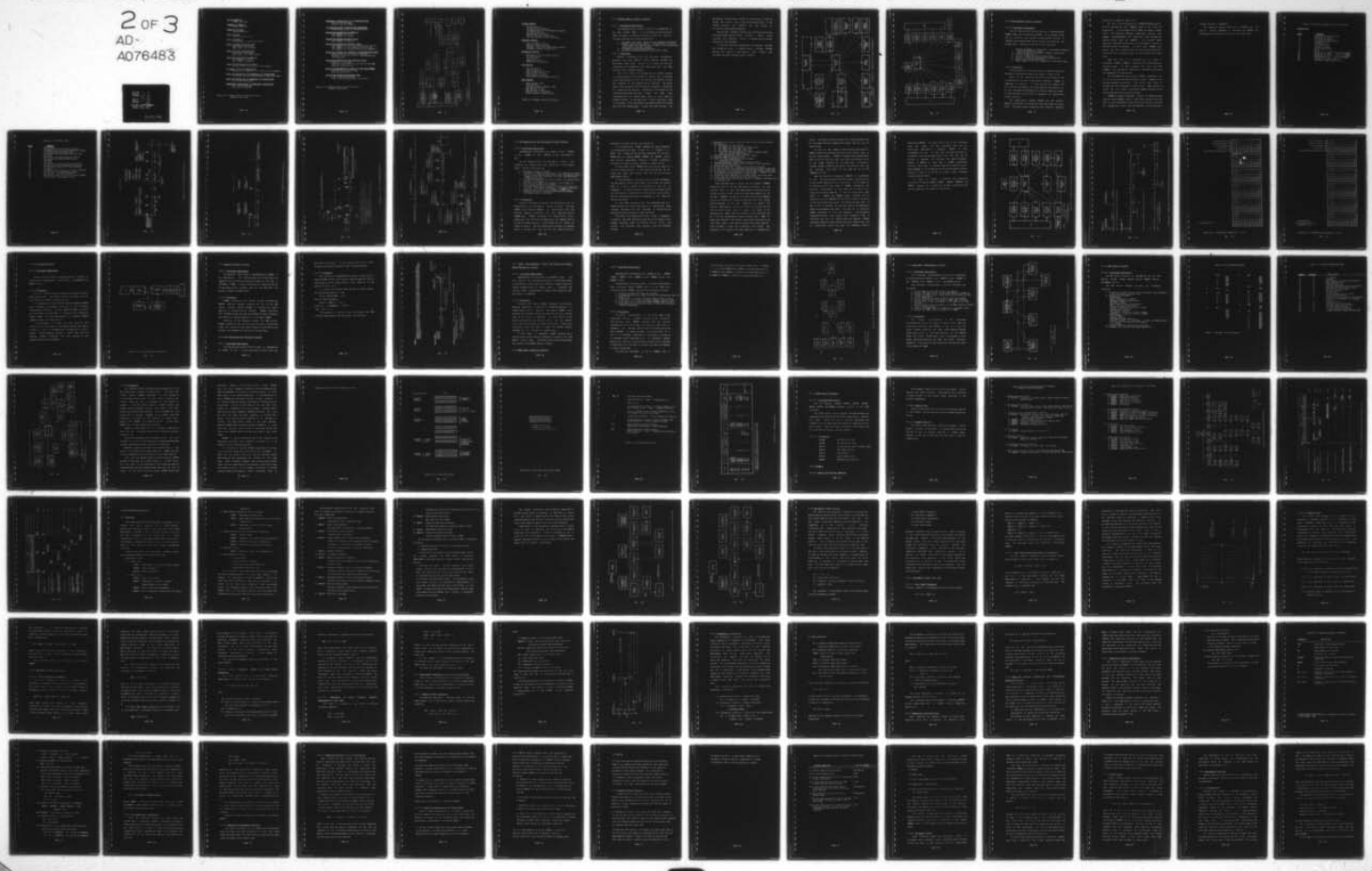


Figure 3.2-1. Master State Transition Control Diagram

AD-A076 483 TEXAS INSTRUMENTS INC DALLAS EQUIPMENT GROUP F/G 17/7
GLOBAL POSITIONING SYSTEMS (GPS), MANPACK/VEHICULAR USER EQUIPM--ETC(U)
AUG 79 F04701-75-C-0181
UNCLASSIFIED SAMSO-SD-TR-79-13-VOL-2 NL

2 OF 3
AD-
A076483



OFF TO POWER UP
Power Interrupt

STANDBY TO POWER UP
Power Interrupt

POWER UP TO START
System Warmed Up

START TO BITE
CDU BITE Flag Is Set

BITE TO POWER UP
CDU Command to Leave BITE State

START TO WARM INITIALIZATION
BITE Flag Cleared and
Warm Start Flip Flop Set

START TO COLD INITIALIZATION
BITE Flag Cleared and
Warm Start Flip Flop Cleared

COLD INITIALIZATION TO POWER UP
CDU Command for BITE
CDU Command to Restart

COLD INITIALIZATION TO SV SELECT
Input of User Position and Time Complete

SV SELECT TO FIRST ACQUISITION
Selection and Parabolic Fit Coefficients Complete

FIRST SV ACQUISITION TO SUBSEQUENT SV ACQUISITION
Time Bias Estimated from Ephemeris and Clock Data

WARM INITIALIZATION TO SUBSEQUENT SV ACQUISITION
FTF Counter Restarted

SUBSEQUENT ACQUISITION TO SUBSEQUENT ACQUISITION
Acquired SV Data and
SV's Left To Acquire

Figure 3.2-1 Master State Transition Control Diagram (continued)

SUBSEQUENT ACQUISITION TO C/A REACQUISITION
Acquired SV Data and
No SV's Left to Acquire

C/A REACQUISITION TO NAVIGATION SEQUENCING
Aiding Data Supports P Reacquisition

NAVIGATION SEQUENCING TO POWER UP
CDU Command for BITE
CDU Command to re-start

NAVIGATION SEQUENCING/RADIO STATE
CDU Command for Radio-X

NAVIGATION SEQUENCING/WAYPOINT STATE
CDU Command for Lat/Long Waypoint Position or
CDU Command for Grid Waypoint Position or
CDU Command for Range and Bearing to Waypoint

NAVIGATION SEQUENCING/COORDINATE TRANSFORMATION STATE
Manual Mode and Fix Button Pushed or
Automatic Mode and 1 Minute Time Boundary or
TTFF Complete

NAVIGATION SEQUENCING/DATA RECOVERY STATE
Delta T $\geq$ 1 hour and
Data And Ionospheric Cycles Synchronized and
Operator Authorization

NAVIGATION SEQUENCING/SV SELECTION AND REPLACEMENT
Operator Authorization and
Not Tracking 6 SV's

NAVIGATION SEQUENCING/DEGRADED MODE
3 SV's and Altitude Hold
2 SV's, Altitude Hold and Time Freeze

Figure 3.2-1 Master State Transition Control Diagram (continued)

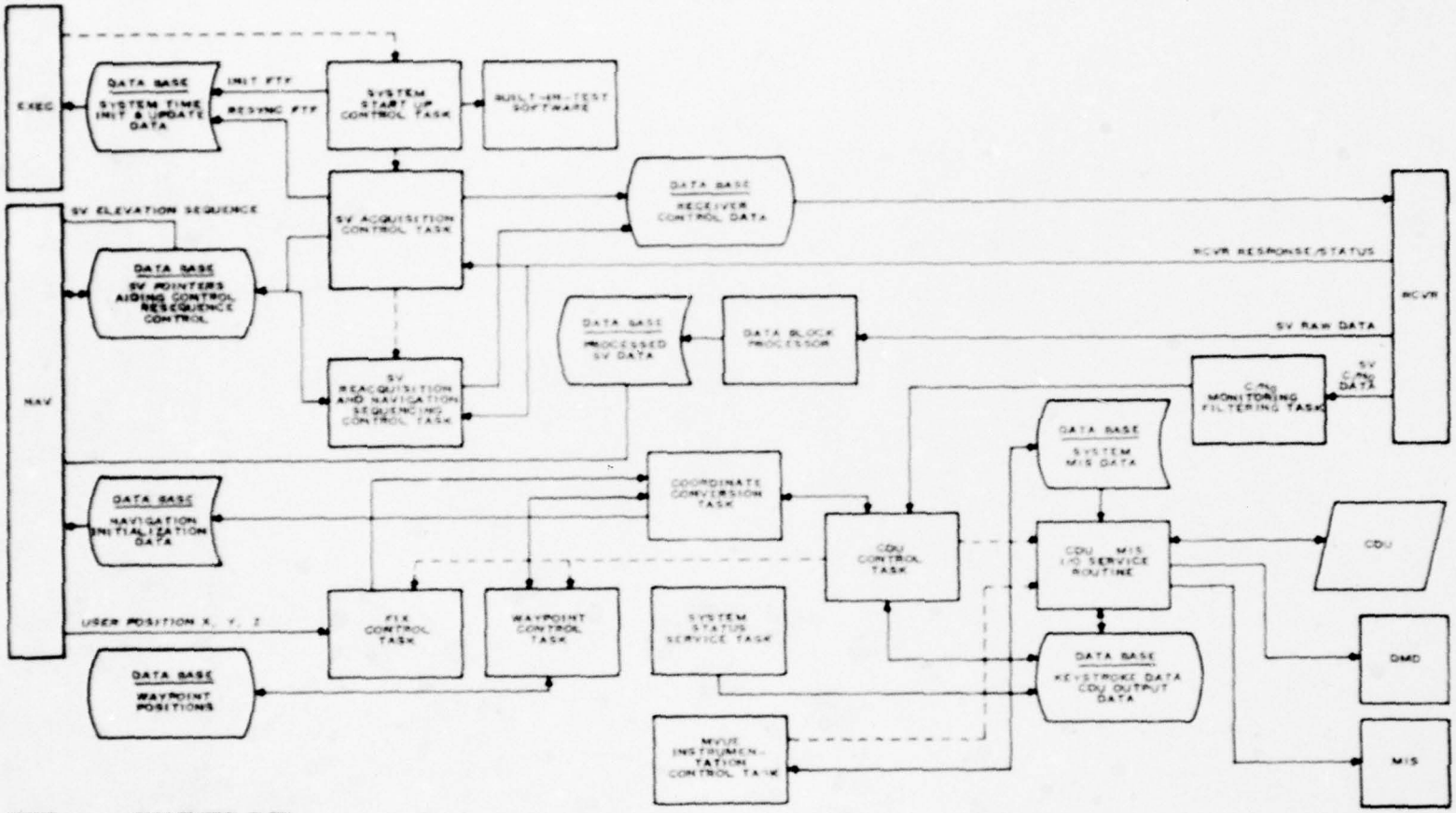


Figure 3.2-2. Master Control Subsystem Configuration

SYSTEM CONTROL

System Start-up
SV Acquisition Control
SV Reacquisition and Navigation Control
SV Status Service
System Status Service
MIS Control and I/O Service
SV C/No Monitoring and Filtering

RECEIVER CONTROL

Reciever Mode Control
Receiver Mode Selection
Ephemeris and Clock Data Update Control
Automatic Almanac Acquisition

NAVIGATION CONTROL

Navigation Initialization Service
Aiding Control
Fix Control
Waypoint Control
Data Block Processing

CDU CONTROL

CDU I/O Control
CDU I/O Service
Data Formatting Service
CDU Function Control
CDU Prompting Control
Coordinate Transformation Service

EIOM CONTROL

Read Standby Timer
Read CRU Bit
Initialize/Start Standby Timer
Set CRU Bit To One
Set CRU Bit To Zero
Read 16 Bits of CRU Data
Write 16 Bits of Data To CRU

Table 3.2-1 Master Control Functions

3.2.1 System Start-up Control Function

3.2.1.1 Functional Description

The system start-up control function is implemented by the task M1ST5M (20ms). It is activated by the Executive after the power up interrupt handler finishes its function. The task executes the following functions:

1. Initiates cold start, warm start and restart processing.
2. Monitors system mode changes. Initiates Built In Test (BITE) mode upon request and proceeds to the normal mode when BITE procedures complete.
3. Activates System Software Modules.
4. Initializes System Data Sets and Control Flags.

3.2.1.2 Processing

M1ST5M interfaces with the Executive, Navigation, Receiver and other Master Control Modules through the associated data sets. Figure 3.2-3 shows the over all configuration of M1ST5M and its relationship with the data sets and other software modules.

The first step of the system start-up control process is initialization of the system FTF counter and activation of the CDU software to turn off the CDU test pattern to test the presence of the system's 20 ms interrupt. The second step is the activation of the Receiver Sequence Controller to initialize the receiver. Depending on the status of the cold-start/warm-start/re-start flags, the task then initialializes the system warm start or cold start or restart process. In the warm start process, precision time is available from calculations performed before the system went into the standby mode. In the cold start process, the

navigation initialization process is initialized in order to accept the initial user position and time input. In the restart process, the operator has the option of re-initializing system parameters.

Appropriate software modules are activated during the cold-start/warm-start/re-start process. After these processes are complete, control is handed over to the SV acquisition task (M1NS20).

If Built-In-Test was requested by the operator through CDU prompting prior to M1ST5M being initiated, M1ST5M cancels the executive self-testing task (X1TST) and activates the BITE software module (T1BITT).

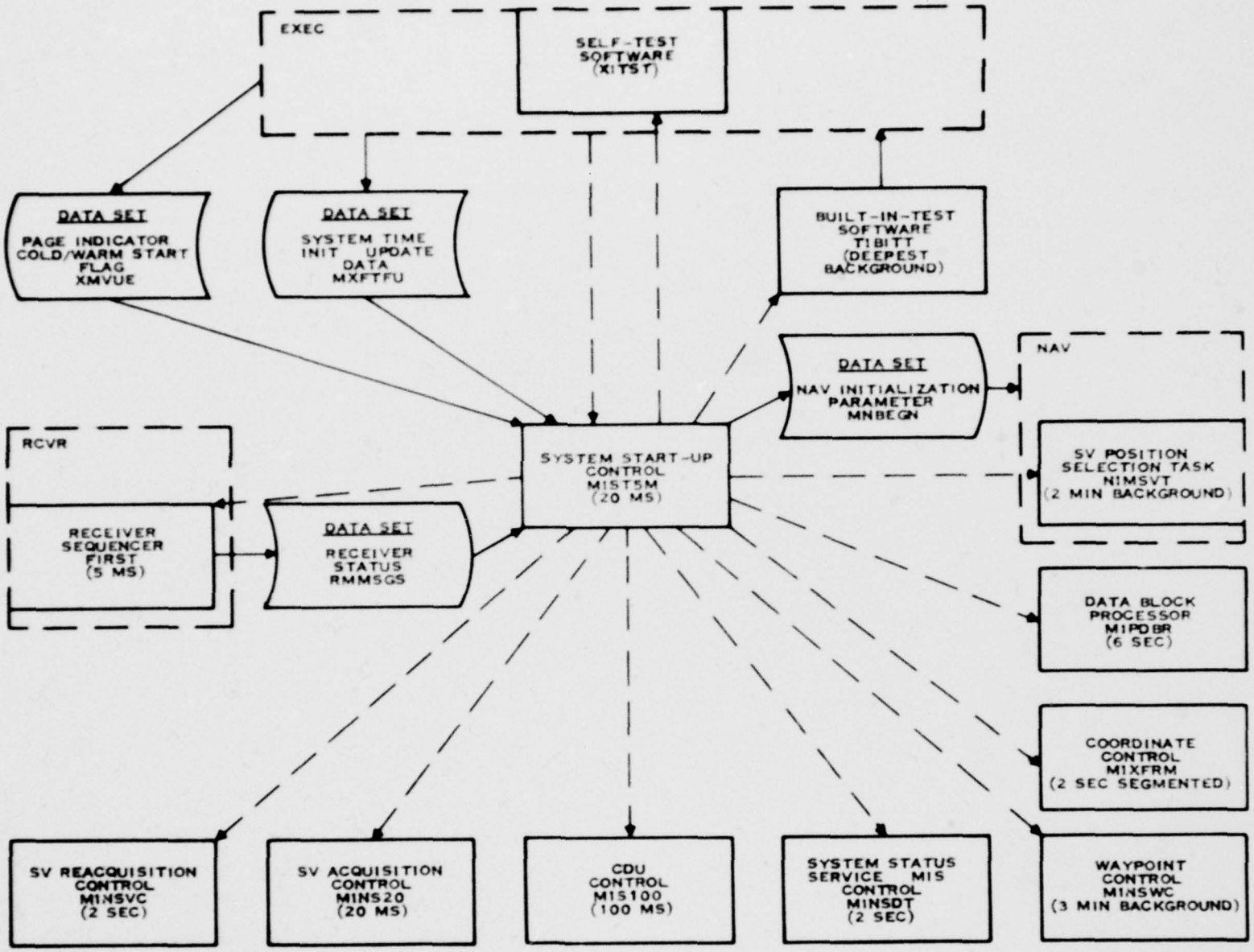


Figure 3.2-3. System Start-Up Control Configuration

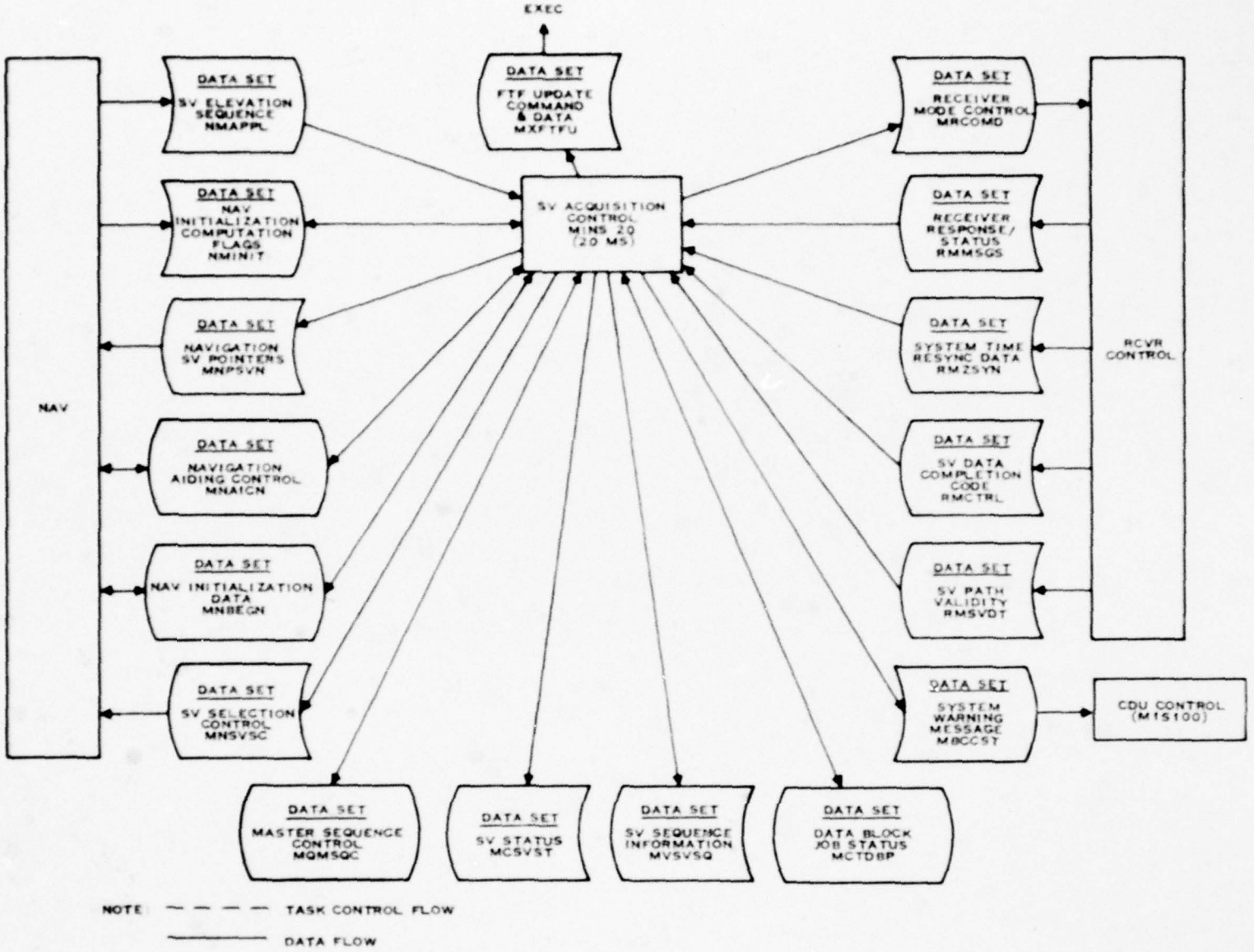


Figure 3.2-4. SV Acquisition Control Configuration

3.2.2 SV Acquisition Control Function

3.2.2.1 Functional Description

The SV Acquisition Control function is implemented by M1NS20 (20ms) and activated by M1ST5M. It is enabled after the SV selection and system initialization process is complete and disabled when the SV acquisition functions are accomplished. The major functions of this task are:

1. Monitoring Number of Visible SV's calculated by Nav SV Selection/Position Control
2. Scheduling Receiver Automatic Almanac Acquisition
3. Control of Nav Aiding
4. Control of Receiver 1st SV Acquisition
5. Control of Receiver Subsequent SV Acquisition
6. Monitoring of SV Data Recovery
7. Readjustment of FTF and Commanding of Precision Time

3.2.2.2 Processing

The SV Acquisition Control Function interfaces with the Navigation and Receiver Modules as shown in Figure 3.2-4.

After the SV selection function in cold-start or the initialization function in warm-start completes, M1NS20 is commanded to execute. It first fetches the highest 6 SV ID's from the SV sequence list generated by the operator or by the Navigation Subsystem during the SV selection state. It then performs the first SV or subsequent SV acquisition control function.

The communication between M1NS20 and the Receiver Sequence Controller is through the data sets shown in Figure 3.2-4. The mode control accepted by the Receiver Sequence

Controller is shown in Table 3.2-2.

For the first SV acquisition, M1NS20 determines which SV is to be acquired and commands mode 2 for first SV acquisition. It also keeps the SV status as shown in Table 3.2-3. The Receiver Sequence Controller replies with command acknowledgement and completion codes through the receiver status data set (RMMSTA). This process takes typically about 45 seconds and can be repeated if the SV is not found within 75 seconds. In this case, M1NS20 will choose the next highest SV for first SV acquisition until the first 4 SV's selected by Nav (or the operator) have been tried.

After the first SV is acquired and it's data is recovered, M1NS20 commands the executive to resynchronize the FTF counter. It also computes the clock bias and commands the Navigation Subsystem to generate aiding data for subsequent SV acquisitions.

For subsequent SV acquisitions, M1NS20 determines the SV ID to be acquired and generates a mode 3 command to the Receiver Sequence Controller. A 30 second time limit is allowed for each subsequent SV acquisition. After the SV is found, and it's data is recovered, M1NS20 proceeds to the next subsequent SV acquisition process.

M1NS20 activates the Master Control SV Reacquisition Control Task (M1NSVC) after it had tried to acquire all the SV's in the SV elevation array (unless too few are acquired for sequencing in which case the operator is notified and a

software restart is commanded).

The detailed system time-line of M1NS20 and the specific events commanded or monitored by M1NS20 are illustrated in Figures 3.2-5, 3.2-6, 3.2-7 and 3.2-8.

Table 3.2-2 Receiver Sequence Controller Modes

COMMAND MODE

VALUE	MEANING
0	No Action/Continue Action
1	GO/NO-GO (L1 Meas.)
2	First SV Acquisition
3	Subsequent SV Acquisition
4	CA Reaquisition
5	P Reacquisition
6	L1/L2 Precision
7	Ephemeris Update
8	New SV Acquisition
9	Reset
10	Resync Done Command (initiate handover)
21	GO/NO-GO (L2 meas.) (Cmd'd by R1RMO)
22	GO/NO-GO Successful (cmd'd by R1RMO)
23	GO/NO-GO Failure (cmd'd by R1RMO)
24	Sequential P Reacquisition
25	Automatic Almanac Acquisition

Table 3.2-3 SV Status Table

VALUE	MEANING
0	Not Defined
1	SV Reacquired W/P Code and Tracking
2	SV Reacquired W/C/A Code (Awaiting P Reacq)
3	SV Acquired But Not Reacquired
4	SV Failed To Be Acquired The First Time
5	Not Used
6	SV Failed To Be Acquired With P Code
7	SV Acquired In Mode 8 (New SV Acq)
8	Not Used
9	Not Used
10	SV Failed To Handover To P Code in S.S.
11	SV Reacq Timed Out-Commanded in Mode 24
12	SV C/A Reacq Time Out - Tried 4 minute C/A Reacq
13	SV Reacq Timed Out-Good Snr-Cmded in Mode 5
14	SV Just Set - No Replacement Found
15	SV Has Set - Ignore Measurements
16	New SV Acquired in S.S. can't collect EPHM
17	SV just set - Replacement Found

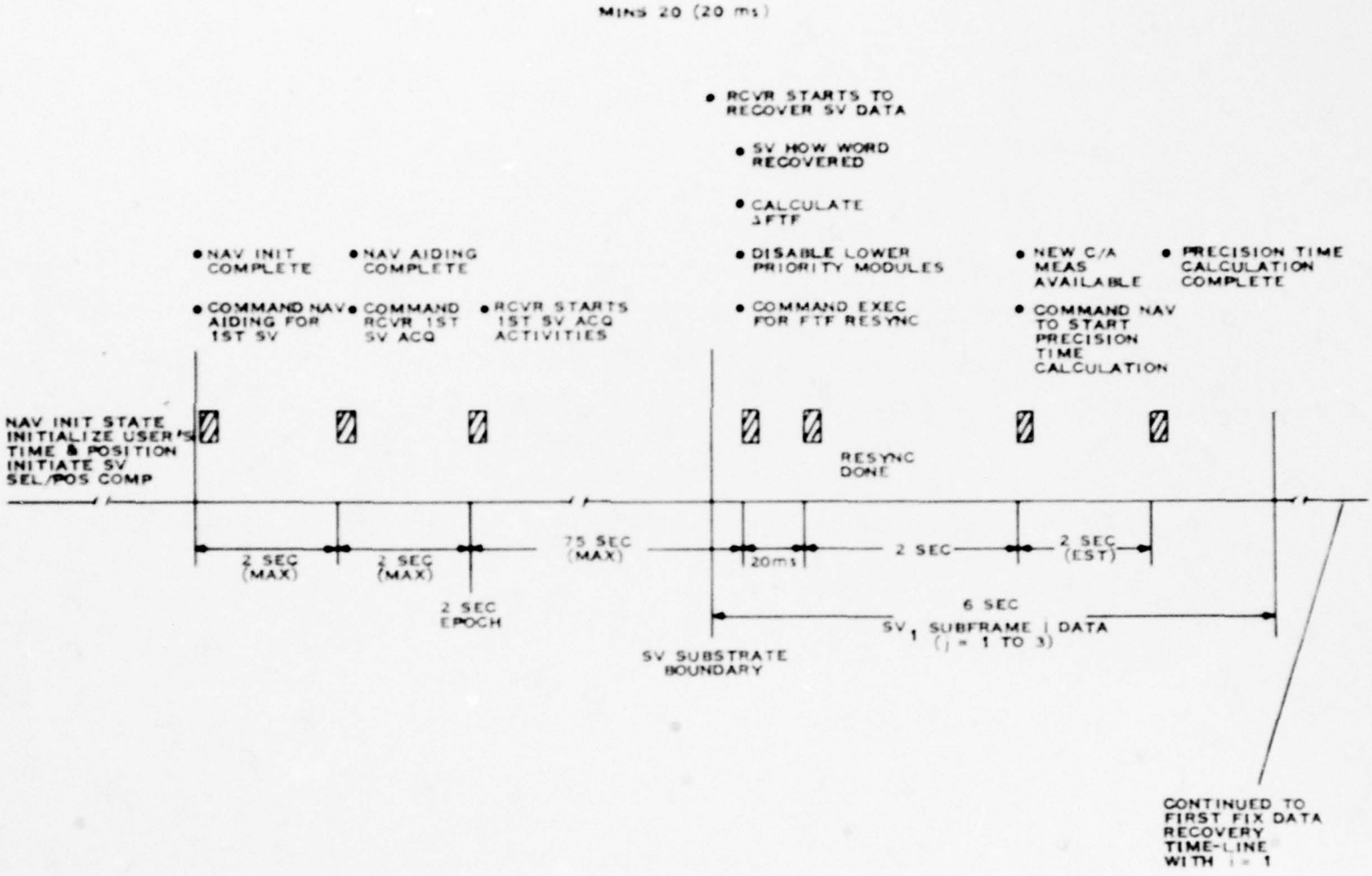


Figure 3.2-5. First SV Acquisition Time-Line

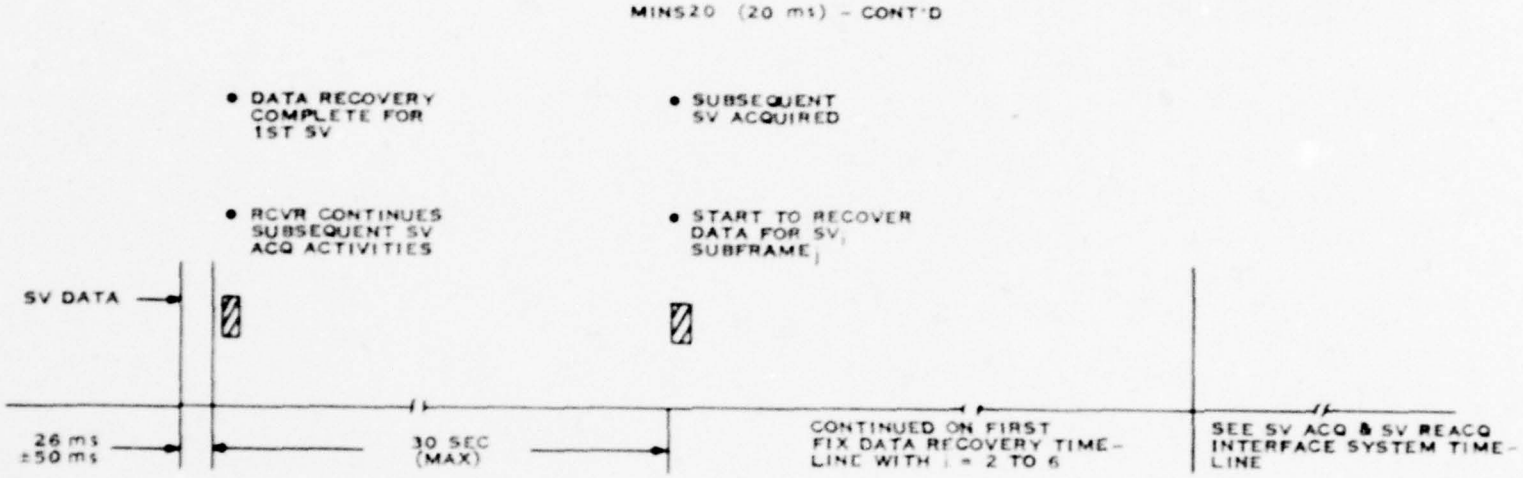
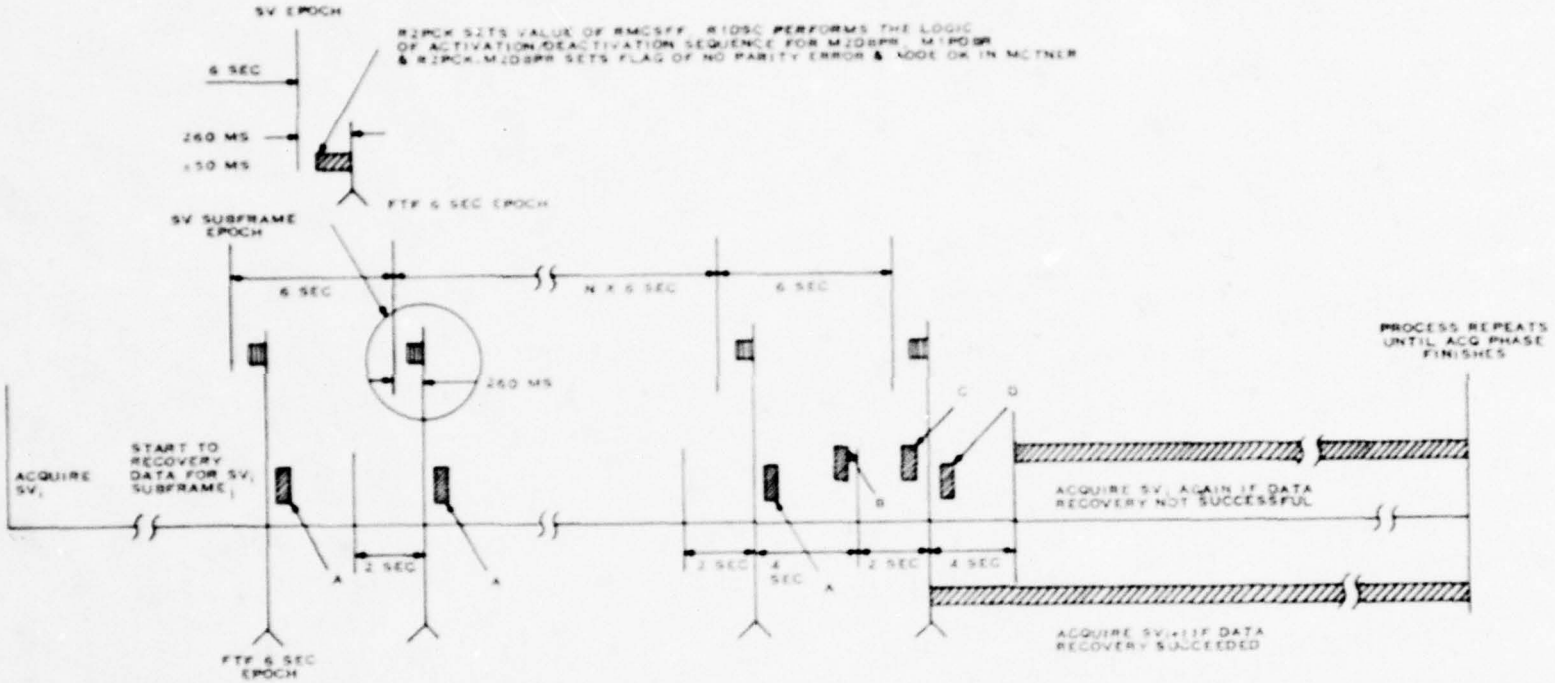


Figure 3.2-6. Subsequent SV Acquisition Time-Line



NOTE A. CHECK IF THIS IS THE LAST SUBFRAME TO BE RECOVERED

B. IF THIS IS THE LAST SUBFRAME, COMMAND NAV TO GENERATE AIDING DATA FOR SV(+1

C. IF THIS IS THE LAST SUBFRAME, COMMAND RCVR TO ACQUIRE SV(+1

D. CHECK IF DATA RECOVERY IS COMPLETE (NO PARITY ERROR & NODE MATCHED)

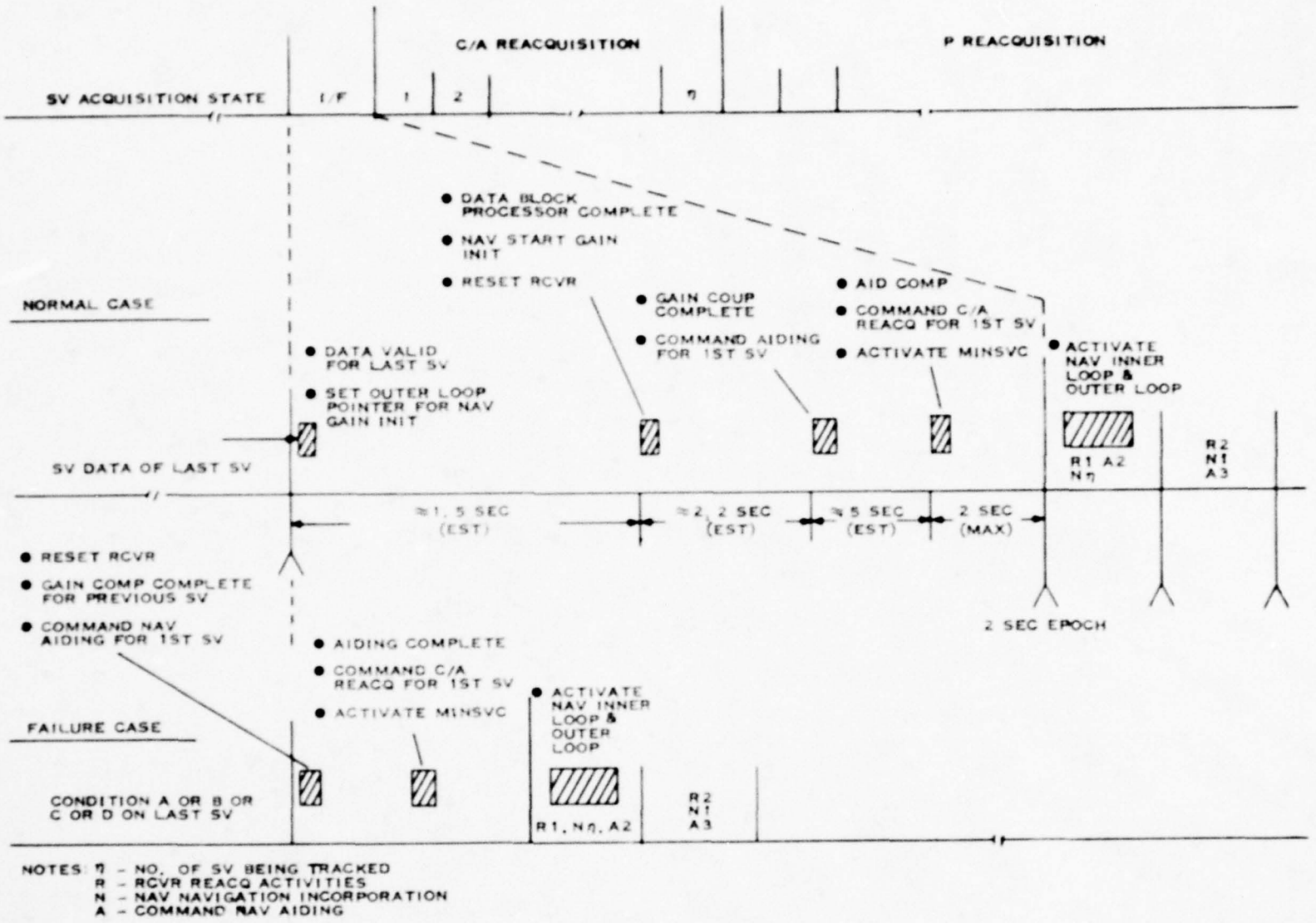
IF YES, RCVR PROCEED NEXT SV (SV(+1) ACQUISITION

IF NO (1) COMMAND NAV AIDING FOR SV(

(2) COMMAND RCVR FOR SUBSEQUENT SV ACQUISITION WITH SV(

E. TRY A TOTAL OF TWO EXTRA TIMES FOR ANY (TH SV IF DATA IS CONTINUALLY BAD

Figure 3.2-7. First Fix Data Recovery Time-Line



NOTES: η – NO. OF SV BEING TRACKED
R – RCVR REACQ ACTIVITIES
N – NAV NAVIGATION INCORPORATION
A – COMMAND NAV AIDING

Figure 3.2-8. System Time-Line for Interface Between SV Acquisition and SV C/A Reacquisition State

3.2.3 SV Reacquisition and Navigation Control Function

3.2.3.1 Functional Description

Implementation S/W Modules are: M1NSVC (2 sec), M2RMDC (2 sec), M2RMOD (2 sec), M2EPHM (2 sec), and M2STAT (2 sec).

The SV Reacquisition and Navigation Control Task schedules SV reacquisition and sequencing in the steady state. Its main functions are:

1. Schedules first fix display
2. Initiates C/A Reacquisition with 2 sec interval for each SV by issuing appropriate receiver and navigation control command to receiver sequence controller and Navigation filter respectively
3. Initiates P reacquisition control after C/A reacquisition process is finished
4. Carries out SV searching strategy if the number of SV's being tracked is less than 6
5. Performs steady state SV sequence control with 6, 5, 4, 3, or 2 SVs. (Including ionospheric correction scheduling)
6. Schedules and controls the ephemeris update mode
7. Commands the CDU to display system warning messages on system failure conditions.

3.2.3.3 Processing

Figure 3.2-9 shows the overall configuration of the SV Reacquisition and Navigation Control Function. The task M1NSVC is activated by M1NS20. It communicates with the Receiver Sequence Controller thru the same data sets as M1NS20 uses. M1NSVC activates C/A reacquisition first, determines the SV ID to be reacquired, and commands Mode 4 for SV C/A reacquisition. It also keeps the SV status as shown in Table 3. The C/A reacquisition process is repeated every 2 seconds for each SV and the reacquisition is

switched to P after the SV's are reacquired.

In P reacquisition, M1NSVC commands the same parameters as C/A reacquisition does, except C/A is changed to P. After the P reacquisition has been commanded for the SV's, M1NSVC and its subtasks M2RMDC, M2RMOD, and M2EPHM control the receiver measurement sequence in normal, ionospheric correction and data recovery (ephemeris update) cycles.

In the normal cycle, M2RMOD sets the receiver mode to 5 (L1 and P reacquisition). It also specifies the SV ID for range and range rate aiding, and the SV ID for which measurements apply.

In the ionospheric correction cycle, control parameters are the same as those of the normal cycle except the control mode is 6 which causes the reciever to use the L2 frequency. It takes two more seconds than the normal cycle for the receiver to perform the L1/L2 process, since both L1 and L2 P reacquisitions must be commanded on the same SV, two seconds apart.

In the data recovery cycle, the commanded mode is 7, eight seconds are used by the receiver to complete the data recovery functions for each subframe (2 seconds for SV acquisition and 6 seconds for data recovery).

The order of SV sequencing of the normal, ionospheric correction and data recovery cycles are as indicated on the system time-line shown on Figures 3.2-10, 3.2-11, and 3.2-12. The functions they perform could be listed as follows:

1. Determine which SV/GT should be used at the current instant
2. Designate
   a. SV number for next aiding
   b. SV number for next Receiver Acquisition
   c. SV number for next NAV inner loop
   d. SV number for next NAV outer loop
   e. Place the above sequences in the SV sequence data base and the SV status table.
3. Interface between NAV inner and outer loops
4. Schedule IONO correction cycles
5. Check for data completeness and activate data block processing
6. Initiate ephemeris update (about every 1 hour) and schedule data acquisition if a new SV just acquired.
7. Control new SV acquisition
8. If one SV times out, reacquire and select a new one
9. If only five SV's are available, decide which goes in 6th slot
10. If only four SV's are available decide which goes in 5th slot
11. If three SV's are available in running state, command altitude hold and use fixed altitude at last value.
12. If two SV's are available in running state, use fixed time bias rate and fixed altitude at last value
13. If three SV's are available on start up, schedule altitude hold on the 4th slot.

Under degraded mode or signal loss environments, M2RMOD handles SV drop out for bad measurement conditions. If the receiver fails to get good measurements from an SV for a certain period of time (consecutive bad measurements for 30 seconds), M2RMOD decrements the tracking SV counter MNPSTK by one and flashes the "Excessive Reacquisition Time" system warning message on the CDU. Depending on whether the missing measurements are due to failure to achieve carrier lock or due to actual loss of signal, two types of SV reacquisition modes will be issued to try to reacquire the SV: (1)If the instantaneous signal-to-noise ratio (SNR) is above the threshold (>90 counts), the system continues to do code peak search with the SV reacquisition mode (mode 5). (2)If the SNR is below the threshold (<90 counts), the sequential SV reacquisition mode (mode 24) is commanded for

the SV. The searching period lasts for 4 minutes before the SV is dropped from the sequence and placed into the new SV search queue.

As soon as the number of SVs tracked drops below 4, M1NSVC starts the altitude hold activity on the SV that is missing measurements. M1NSVC schedules the altitude hold mode on the SV inner and outer loop slots two seconds prior to the normal sequence of its outer loop. If the SV is dropped, M1NSVC schedules the new SV acquisition mode and the altitude hold mode for the same SV ID on the (MNPSTK+1)th slot.

When the lost SV is reacquired, MNPSTK is incremented by one. The altitude hold mode ID dropped 2 seconds prior to the normal sequence of it's outer loop. If the number of SV tracked is still less than 4, M1NSVC reschedules the altitude incorporation on the other SV slot which is in reacquisition mode (mode 24) or new SV acquisition mode (mode 8). M1NSVC and M2RMOD always schedule new SV acquisition on the (MNPSTK+1)th SV slot if there is an SV ID in the new SV searching queue. The searching time limit is set to be 4 minutes to cover the 1000 p-chip sequential search approximately two times. If a new SV is acquired, M1NSVC schedules it into the sequence. The navigation subsystem provides self aiding until ephemeris data is recovered and new fit coefficients are computed. M1NSVC schedules ephemeris data recovery and sets flags to Nav for fit coefficient calculation when the ephemeris data is

computed by M2EPHM. The outer loop is not to be scheduled until Nav resets the flag indicating that the fit coefficient computation is complete. MNPSTK is then incremented by one. In case the altitude hold mode is scheduled on the new SV acquisition slot and the new SV process is complete, the altitude hold mode is dropped. However, if MNPSTK is less than 4, M1NSVC reschedules altitude hold mode on another mode 24 or mode 8 SV slot. Module M2RMDC in the SV Reacquisition and Navigation Control Function is used to record the SV status under different system operation modes.

In order to further illustrate the processing structures of modules M1NSVC, M2RMDC, M2RMOD, M2EPHM, and M2STAT, Appendix B includes the variable listings and the top and detailed flow charts of the modules.

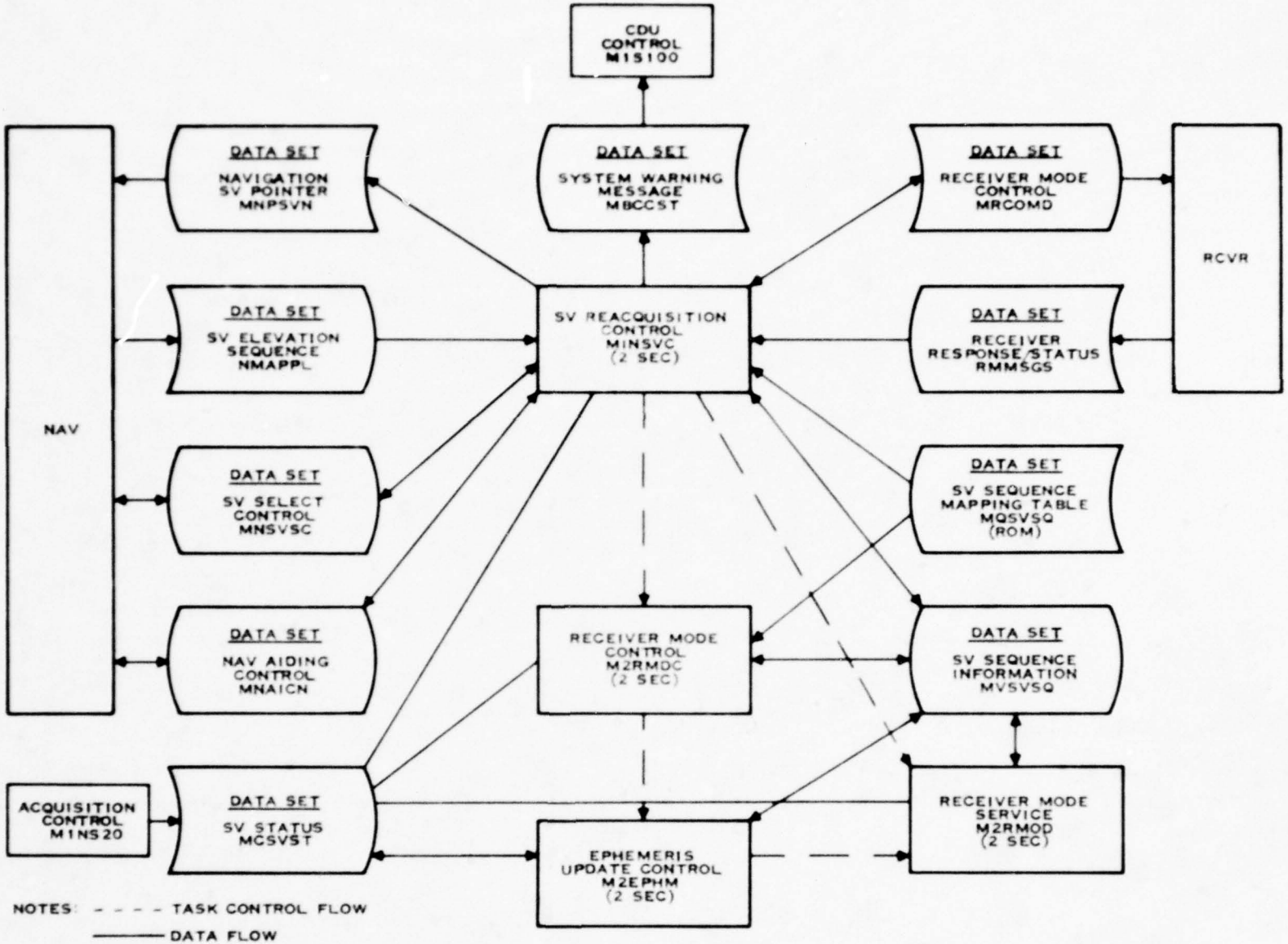


Figure 3.2-9. SV Reacquisition and Navigation Control Configuration

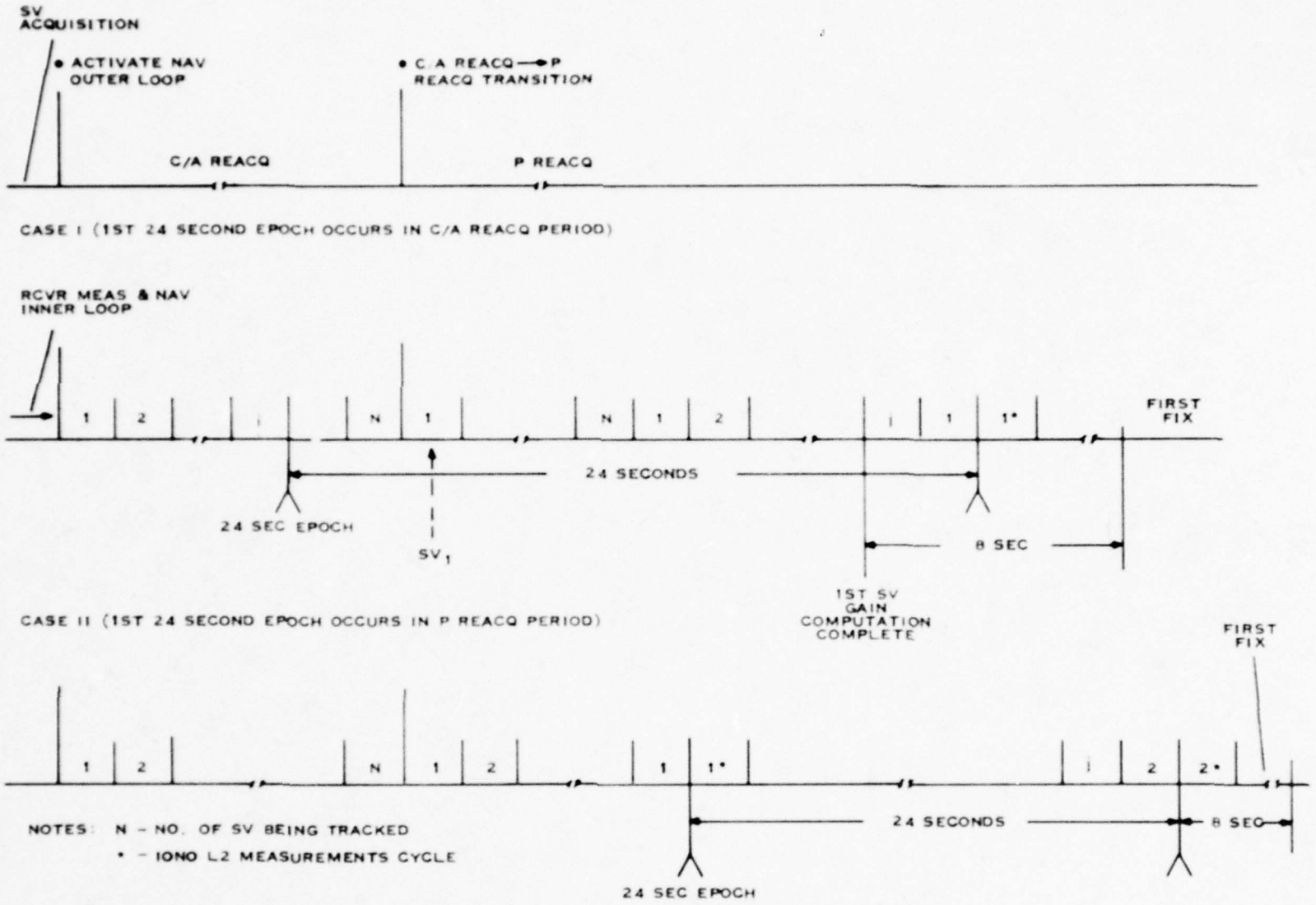


Figure 3.2-10. System Time-Line for Nav Outer Loop Sychronization-P Reacquisition Initialization



Figure 3.2-11. SV Sequencing (Steady State - 6 SV's)

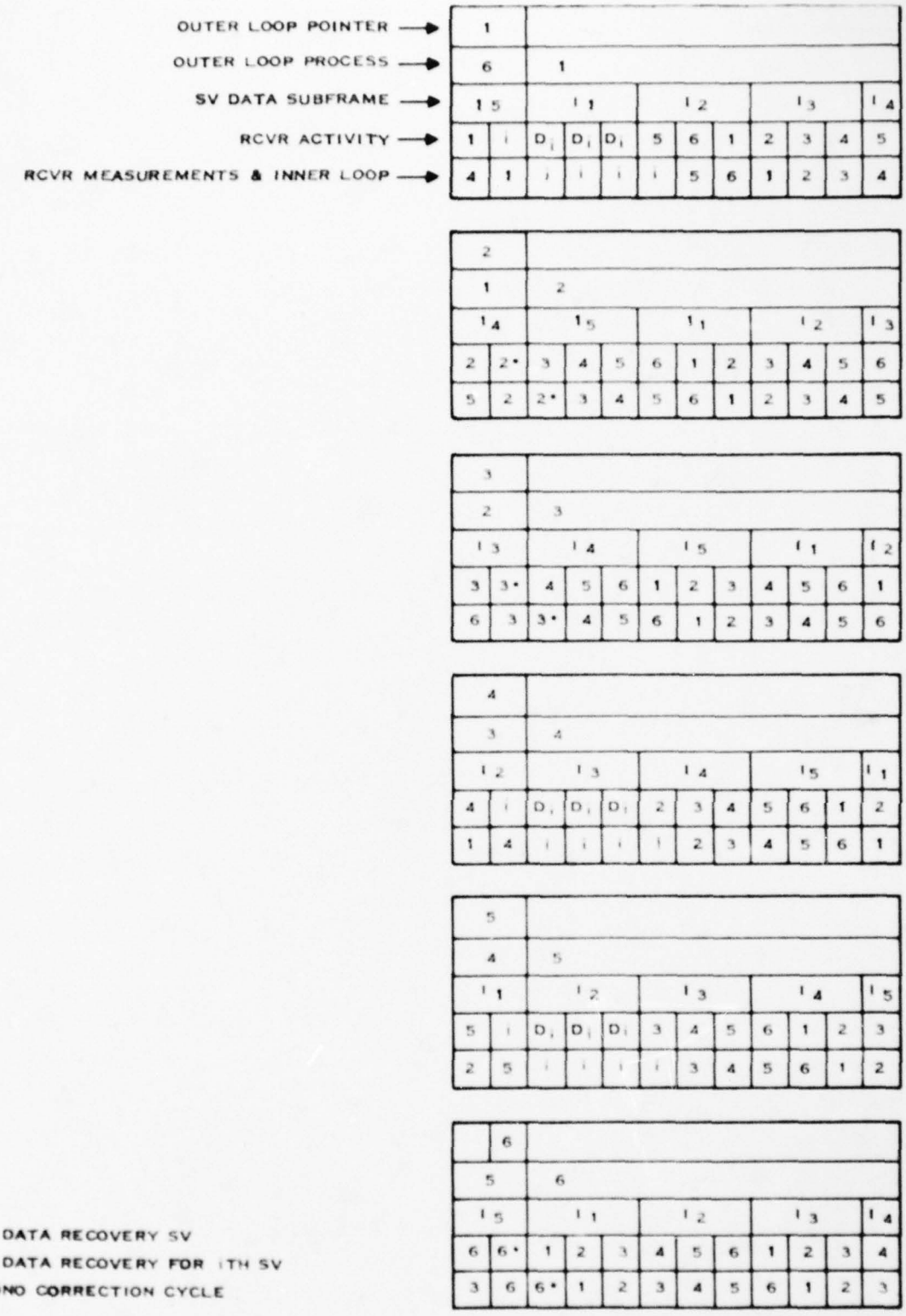


Figure 3.2-12. SV Sequencing (Data Recovery - 6 SV's)

3.2.4 Fix Control Function

3.2.4.1 Functional Description

The Fix Control Function schedules the fix display in either auto or manual mode. This function is implemented by M1NST2 (1 sec).

3.2.4.2 Processing

The fix Control Function executes the manual and auto mode control logic. The overall control and data flow of this function is shown in Figure 3.2-13.

In the manual fix mode, the CDU software enables M1NST2 which transfers coordinates from Nav to the coordinate transformation data set. It then commands M1XFRM to convert the coordinates into LAT/LONG or Military Grid Reference System (MGRS). Once the transformation is complete, M1NST2 commands M1S100 to display the fix.

In the automatic fix mode, the data structure and control flow is the same as in the manual mode except that a counter is used to automatically display the fix once a minute. If the automatic display is other than the fix display, M1NST2 schedules the next display of the appropriate function by M1S100.

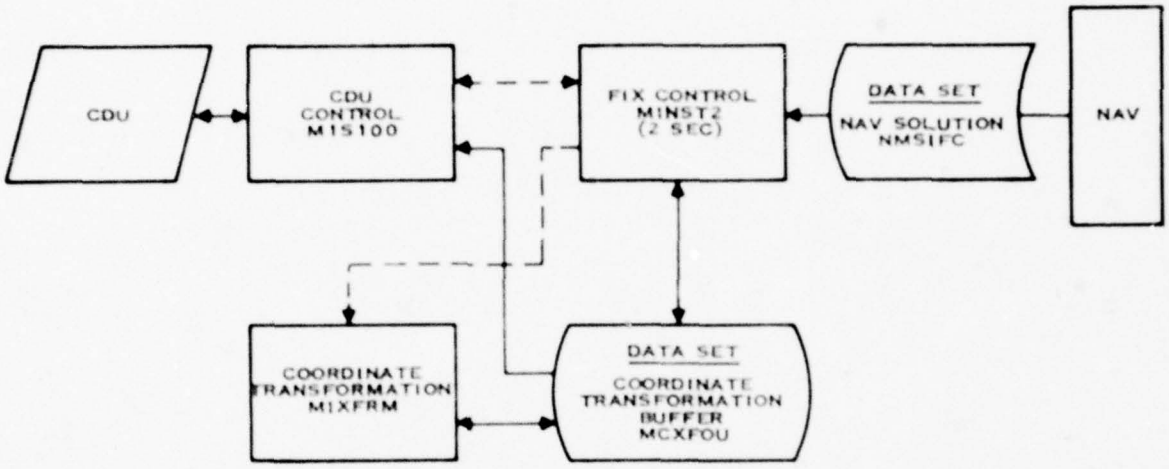


Figure 3.2-13. Fix Control Task Configuration

3.2.5 Waypoint Control Function

3.2.5.1 Functional Description

The waypoint control task is implemented by M1NSWC (3 min Background). The task executes the initialization of waypoints and controls the waypoint display on the CDU in LAT/LONG or MGRS. It also calculates the range and bearing to any waypoint and displays them on the CDU when the operator presses the RNG button.

3.2.5.2 Processing

M1NSWC interfaces with M1S100 through the data set MWPCOD. When the operator presses the LAT or the GRD button, M1S100 enables M1NSWC to display the latest waypoint, N, selected by the operator. M1NSWC interfaces with M1XFRM through the data set MCXFOU and then interfaces with M1S100 to display waypoint N in LAT/LONG or MGRS.

Similarly, if the operator presses the RNG button, M1NSWC fetches the user position and velocity to compute the range and bearing to the latest waypoint N selected by the operator and commands the CDU S/W to display them.

3.2.6 C/No Monitoring and Filtering Function

3.2.6.1 Functional Description

The C/No monitoring and filtering task is implemented by M1CNSV (2 sec). It receives signal to noise ratio raw

data from the receiver. It then computes the C/No in dB-Hz through a filtering process for each SV being tracked.

3.2.6.2 Processing

The function is implemented as shown in Figure 3.2-14. Module M1CNSV filters the receiver C/No raw data for each SV and stores it to an array MFILTR (2,N) where N is the generic SV ID (1 to 6).

To convert the filtered SNR raw data to C/No in dB-Hz, the following equation is used:

dB-Hz = 20*log(SNR) - 2.96

Which is approximated by:

dB-Hz = .068*X(i) + 26.0

Where X(i) = 1/8*SNR*CAL + 7/8*X(i-1)

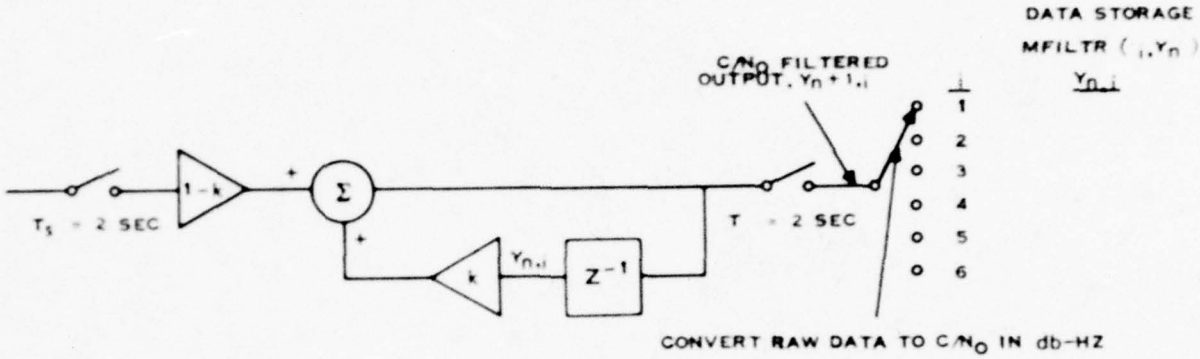
and CAL = 1.0

This equation is derived from calibrating the MVUE receiver measurements with the actual C/No settings.

PURPOSE

AVERAGES RECEIVER C/N_0 RAW DATA ON AN EXPONENTIAL WEIGHTED BASIS FOR EACH SV/GT BEING TRACKED. BASED ON THE AVERAGED RAW DATA, DETERMINES EACH SV/GT'S AND ALSO THE SYSTEM'S C/N_0 LEVEL. IF ANY SV/GT OR THE SYSTEM C/N_0 LEVEL IS BELOW THE THRESHOLD, FLASHES SYSTEM WARNING MESSAGE ON CDU DISPLAY. OPERATOR CAN KNOW WHICH SV IS CAUSING A LOW C/N_0 BY LOOKING AT THE DATA STORAGE THRU THE CDU MEMORY R/W FEATURE.

BLOCK DIAGRAM



COMPUTATION ALGORITHM i IS THE SV ID INDEX (1-N). INCREMENTS EVERY 2 SECONDS

INITIAL FILTER INPUT VALUE $X_{0,i}$

FILTERED C/N_0 ESTIMATION $Y_{nH,i} = (1-k)\, X_{nH,i} + k\, Y_{n,i}$

WHERE: n INCREMENTS EVERY $N \cdot 2$ SECONDS

k IS THE FILTER GAIN CONSTANT

N IS # OF SV'S TRACKED

Figure 3.2-14. MVUE C/N_0 Recursive Filter

3.2.7 MVUE Instrumentation System MIS Control and System Status Monitoring Function

3.2.7.1 Functional Description:

Implementation of this task is by M1NSDT (2 sec). The task executes the following functions: A. Performs system initialization during start-up B. Monitors system status and reports systems errors in steady state C. Initiates and controls MVUE Instrumentation System (MIS) operation when MIS output is commanded.

3.2.7.2 Processing

Initially, the module M1NSDT commands the Receiver Sequence Controller to execute it's GO/NO-GO sequence. In steady state, every 2 seconds, the module M1NSDT first monitors for processor errors and sets the CDU error display flag if an error is detected. It then checks for the excessive spherical user position error, the low battery error and the excessive oscillator bias error. These error conditions cause the CDU to flash the system warning messages "W", "P", "B" and "K", respectively.

If MIS output is commanded, M1NSDT schedules the 2 second and 24 second data and transmits the data to the MIS 990/10 9-track tape. The MIS 2 second and 24 second data are listed in the M1NSDT module listings.

3.2.8 Data Block Processing Function

3.2.8.1 Functional Description

Implementation S/W Modules are: M1PDBR (6 sec), M2DBPR (200ms), M2DBS1 (6 sec), M2DBS2 (6 sec), M2DBS3 (6 sec), and M2MOVE (6 sec).

The Data Block Processing Task, including a 200ms SV/GT data collection module M2DBPR and a 6 sec data block processing module M1PDBR, executes the following functions:

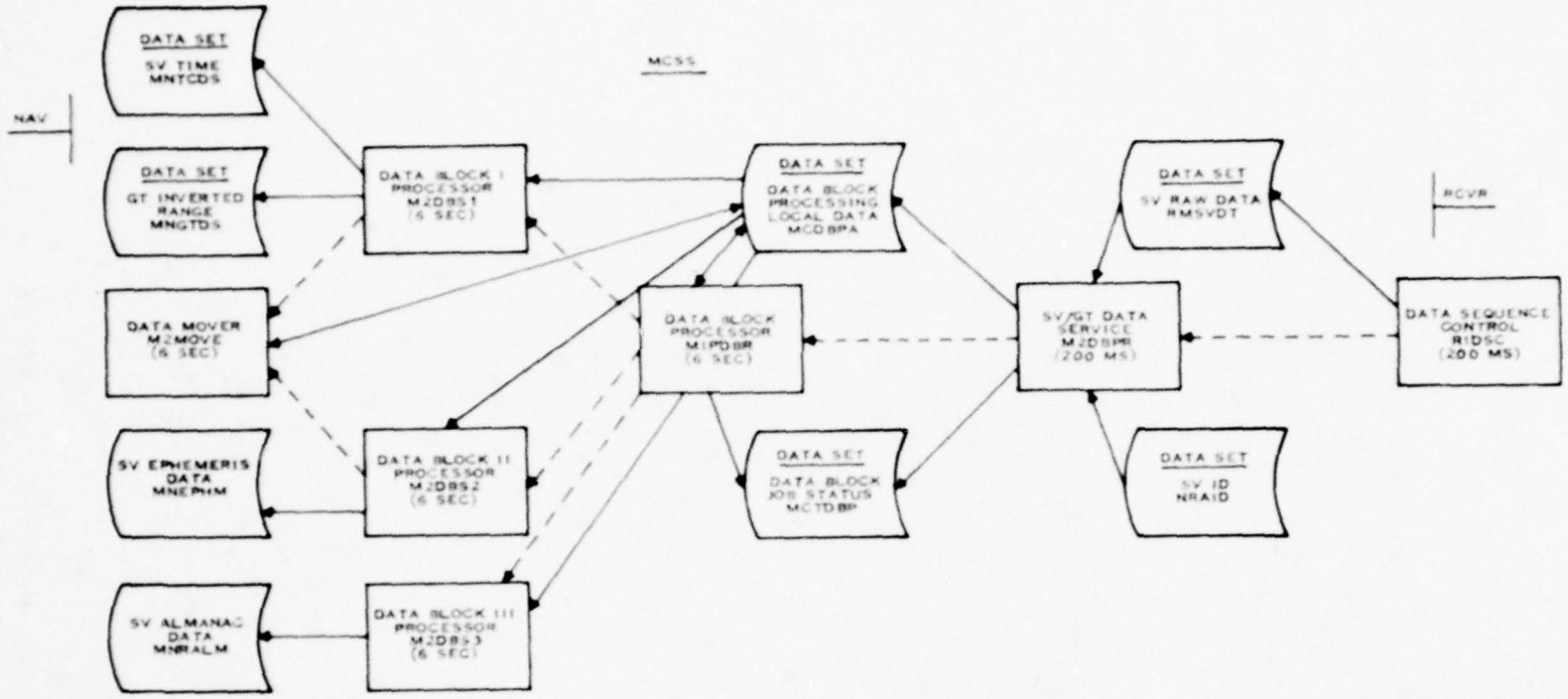
1. Collects SV data from receiver software
2. Performs data validity check for each SV subframe and each SV data block.
3. If SV block I is valid, processes data for SV's or GT's.
4. If SV block II is valid processes ephemeris data for SV's.
5. If SV block III is valid processes almanac data for SV's.
6. Flags data block processing status to Receiver and Master Control subsystems.

3.2.8.2 Processing.

The overall configuration of the SV/GT data block processing function is shown in Figure 3.2-15. During the data recovery cycle, M2DBPR receives from the receiver subsystem 24 bit words of data, one word at a time, which it assembles into complete data blocks for processing by the module M1PDBR. For satellite data, it collects words 8, 9 and 10 of subframe 1 (Data Block I) and words 3 through 10 of subframe 2 and 3 (Data Block II). In Automatic Almanac Acquisition mode it collects words 3 through 10 of subframe 5 (Data Block III) for each of the SV's for which an almanac is being transmitted.

The enabling flag MCDBFL is set by M2DBPR when it

collects data sufficient to process a data block. If MCDBFL = 1 or 3 then M1PDBR calls M2DBS1 to process data block I, if MCDBFL=2 then M2DBS2 is called to process data block II. If MCDBFL=5, M2DBS3 is called to process data block III.



NOTES - - - - TASK CONTROL FLOW
——— DATA FLOW
ALL TASKS ARE FOREGROUND

Figure 3.2-15. Data Block Processor Configuration

3.2.9 Coordinate Transformation Function

3.2.9.1 Functional Description

The Coordinate Transformation Function is implemented by the S/W Modules M1XFRM (2 sec), M2EFLD (2 sec), M2MGGP (2 sec), M2GPMG (2 sec) M2MSLH (2 sec), and M20SMG (2 sec).

The coordinate transformation function performs the following:

1. Convert MGRS to LAT/LONG (semicircle, WGS-72)
2. Convert LAT/LONG (local) to LAT/LONG (semicircle, WGS-72)
3. Convert LAT/LONG (local), mean sea level altitude to earth fixed coordinates
4. Convert MGRS MSL altitude to earth fixed coordinates
5. Convert earth fixed coordinates to MGRS, MSL altitude
6. Convert earth fixed coordinates to LAT/LONG (local) MSL altitude
7. Convert earth fixed coordinates to LAT/LONG (semicircle, WGS-7 and convergence angle
8. Convert LAT/LONG (semicircle, WGS-72) to LAT/LONG (local)
9. Convert LAT/LONG (semicircle, WGS-72) to MGRS

3.2.9.2 Processing

The overall configuration of the coordinate transformation function is shown in Figure 3.2-16. When the coordinate conversion code, MCXOCD, is set to a non-zero value, M1XFRM schedules the data transformation between either earth fixed or latitude/longitude for the WGS-72 datum and either UTM-Military Grid coordinates or local datum latitude/longitude and mean sea level altitude, depending on the value of the conversion code and the value of the datum ID number.

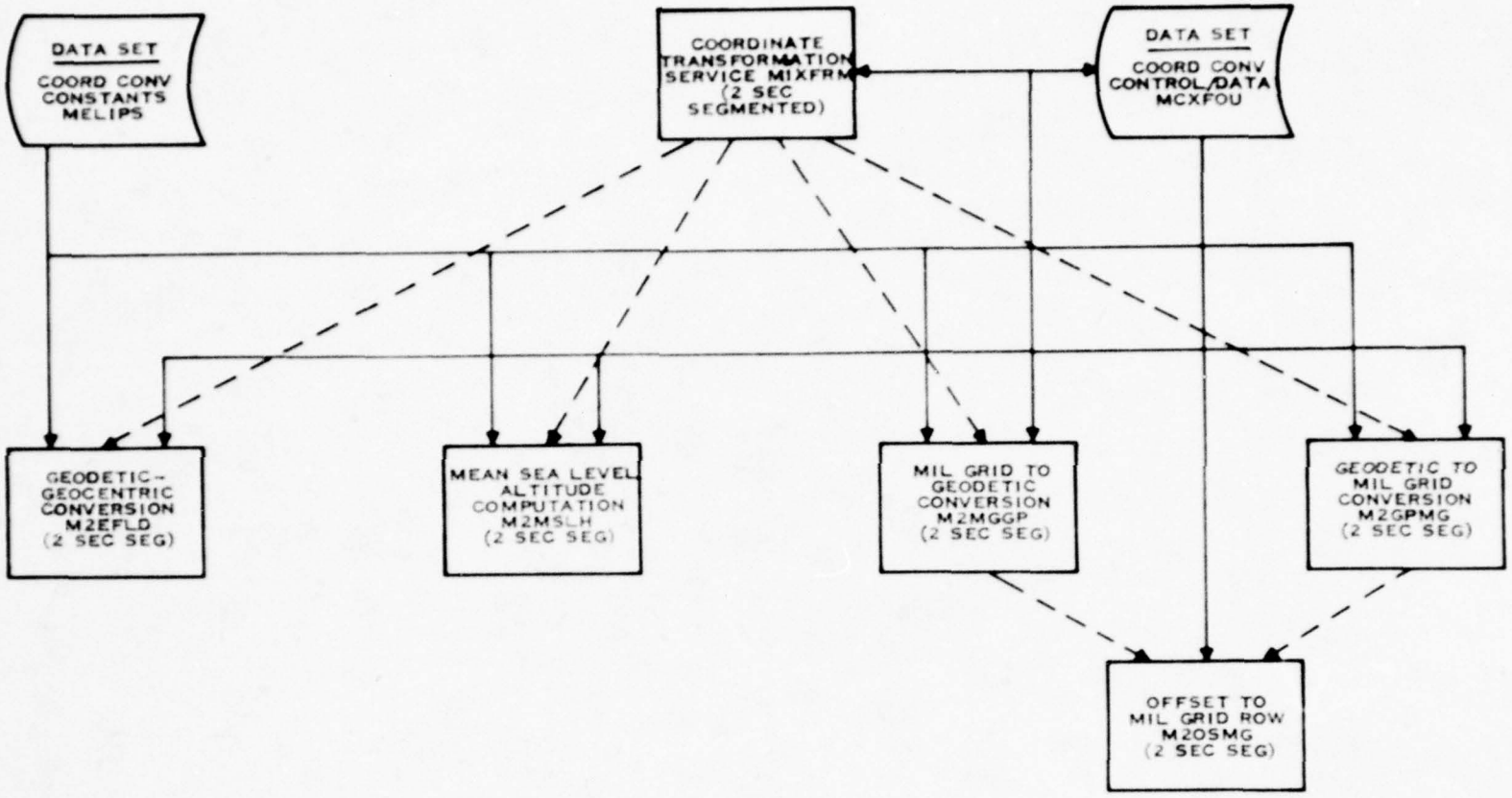


Figure 3.2-16. Coordinate Transformation Configuration

3.2.10 CDU Control Function

3.2.10.1 Functional Description

The CDU Control Function is implemented by the S/W Modules: M1S100 (100ms), M2NCDF (100 ms), M2PRMT (100 ms), and M2CDMI (20 ms).

The CDU control software executes the following functions:

1. Accepts input data through first and second level prompting (see CDU prompting table 3.2-4)
2. Decodes and initiates
   - MIS Request
   - Radio transmission command
   - Ephemeris Update Authorization
   - NAV Mode command
   - New SV acquisition authorization
   - Radio free text mode request
   - Automatic Almanac Acquisition command
   - System restart request
   - Ram Almanac request
   - Ionospheric correction inhibit command
   - Atmospheric correction inhibit command
   - BITE Command
   - Standby request
   - Auto/Manual mode selection
   - Waypoint request (include Range, LAT/LON, and MGRS request)
   - Fix request (include altitude request)
   - Time request
3. Displays data and system warning message
4. Flashes error code for CDU operational error

Table 3.2-4 CDU PROMPTING MENU

1	UTM		5	OP2	
	.	WPT		.	ALM
	.	SPH		.	RST
	F	GRD		.	RAM
	F	MG		.	ION
	F	ESG		.	ATM
	F	NRG			
			6	BIT	
2	ALT			.	NUM
	.	ALT			
			7	SV	
3	TIM			F	SV1
	.	OUT		F	SV2
	F	YR		F	SV3
	F	DAY		F	SV4
	F	HR		F	SV5
	F	MIN		F	SV6
	F	SEC			
			8	MEM	
					ADR
4	OPT				CNT
	.	MIS			
	.	RAD	9	LAT	
	.	EPH		.	WPT
	.	MOV		.	SPH
	.	ACQ		F	DIR
	.	TXT		F	DEG
				F	MIN
				F	SEC
				F	DIR
				F	DEG
				F	MIN
				F	SEC

NOTE: F indicates forced prompting.

TABLE 3.2-5 SYSTEM WARNING MESSAGES

NUMBER	MESSAGE	DEFINITION
1	B	Low Battery
2	C	Complete
3	E	Need Ephemeris Update Authorization
4	F	Fatal System Error
5	H	Altitude Required
6	I	Initialization Required for First Fix
7	M	Need New SV Search Authorization
8	P	Position Error Excessive
9	R	Receiver Failure
10	S	Too Few SV's
11	T	Excessive Reacquisition Time
12	K	Clock Error Excessive
13	Z	System Variable Previously Initialized
14		First Fix or Automatic Fix Display pending
15	W	Processor Error
16	X	Operator Input Prohibited
17	O	Initiate Keyboard Test (BIT)
18	G	SV C/NO below threshold
19	?	Illegal Keystroke obtained
20	#	Illegal Hardware Keystroke Obtained

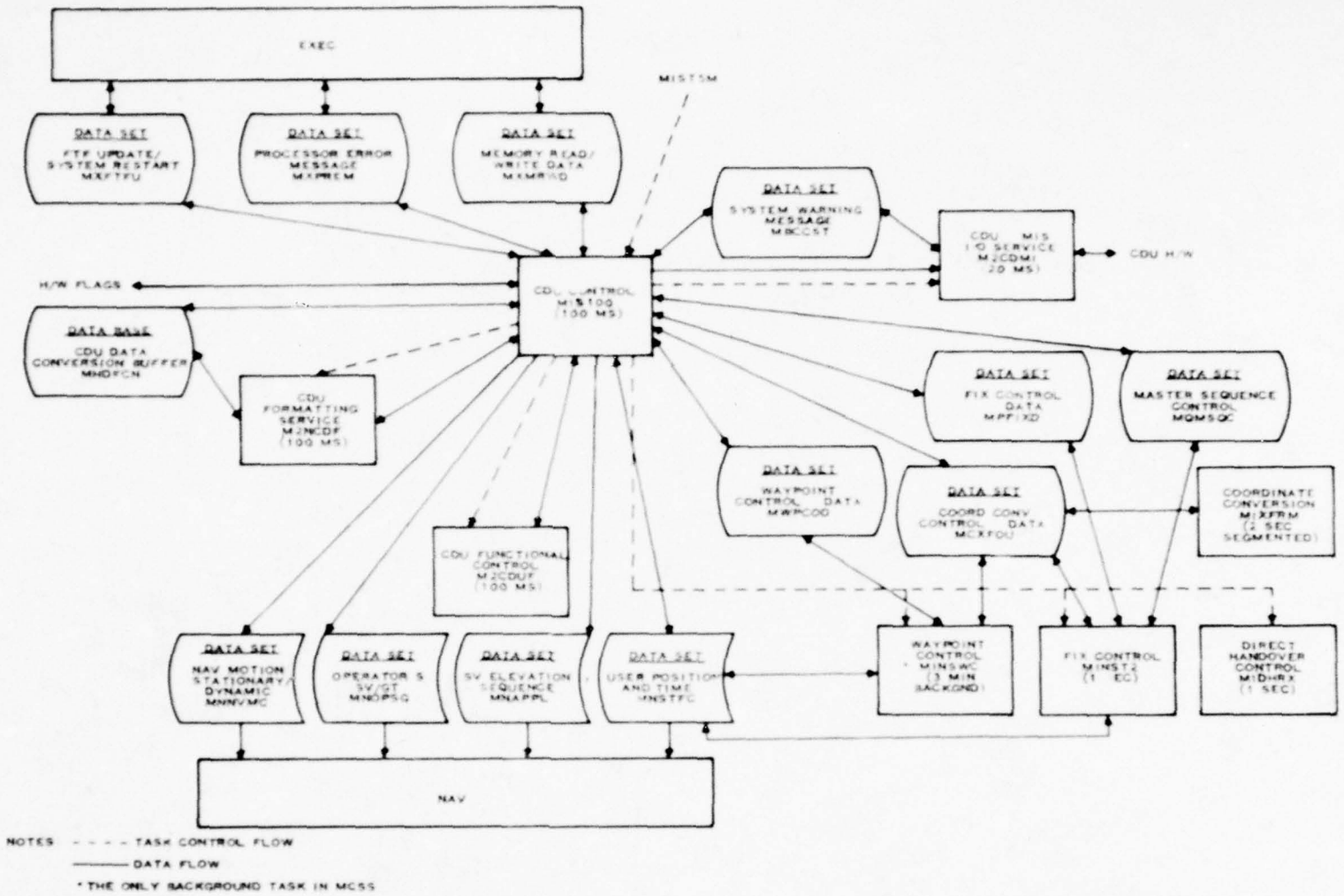


Figure 3.2-17. CDU Software Configuration

3.2.10.2 Processing

The overall control and data flow configuration of the CDU control task is shown in Figure 3.2-17. The main CDU control module M1S100 processes (1) the navigation initialization control and (2) the control display unit control when CDU I/O is requested by the system or operator. In the CDU control portion, M1S100 handles the system warning message display (see table 3.2-5), BITE monitoring and BITE preprocessing. It calls M2CDUF for the processing of operator commands to the system. When CDU prompting is initiated by the operator for data input, M1S100 calls M2PRMT for prompting control. It also calls M2NCDF for I/O data formatting processing.

M2CDMI is responsible for all software interactions with the CDU. It accepts inputs from the CDU and supplies outputs to it.

Inputs are accepted one per 20-msec period. An input consists of a 16-bit word advising of standby/operate mode changes, keystroke entries, and value of keystroke.

M2CDMI is aware of the CDU control state since it has access to the CDU control state data base. M2CDMI also has an input template telling it what to do with data entries.

Thus, when the operator makes a keystroke entry, M2CDMI decides if the entry is a control entry or a data entry. For the entry to be a data entry, the prompting data I/O flag obtained from the prompting data base must be set to input. If the flag is set to output, M2CDMI ignores any

data entry. However, if this flag is set to input, M2CDMI uses the input template obtained from the prompting data base to determine if the entry is a control entry, a valid data entry, or an invalid data entry. If the data entry is valid, M2CDMI puts the entry into the correct location in the desured-state-of-display data base for echoing back to the display. It also puts the entry y into the CDU input buffer for subsequent use by the software. Anytime that a data entry has been completed, M2CDMI determines this fact and sets the data available semaphore in the CDU input buffer. This flag allows the remainder of the software to process the data entry stored in the input message. Whenever M2CDMI sets the data available semaphore, it also sets the lock-out flag in order to not accept further CDU inputs until M1S100 returns the lock-out flag to the input state.

M2CDMI is able to determine the correct length of the data entry using the input template furnished to it by M1S100 via the prompting data base.

If the entry is invalid, M2CDMI determines the correct error code and causes this error code to be displayed. It does this by putting the error code into the CDU control data base and then displaying the contents of this data base. Other software elements may be used to put error codes into this data base but the operator input errors have the highest priority. For a summary illustration of the CDU display format and prompting control algorithm, refer to

Figures 3.2-18, 3.2-19, 3.2-20 and 3.2-21

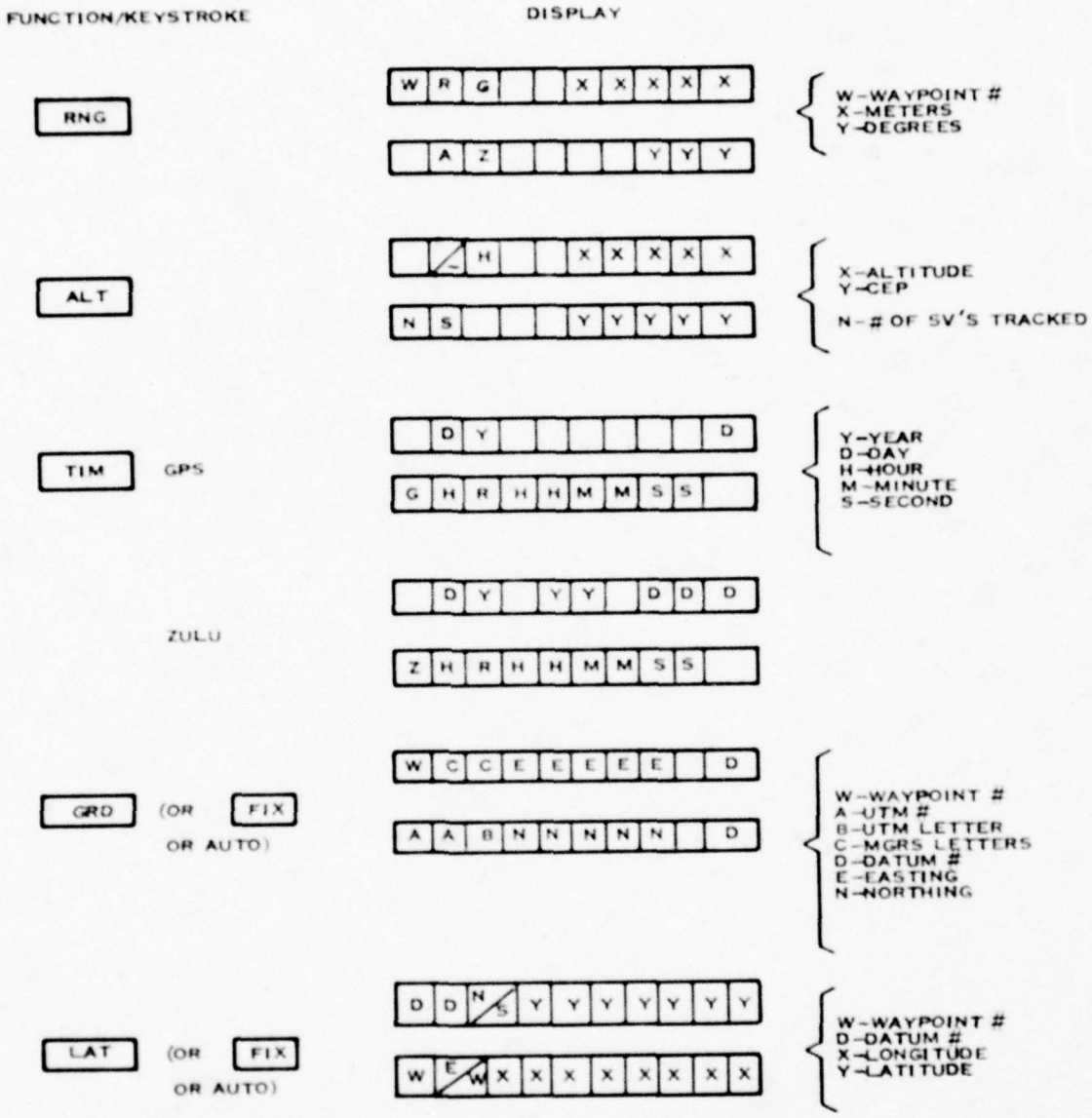
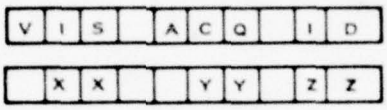


Figure 3.2-18. CDU Display Formats



X – NUMBER OF VISIBLE SV'S

Y – NUMBER OF SV'S ACQUIRED

Z – ID OF SV CURRENTLY BEING SOUGHT

Figure 3.2-19. Acquisition Status Display Format

SEL nn	Puts CDU into Input Mode Positions First - Level - Prompting at nn Sets m = 0 If no Value of nn Given or nn Out of Range, Then SEL Advances First - Level - Prompting by One nn = "-" Resets First - Level Prompting to Zero and Removes CDU from Input Mode
m	Moves CDU to Second - Level Prompting at Entry m If No Value of m Given or m Out of Range, Then Advances Second - Level Prompting by One
CLR	Clears Data from Input Display Removes Current Second - Level Prompting
ENT	Enters Data from Input Display Returns Second - Level - Prompting at Last Value of nn and m.

Figure 3.2-20 Prompting Control

ENTRY	STATES BEFORE ENTRY				STATES AFTER ENTRY				NOTES
	I/O	1ST LEVEL PROMPT	2ND LEVEL PROMPT	DATA I/O	I/O	1ST LEVEL PROMPT	2ND LEVEL PROMPT	DATA I/O	
SEL .	OUTPUT	–	–	–	INPUT	01	0	OUTPUT	
SEL nn	OUTPUT	–	–	–	INPUT	nn	0	OUTPUT	
SEL–	OUTPUT	–	–	–	OUTPUT	–	–	–	
.	OUTPUT	–	–	–	OUTPUT	–	–	–	
ENT	OUTPUT	–	–	–	OUTPUT	–	–	–	
CLR	OUTPUT	–	–	–	OUTPUT	–	–	–	
SEL	INPUT	aa	–	–	INPUT	aa + 1	0	OUTPUT	
SEL nn	INPUT	aa	–	–	INPUT	nn	0	OUTPUT	
SEL	INPUT	aa	–	–	OUTPUT	–	–		
. m	INPUT	aa	b	–	INPUT	aa	b + 1	OUTPUT	
ENT	INPUT	aa	b	OUTPUT	INPUT	aa	m	OUTPUT	
CLR	INPUT	aa	b	OUTPUT	INPUT	aa	b	OUTPUT	
							b	INPUT	
ENT	INPUT	aa	b	INPUT	INPUT	aa	b	(1)	
CLR	INPUT	aa	b	INPUT	INPUT		b	INPUT	CLEARS DATA DISP
ENT	INPUT	aa	b	ERR	INPUT	aa	b	ERR	
CLR	INPUT	aa	b	ERR	INPUT	aa	b	INPUT	

1. RESULTS IN OUTPUT IF ENOUGH DATA ENTERED; ELSE RESULT IS ERR.

2. DEPRESSING ANY OF THE OUTPUT DISPLAY BUTTONS OR RADIO HAS THE SAME EFFECT AS SEL– IN THAT THIS ACTION RETURNS I/O TO OUTPUT.

Figure 3.2-21. Prompting Operation

3.2.11 EIOM Control Utilities

3.2.11.1 Functional Description

The S/W Modules: M3LSBO, M3LSBZ, M3STIM, M3CDUO, M3STLR, M3RTIM, and M3ODHO implement control of the EIOM utilities.

The EIOM control utility modules interface between the system and the EIOM through the 9900 communication register unit (CRU). These I/O service routines manipulate the contents of a user-specified CRU address by setting a bit to one (or zero). They also input or output a 16-bit word from or to the CRU during each calling sequence.

3.2.11.2 Processing

M3LSBO	-	set CRU bit to one
M3LSBZ	-	set CRU bit to zero
M3STIM	-	initialize and start standby timer
M3CDUO	-	CDU output service
M3STCR	-	read CRU bit
M3RTIM	-	read standby timer
M3ODHO	-	DHO/MIS output service

3.2.12 Summary

3.2.12.1 Module and Function Mappings

As a summary, table 3.2-5 lists all the master control modules and their functions. These modules are classified in terms of each of the eleven tasks described in the previous paragraphs.

3.2.12.2 Control Flow

Figure 3.2-22 shows the calling and activating sequence of the Master Control modules during the MVUE operational period.

3.2.12.3 System Time-Line

The overall MVUE processor time-line of master control modules consists of two parts: (1) System time-line during TTFF period and (2) System time-line in steady state. Figures 3.2-23 and 3.2-24 shows the time-lines (1) and (2) respectively.

Table 3.2-5 Task Classification for Modules
in Master Control Subsystem

1. System Start-Up Control
   a. M1ST5M - schedules cold/warm start, system restart process and BIT mode

2. SV Acquisition Control
   a. M1NS20 - receiver mode control, Nav aiding control, Nav filter initialization control, executive FTF resync control

3. SV Reacquisition and Navigation Control
   a. M1NSVC - Nav aiding control, Nav inner and outer loop SV control, ionospheric correction scheduling, degraded mode navigation control
   B. M2RMOD - receiver mode control
   c. M2RMDC - receiver mode selection and status check
   d. M2EPHM - ephemeris update control
   e. M2STAT - SV status recording service

4. Fix Control
   a. M1NST2 - prepare data for position fix

5. Waypoint Control
   a. M1NSWC - waypoint display, range and bearing to selected waypoint calculation

6. C/NO Monitoring and Filtering
   a. M1CNSV - SV Signal-to-noise ratio calculation

7. MVUE Instrumentation Control and System Status Monitoring
   a. M1NSDT - system initialization, status monitoring, MIS control

Table 3.2-5 Master Control Modules (continued)

8. Data Block Processing
   a. M1PDBR - data block processing
   b. M2DBPR - SV data collection
   c. M2DBS1 - data block I service
   d. M2DBS2 - data block II service
   e. M2DBS3 - data block III service
   f. M2MOVE - data mover

9. Coordinate Tansformation Service
   a. M1XFRM - coordinate conversion control
   b. M2EFLD - geodetic and WGS-72 geodetic conversion
   c. M2GPMG - geographic position to MGRS conversion
   d. M2MGGP - MGRS to geographic position conversion
   e. M2MSLH - mean sea level computation
   f. M2OSMG - offset to MGRS row ID computation

10. CDU Control
   a. M1S100 - CDU I/O control
   b. M2CDMI - CDU I/O and MIS I/O service
   c. M2CDUF - CDU function control
   d. M2PRMT - CDU prompting control
   e. M2NCDF - data formatting service

11. EIOM control Utilities
   a. M3LSBO - set CRU bit to one
   b. M3LSBZ - set CRU bit to zero
   c. M3STIM - start standby timer
   d. M3CDUO - CDU data output service
   e. M3STCR - read CRU bit
   f. M3RTIM - read standby timer
   g. M3ODHO - DHO/MIS data output service

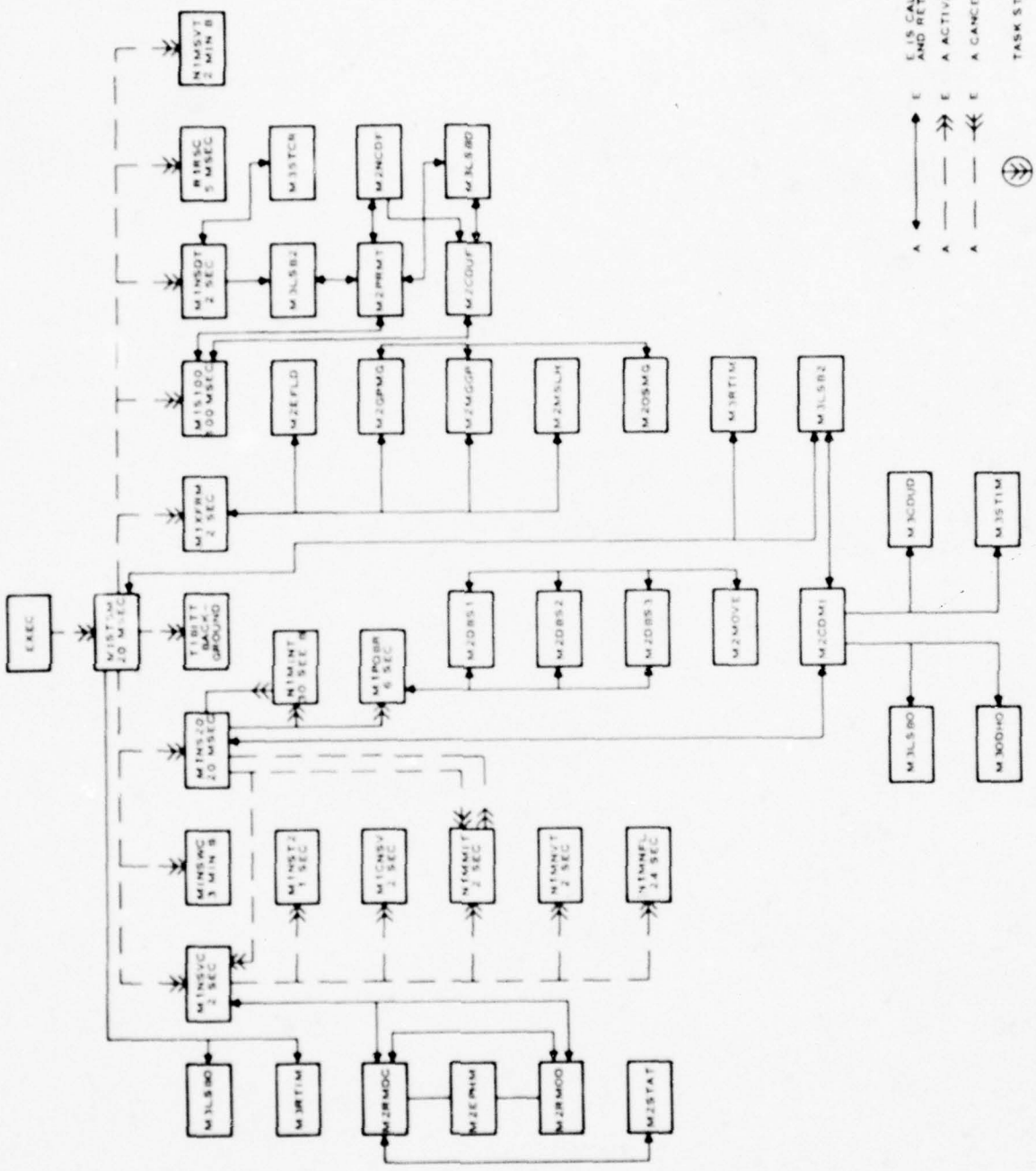


Figure 3.2-22. Master Control Subsystem Flow

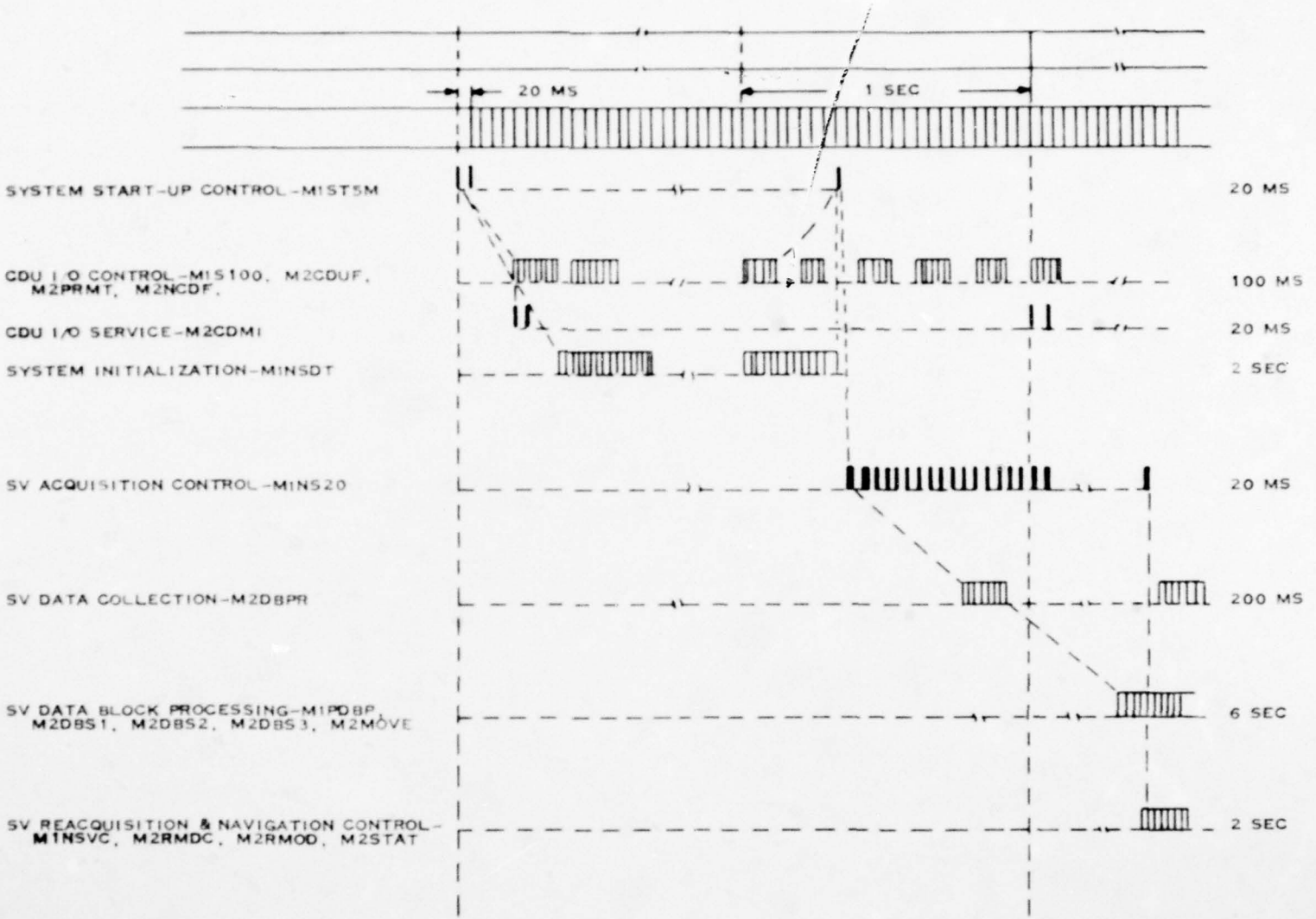


Figure 3.2-23. Time-Line of Master Control for Period before First Fix

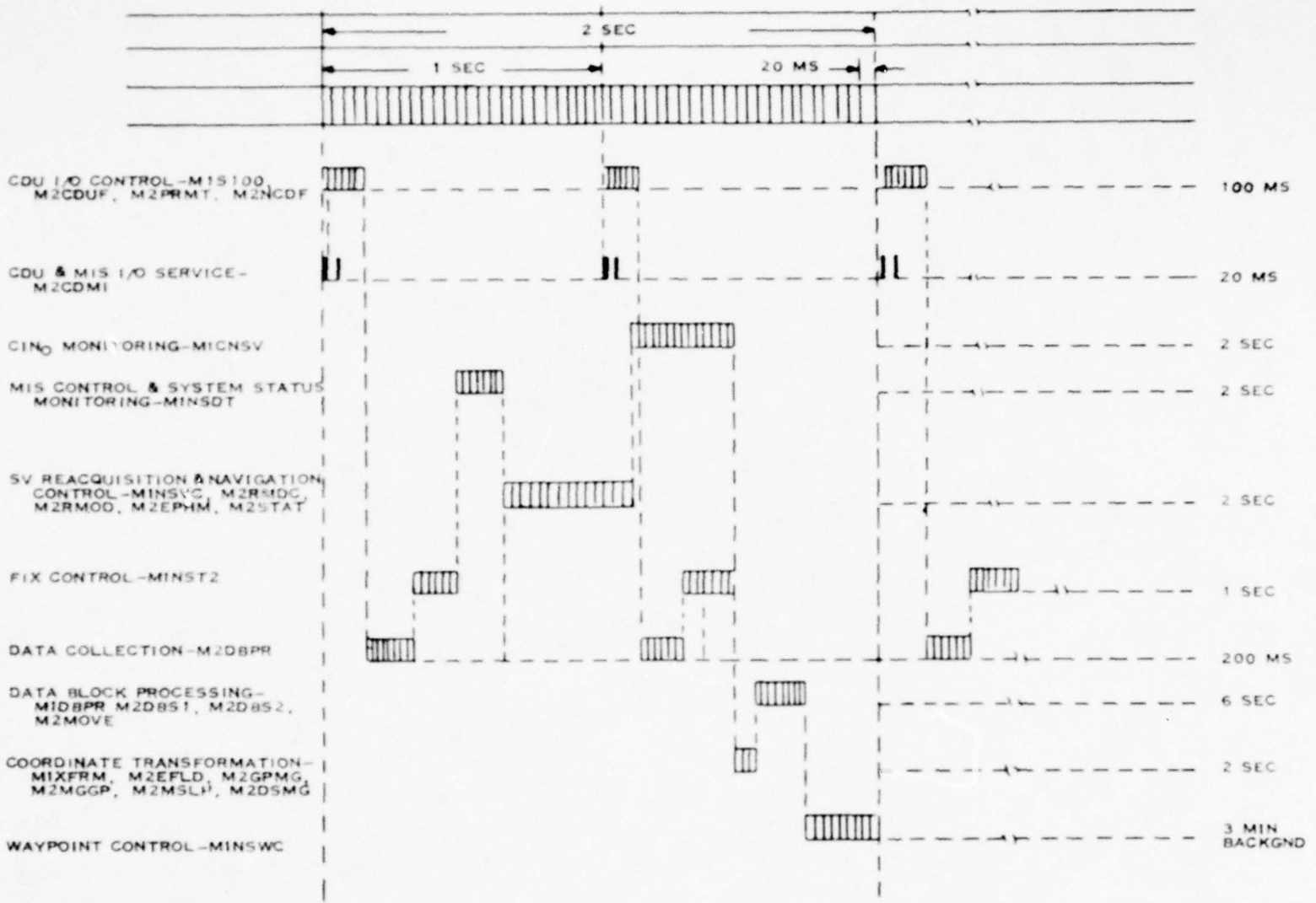


Figure 3.2-24. Time-Line of Master Control in Steady State

3.3 MVUE NAVIGATION SUBSYSTEM

3.3.1 Overview

The primary purpose of the navigation subsystem is to compute the user's position in an earth-centered, earth-fixed coordinate system using the time and range measurement information sent from the receiver, and using the orbit parameters for the satellites (or ground transmitters) sent in the data message from the satellite. The navigation subsystem's operation will be described in terms of four major functions and several supplemental functions.

These functions and the associated software modules which implement these functions are as follows:

1. Navigation Filter
   a. Inner Loop
      - N1MMIT - Measurement incorporation/state update
      - N2MNEG - State propagation
      - N2MRNG - Range computation
   b. Outer Loop
      - N1MNFL - Outer Loop control
      - N2MFOT - Computation of matrix relating measurements to user state
      - N2MCPR - Error covariance propagation
      - N2MCUP - Error covariance update and filter gains

computation

2. Measurement Computations and Corrections

N1MNVT - Navigation control task

N2MSCI - Measurement and satellite clock correction computations

N2MINC - Atmospheric corrections for range measurements

3. Satellite Position and Constellation Selection

N1MSVT - Control task

N2MSVP - Quadratic fit coefficient computations

N2MSVE - Satellite position computations

N2MSVS - Satellite constellation selection

4. Receiver Aiding

N2MAID - Range and range rate computations

5. Supplemental Functions

a. Initialization

b. Spherical Error Estimate

c. Stationary User State Smoothing

d. Range Bias Rate Monitoring

The functions listed above are not entirely separable and overlap somewhat within the associated modules. For example, the computation of range by N2MRNG is used in the outer loop and for receiver range aiding although it is listed as an inner loop navigation filter associated module. All navigation modules are listed above except for N1MINT which is the control task for inner and outer loop computations during the satellite acquisition period only.

The Navigation Subsystem utilizes the following data sets to communicate between modules and to communicate with the other subsystems.

1. NAGINR - Inner Loop Variables

   Includes the user's state and time.

2. NBGOUT - Outer Loop Variables

   Includes the U-D formulation covariance matrix.

3. NCGIOU - Inner/Outer Loop Variables

   Includes the filter gains.

4. NDGSYS - Common Support and Initialization Variables

   Contains a collection of variables which are system constants, or are used in more than one task.

   Includes inner and outer loop SV ID identifier.

5. NECNST - Global Constants

6. NFITCN - Intratask Constants

7. NGGSVP - Satellite Position Variables

   Collection of SV variables used by the SV Selection/position task.

8. NMINIT - Navigation/Master Control Interface Variables

   Contains variables required by Master Control during initialization and satellite acquisition.

9. NMSIFC - Navigation/Master Control Interface Variables

   Contains user state variables passed to master control.

10. NRAIDF - Receiver Aiding Data

    Contains navigation data needed by the receiver for SV acquisition/reacquisition.

11. NRTIMF - Precision Time Data

Contains the information needed by the receiver for SV acquisition/reacquisition.

12. NMDHOB - Data Handover Variables

Not used in final system.

13. NMAPPL - Satellite Selection Variables

Includes the elevation array and number of SVs.

14. NVASEL - RAM Almanac Selection Flag

15. NNRALM - Satellite Almanac Variables

Contains almanac data located in PROM.

The navigation subsystem has two primary modes of operation as follows:

1. Satellite acquisition/filter initialization mode.
2. Steady-state mode.

In addition the subsystem has two degraded modes which are invoked whenever the MVUE System is receiving measurements from less than four signal sources. They are as follows:

1. Altitude hold mode - invoked whenever only three signal sources are available for measurements. In this mode, the range from the user to the center of the earth is computed and used as a fourth measurement.
2. Altitude hold/time freeze mode - invoked whenever only two signal sources are available for measurements. In this mode, the range from the user to the center of the earth is used as an additional measurement, and the time bias states are not updated which allows a navigation solution for position.

The overall structure of the navigation subsystem for the two primary modes of operation is depicted in Figure 3.3-1 and 3.3-2. in these figures the lines without arrows indicate module calls and the lines with arrows indicate the flow of the essential data in and out of the subsystem.

Computations in the navigation subsystem are in scaled units in order to maximize the accurracy of the REAL*4 floating point computations. Distance computations are in units of 1/17 p-chip where 1/17 p-chip = 1.7238368 meters. Angular computations are in units of semicircles where one semicircle = PI radians = 180 degrees.

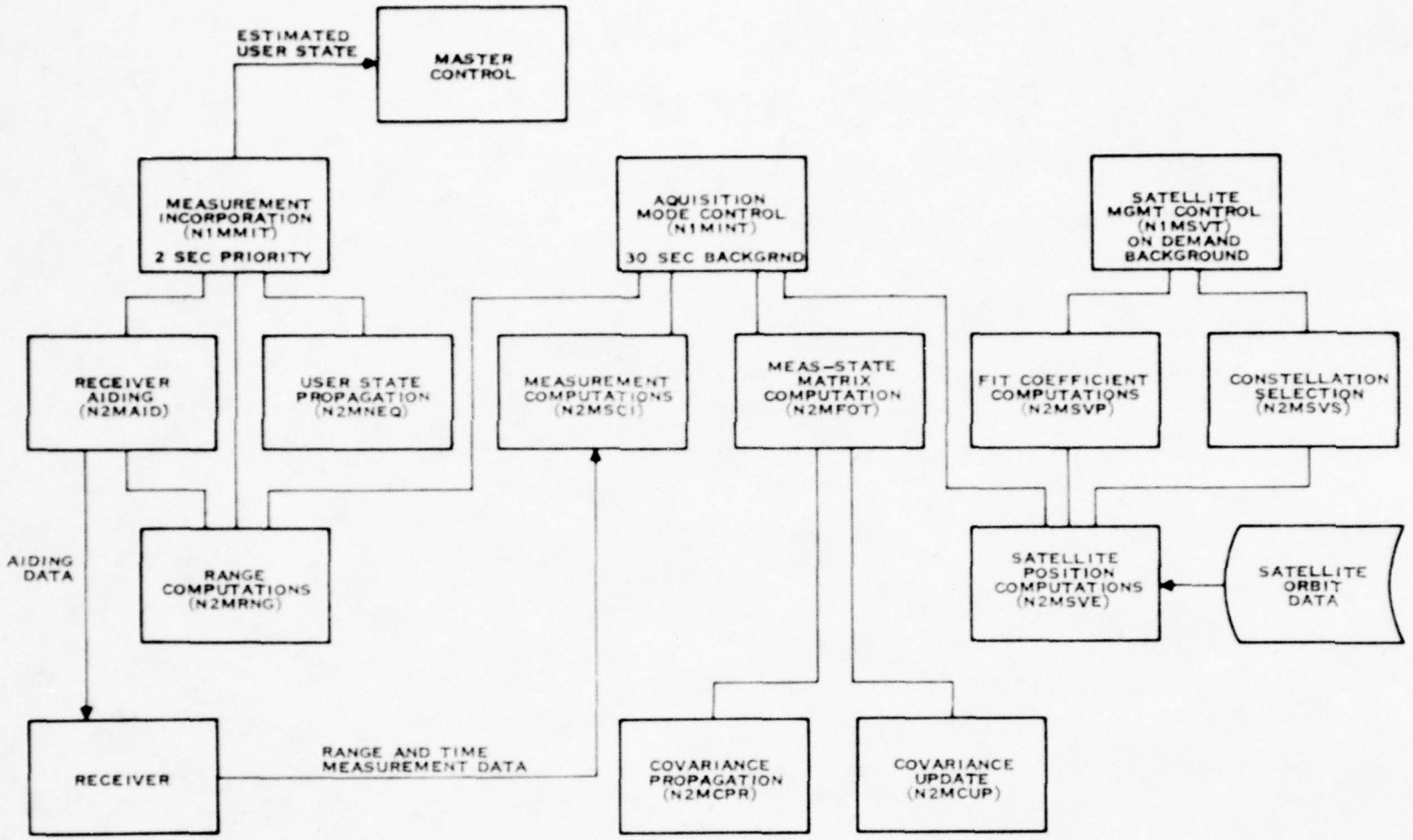


Figure 3.3-1. Navigation Subsystem Structure Satellite Acquisition and Filter Initialization Mode

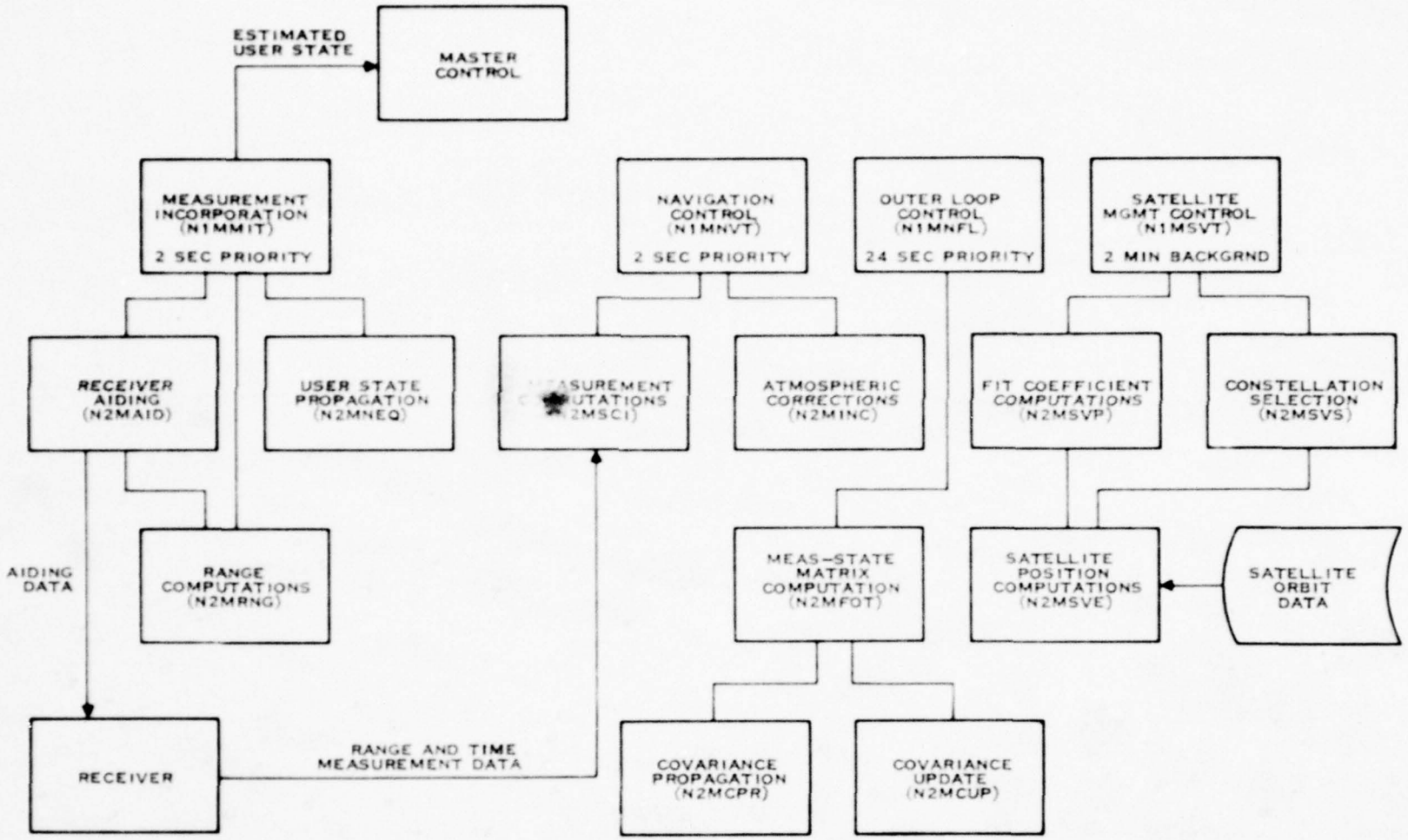


Figure 3.3-2. Navigation Subsystem Structure Steady-State Mode

3.3.2 Navigation Filter Function

The heart of the navigation subsystem is a suboptional Kalman data processing filter whose output is an estimate of the current position and velocity state of the user. The user state is an eight component vector denoted by $\underline{X}$. The components of $\underline{X}$ are position (x, y, z), velocity (xdot, ydot, zdot), range bias rb, and range bias rate rbdot. The user's position and velocity is expressed in a right handed, cartesian, earth centered, earth-fixed coordinate system, whose origin is at the center of the WGS-72 spheroid. The variables rb and rbdot are the user's clock bias and clock bias rate multiplied by the speed-of-light.

In theory, the range bias state rb is the total bias in the user's clock multiplied by the speed-of-light. However, in order to maintain accuracy in REAL*4, a constant equal to the estimate of the initial time bias when the first satellite is acquired is subtracted from the total time bias. Thus the range bias state rb is related to the total user clock bias by the equation:

rb = C (TU - TC)

TU = total user clock bias

TC = constant = initial estimate of user clock bias

C = speed of light

The operation of the Kalman filter can be partitioned into the following processes:

(1) User State propagation

(2) Covariance propagation

(3) Filter gains computation

(4) Covariance update

(5) User state update

Normally, a Kalman filter proceeds through these processes in the order shown above and all the processes are done at the same rate. However, in the MVUE implementation of the Kalman filter, the user state propagation and user state update are performed every two seconds, whereas the covariance propagation, gains computation, and covariance update are performed every twenty-four seconds. It is possible to operate the filter in this fashion because of the relatively slow variation of the filter gains and covariance as a function of time. The two-second filter computations are defined as Inner Loop operations, and the twenty-four second filter computations are defined as Outer Loop operations.

3.3.2.1 Navigation Filter Inner Loop

3.3.2.1.1 User State Propagation

The user's state $\underline{X}$ is propagated according to the equation:

$$\underline{X}(t + dt) = \underline{PHI}\ \underline{X}'(t)$$

where $\underline{X}'(t)$ denotes the updated (or "best estimate") user state at time t and PHI is an 8 by 8 transition matrix and has the following matrix elements:

$\underline{PHI}(1,1) = \underline{PHI}(2,2) = \underline{PHI}(3,3) = 1$

$\underline{PHI}(4,4) = \underline{PHI}(5,5) = \underline{PHI}(6,6) = EXP(dt/TV)$

$\underline{PHI}(8,8) = dt$

$\underline{PHI}(1,4) = \underline{PHI}(2,5) = \underline{PHI}(3,6) = TV * (1-EXP(dt/TV))$

All other elements of PHI are 0. The time of propagation dt is 2 seconds, and TV is defined as the velocity correlation time. The preceding tasks are performed in the module N2MNEG.

3.3.2.1.2 User State Update/Measurement Incorporation

The user's state is updated to give the Kalman filter's best estimate of the current state using the equation:

$$\underline{X}'(t+dt) = \underline{X}(t+dt) + \underline{K}(I) * Z(I)$$

In this equation, $\underline{K}(I)$ is the gain vector for satellite I, and Z(I) is the measurement residual for the range measurement to satellite I. The elements of $\underline{K}(I)$ are computed in the Outer Loop and will be defined later. The residual Z(I) is computed from:

$$Z(I) = RM(I) - RC(I)$$

where RM(I) is the measured range to satellite I (see para. 3.3.3.1) based on receiver raw measurement data and RC(I) is the computed range to satellite I based on the current estimate of the user state and the satellite position. In the MVUE implementation of the update equation, the elements of $\underline{K}(I)$ are multiplied by 10 when updating the velocity and range bias rate components of the state. This is not a standard implementation but gives the MVUE an improved performance when the system is dynamic and does not degrade the performance while the system is static.

The state is propagated and updated every two seconds. Each update is based on a new measurement from a particular satellite. One satellite measurement is made by the receiver in each two second period and up to six satellite measurements may be made according the satellite sequence scheme shown in Figure 3.3-3. A measurement at L2 frequency is made during the ionospheric cycle shown in the figure, and this measurement is used along with the preceding measurement at L1 frequency to compute a correction for the delay of the signal caused by the ionosphere. The state is updated only on cycles where a measurement at the L1 frequency is available; thus, the state is not updated during an ionospheric cycle. The preceding tasks are performed in the module NIMMIT.

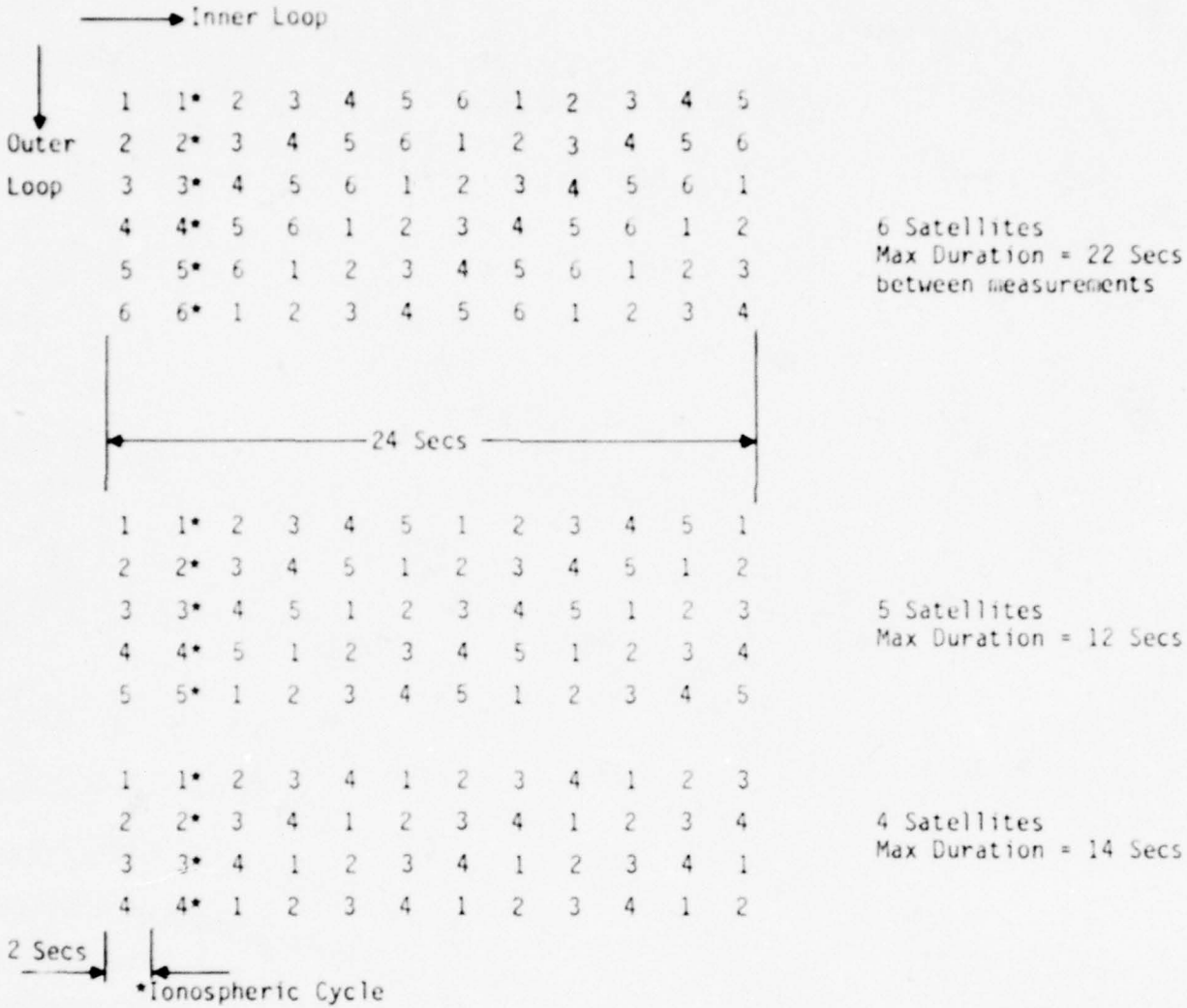


Figure 3.3-3. SV Sequence Table for 4, 5, and 6 Satellites

3.3.2.1.3 Computed Range

The current best estimate of the range RC to a satellite is computed using the x, y, z components of the user's estimated state and the x, y, z components of the satellite's position at the time when the signal is transmitted from the satellite. The satellite's position components are computed using quadratic fit coefficients which are computed by the Satellite Position Computations and Constellation Selection Function (Section 3.3.4). The equations for computing the satellite x, y, z components using the fit coefficients are of the form:

SP = F0 + F1 * (t-FT)/120 + F2 * ((t-FT)/120)**2)

where there is an equation of this form for each component of the satellite's position and

SP = x, y, z components of satellite position denoted below in the range computation equation as xs, ys, zs.

F0 = x, y, z components of zero-th order fit coefficients.

F1 = x, y, z components of first order fit coefficients.

F2 = x, y, z components of second order fit coefficients.

FT = time at center of quadratic fit to 120 seconds of satellite orbit.

The satellite's x, y, z position components are corrected for the earths rotation during the time that the signal is traveling from the satellite to the user and then the range RC is computed from:

$$RC = SQRT((xs-x)**2 + (ys-y)**2 + (zs-z)**2)$$

where xs, ys, and zs are the components of the satellite's position and x, y, and z are the components of the estimated user's position.

The preceding tasks are performed in the module N2MRNG.

3.3.2.2 Navigation Filter Outer Loop

3.3.2.2.1 Error Covariance Propagation

The error covariance is an 8 by 8 matrix which represents an estimate of the uncertainty in the estimate of the user's state. This covariance, here denoted by COV, is propagated every 24 seconds according to the matrix equation

$$\underline{COV}(t+dt) = \underline{PHI} * \underline{COV}'(t) * \underline{PHIT} + \underline{Q}$$

where COV' denotes the updated (or "best estimate") covariance at time t, dt is the propagation interval equal to 24 seconds, PHI is the outer loop transition matrix, PHIT is the transpose of PHI, and Q is a column vector whose

components are terms known as process noise. The process noise terms as implemented in MVUE are constants. (If filter adaptation had been added to the MVUE design, these process noise terms would have been used to adapt the covariance to system conditions based on the current magnitudes of measurement residuals.) The Outer Loop transition matrix PHI is identical in form to the Inner Loop transition matrix PHI except that the time of propagation constant dt is given the value 24 sec corresponding to the longer propagation time.

In reality the above equations are not carried out directly. For computational accuracy and stability, the covariance is decomposed in the form:

$$\underline{COV} = \underline{U} * \underline{D} * \underline{UT}$$

where $\underline{U}$ is an upper triangular 8 by 8 matrix with all diagonal entries equal 1, $\underline{UT}$ is the transpose of $\underline{U}$, and $\underline{D}$ is a diagonal matrix with positive diagonal entries. The $\underline{U}$ and $\underline{D}$ elements are stored in the MVUE in a single 8 X 8 matrix whose off diagonal entries are the off diagonal elements of $\underline{U}$ and whose diagonal entries are the diagonal elements of $\underline{D}$.

The PHI * COV * PHIT computations are performed in the $\underline{U}$ - $\underline{D}$ formulation. The actual covariance is computed from:

$$\underline{COV} = \underline{U} * \underline{D} * \underline{UT}$$

and the matrix $\underline{Q}$ is added to the result. A Modified Cholesky Decomposition formula is then used to transform the resulting propagated covariance back to the $\underline{U}$-$\underline{D}$ form. The MVUE system always stores the covariance in the $\underline{U}$-$\underline{D}$ formulation (but in a single 8 by 8 matrix as described earlier). If the true covariance representing state estimation uncertainty is desired, it must always be computed from the $\underline{U}$-$\underline{D}$ elements.

The covariance propagation tasks are performed in the module N2MCPR.

3.3.2.2.2 Error Covariance Update and Filter Gains Computation

The filter gains $\underline{K}$ for a particular satellite measurement incorporation are computed by the equation:

$$\underline{K} = \underline{COV} \cdot \underline{HT} / (\underline{H} \cdot \underline{COV} \cdot \underline{HT} + N)$$

where

$\underline{COV}$ = Covariance matrix after propagation

$\underline{H}$ = matrix relating particular satellite range measurement and user state defined in paragraph 3.2.2.3

$\underline{HT}$ = transpose of $\underline{H}$

N = Variance of receiver range measurement noise for the particular satellite (The value is a preset constant)

The error covariance is updated according to the equation

$$\underline{COV}' = (\underline{I} - \underline{K} * \underline{H}) * \underline{COV}$$

where the prime denotes the updated value of the covariance and $\underline{I}$ is the 8 by 8 unity matrix with diagonal elements equal 1 and off diagonal elements equal 0.

In actuality, these equations are not implemented directly, since the covariance is decomposed into a U-D formulation as defined in 3.3.2.2.1. All computations are computed in the U-D formulation and the actual covariance is never computed or used. The covariance update and gains computation tasks are performed in the module N2MCUP. The gains for only one satellite are computed in each 24 second outer loop. Thus, new gains for a particular satellite are computed once every 96 seconds when tracking 4 satellites, once every 120 seconds for 5 satellite, and once every 144 seconds for 6 satellites.

3.3.2.2.3 Computation of Matrix Relating Receiver Measurements to User State

This matrix is actually a row vector $\underline{H}$ with the following components

$$\underline{H}(1) = (x-xs)/RC$$

$$\underline{H}(2) = (y-ys)/RC$$

$$\underline{H}(3) = (z-zs)/RC$$

$$\underline{H}(4) = \underline{H}(5) = \underline{H}(6) = \underline{H}(8) = 0$$

$$\underline{H}(7) = -1$$

where x, y, and z are the position components of the user's state vector; xs, ys, and zs are the position components of a particular satellite; and RC is the computed range to the satellite.

If the system is in a degraded mode and the $\underline{H}$ matrix for altitude hold is being computed, the equations are the same except xs, ys, and zs equal zero and $\underline{H}(7) = 0$.

The tasks are performed in the module N2MFOT.

3.3.3 Measurement Computations and Corrections Function

This function is responsible for computing the measured range to each satellite based on raw receiver measurement data and for correcting this measurement for satellite clock error and atmospheric propagation delay errors.

3.3.3.1 Measured Range Computation

The measured range RM is computed based on receiver measurements for a particular satellite according to the equaltion:

$$RM = 0.02\ C\ (\ User\ FTF - SV\ FTF\ ) -$$
$$PR + rb + C\ (\ TS - TE + TC\ )$$

where

C = Speed of light in 1/17 pchip/second units

USER FTF = User clock 20 millisecond count since the preceding midnight Saturday/Sunday

SV FTF = Satellite Clock 20 millisecond count since the preceding midnight Saturday/Sunday

PR = Pseudo range count in 1/17 pchip units

rb = User range bias state

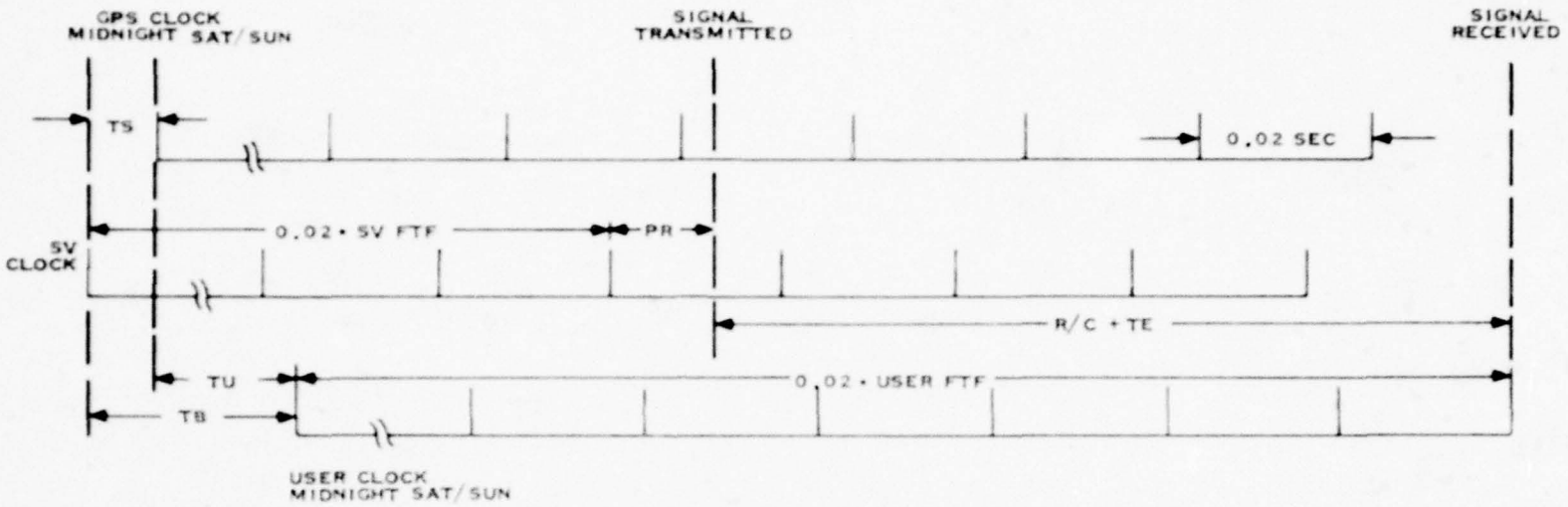
TS = Satellite clock correction

TE = Atmospheric delay correction

TC = Initial estimate of user's clock bias

The relationships between the various clocks and the true range R from the user to the satellite are depicted in Figure 3.3-4.

The preceding tasks are performed in the module N2MSCI except for the addition of the atmospheric correction to the measured range. This addition is done in the module N1MNVT in steady-state and in task N1MINT during satellite acquisition.



C ≡ SPEED OF LIGHT

PR ≡ PSUEDO RANGE COUNT IN 1/17 PCHIP UNITS

R ≡ TRUE SLANT RANGE FROM SATELLITE TO USER

TE ≡ ATMOSPHERIC TIME DELAY

TU ≡ USER CLOCK BIAS = GPS CLOCK READING − USER CLOCK READING

TS ≡ SATELLITE CLOCK BIAS = SV CLOCK READING − GPS CLOCK READING

TB ≡ USER TO SV TIME BIAS = TU + TS = SV CLOCK READING − USER CLOCK READING

Figure 3.3-4. MVUE Time and Measurement Relationships

3.3.3.2 Atmospheric Corrections

The atmospheric correction TE used in the measured range computation is composed of an ionospheric time delay correction and a tropospheric time delay correction. During the acquisition mode, the corrections are both computed according to simple models which do not require any measurement data. During steady-state operation, the corrections are computed once each 24 seconds for a particular satellite. Thus, when four satellites are being tracked, the time between atmospheric correction updates is 96 seconds. for 5 satellites the update time is 120 seconds and for 6 satellites is 144 seconds. During steady-state operation, the ionospheric correction is based on an L1/L2 measurement technique, whereas the tropospheric correction is based on the same model used during the acquisition mode.

The following equations are used to compute the atmospheric corrections.

(1) Ionosphere correction - acquisition mode

RI = -2.15E07 * RC / (RC**2 - 2.237E14)

(2) Ionosphere correction - steady-state mode

RI = -1.5457278 * (PRL2 - PRL1) +
0.60369363*(PRDOT)

(3) Troposphere correction - acquisition and steady-state

RT = (((-0.2873 * ALT + 2316.0) ALT -
9.337E6) * RC) / (RC**2 - 2.237E14)

In these equations,

RI = Ionsphere range measurement correction for a particular satellite in units of 1/17 pchip

RC = Computed range to a particular satellite

PRDOT = Sum of L1 and L2 pseudo range rate measurements

PRL1 = L1 pseudo range measurement

PRL2 = L2 pseudo range measurement

RT = Troposphere range measurement correction for a particular satellite in units of 1/17 pchip

ALT = Altitude of user above WGS-72 spheroid in units of 1/17 pchip

Thus, the total atmospheric time delay correction is given by

TE = (RI + RT) / C

If the signal source is a ground transmitter, no ionospheric corrections are made to the measured range and the troposphere correction is computed by

RT = RC * 3.13E-4

where RC is the computed range to the particular ground transmitter.

The ionosphere correction for a particular satellite is smoothed by applying an exponential filter to the individual corrections resulting from the individual L1/L2 pseudo range measurements. The filter has a 6.4 minute time constant and is given by

$$RI(t) = RI(t-T) + 0.25 * (RI - RI(t-T)$$

where

RI(t) = Smoothed ionosphere correction at time t

RI(t-T) = Smoothed ionosphere correction at time t-T

RI = Individual ionosphere correction just computed from L1/L2 measurements

T = Time delay since last ionosphere correction was computed

The total atmosphere correction is limited to be between 100 and -100 1/17 pchip.

The preceding tasks are performed in the module N2MINC during steady-state and in N1MINT during satellite acquisition.

3.3.3.3 Satellite Clock Correction

When computing the measured range, a correction for satellite clock error is applied. the satellite clock

correction TS is computed according to the equation.

$$TS = A0 + A1 * (t-t0) + A2*(t-t0)**2$$

where A0, A1, A2, and t0 are parameters whose values are found in the data message from a particular satellite, and t is the current time in seconds relative to the preceding midnight Saturday/Sunday. The A0, A1, and t0 parameters are also available in the almanac satellite data, and A2 is assumed to be 0 when correcting the clock based on almanac data.

This task is performed in the module N2MSCI.

3.3.4 Satellite Position Computations and Constellation Selection Function

This function is invoked every two minutes during steady-state and is invoked each time a new satellite is acquired during the satellite acquisition mode. In addition, the function is commanded once before any satellites have been acquired so that an approximate range to each satellite can be computed based on satellite almanac data stored in the MVUE prior to satellite acquisition. This function can be subdivided into the following three subfunctions:

(1) Satellite position computations (2) Fit coefficient computations (3) Satellite constellation selection

The position of each satellite is computed for three points in time separated by 60 seconds. A quadratic fit is

made to these three points and the corresponding fit coefficients are used by the Inner Loop every two seconds to compute the satellite position at any desired time. The satellite constellation is selected based on the visibility and elevation of the satellites as determined from the magnitude of the satellite-to-user range. The control of these tasks is performed in the module N1MSVT.

3.3.4.1 Satellite Position Computations

The (x,y,z) components of any satellite are computed given the orbital parameters of the satellite, and the time for which the position is to be computed. The orbital parameters are obtained either from the almanac data base, or from the ephemeris data which is sent down in the data message from the satellite. The almanac data is used whenever the approximate position of the satellite is needed, but the satellite has not been acquired and ephemeris data is not avaialbe. Ephemeris data is used after the satellite has been acquired and a more exact position calculation is desired.

Satellite ephemeris/almanac parameters are defined in Table 3.3-1. The computations involved in determining the x, y, and z components in the earth-fixed, earth centered cartesian coordinates at time t are summarized below. the equations used are those defined in the GPS Phase I Interface Control Document (ICD).

(1) Compute mean motion NO

NO = sqrt(MU/A**3)

where MU is the WGS-72 value of the earth's universal gravitational parameter. NO is computed by Data Block Processing (Master Control Function) and is stored in the ephemeris/almanac data base.

(2) Compute mean anomaly MK at time t

MK = MO + NO*(t-TOE)

(3) Solve Kepler's equation for the eccentric anomaly EK

EK = MK - e * Sin EK

This equation is solved for EK by iteration, with EK initialized to MK for the first iteration.

Table 3.3-1 Ephemeris/Almanac Parameters

PARAMETER	DEFINITION
TOE	GPS time of data applicability
A	Semi-major axis of orbit
MO	Mean anomaly at time TOE
e	Eccentricity of orbit
OMEGAO	Right ascension of the ascending node at time TOE
OMEGA'	Drift rate of the right ascension
IO	Inclination of the orbit
W	Argument of perigee
CUC, CUS *	Harmonic coefficients for the argument of latitude correction
CIC, CIS *	Harmonic coefficients for orbit inclination correction
CRC, CRS *	Harmonic coefficients for satellite radius correction

* These higher order correction parameters are not included in the almanac data

(4) Compute true anomaly VK from

cos(VK) = (cos(EK) - e) / (1-e cos(EK))

sin(VK) = sqrt(1 - e**2) sin(EK) / (1 - e cos(EK))

(5) Compute argument of latitude PHIK

PHIK = VK + W

(6) Compute second harmonic perturbation DUK, DRK,
and DIK if ephemeris data is being used. Otherwise,
skip these computations, and set perturbations to 0.

DUK = CUS sin(2 PHIK) + CUC cos(2 PHIK)

DRK = CRU cos(2 PHIK) + CRS sin(2 PHIK)

DIK = CIC cos(2 PHIK) + CIS sin(2 PHIK)

(7) Compute corrected argument of latitude UK,
orbit radius RK, and inclination of orbit IK.

UK = PHIK + DUK

RK = A(1 - e cos(EK)) + DRK

IK = IO + DIK

(8) Compute longitude of ascending node OMEGAK

OMEGAK = OMEGAO + (OMEGA'-OMEGAE')(t-TOE)
- OMEGAE' TOE

where OMEGAE' is the earth's rotational rate

(9) Compute Position in orbital plane

XK' = K cos(UK)

YK' = RK sin(UK)

(10) Compute the (x,y,z) components of the satellite
position in earth-fixed coordinates.

XK = XK' cos(OMEGAK) - YK' cos(IK) sin(OMEGAK)

YK = XK' sin(OMEGAK) - YK' cos(IK) cos(OMEGAK)

$$ZK = YK' \sin(IK)$$

If a ground transmitter is being used, the x, y, z components are stored in the data base and do not have to be computed.

The preceding tasks are performed in the module N2MSVE. Special techniques have been used in the module computations to maximize accuracy using REAL*4 precision. These techniques tend to make the code appear more complicated than the above equations would indicate. Also, when using almanac data, the number of weeks since the almanac was stored must be accounted for. This is done by correcting TOE according to the equation

$$TOE = TOE - 604800.0*(NMSWKS - MNRWKS)$$

where NMSWKS is the current week number since Jan. 1, 1978 and MNRWKS is week number relative to Jan. 1, 1978 for which the almanac data was applicable.

3.3.4.2 Fit Coefficient Computations

After the satellite position for three points 60 seconds apart is computed in N2MSVE, a parabola is fitted to these three points so that the position of the satellite for any time within or close to the 2 minute period can be computed with fewer computational steps. The quadratic fit coefficients F0, F1, and F2 are computed using equations of the form:

$$F0_x = XK(2)$$

$$F1_x = XK(3) - XK(1)$$

$$F2_x = 2 * XK(1) - 4 * XK(2) + 2 * XK(3)$$

where $F0_x$, $F1_x$, and $F2_x$ are the x components of the zeroth, first, and second order fit coefficients, and XK(1), XK(2), and XK(3) are the x components of the satellite position for the first, second, and third point in time along the orbit. Similar equations are used to compute the y and z fit coefficients. The fit coefficients are normalized to a time of 120 seconds with zero time at the middle time point. The absolute time for the middle time point is stored in a fourth fit coefficient parameter which is denoted here as FT.

Fit coefficients are buffered so that while the system is using the fit coefficients for one 2 minute period, the fit coefficients for the next 2 minute period can be computed.

These fit coefficient tasks are performed in the module N2MSVP.

3.3.4.3 Satellite Constellation Selection

The tasks performed by the Satellite Constellation Selection Subfunction are conveniently divided into those tasks performed before the satellites are acquired and those tasks performed during steady state.

3.3.4.3.1 Satellite Selection Prior to Acquisition

When initializing the system, the operator has the choice of selecting the satellites to be acquired and used for navigation or allowing the system to select the satellites. If the operator selects the satellites, the satellite selection task in the Navigation Subsystem has very little to do. The only task is to fill an array with the satellite ID's that the user selected so that their position can be computed and fit coefficients generated. If the operator does not select the satellites then the following steps are gone through to determine what satellites for the system to acquire.

(1) Compute the square of the range for each satellite for which almanac data is included in the data base. This is accomplished by calling the module N2MSVE and calculating the x, y and z components of the satellite position at the current time as input by the operator and then computing the square of the range R**2 according to the equation

$$R^{**}2 = (x_s-x)^{**}2 + (y_s-y)^{**}2 + (z_s-z)^{**}2$$

where x_s, y_s and z_s are the satellites position components and x, y and z are the position components of the user as computed by the coordinate transformation function in the Master Control Subsystem based on the latitude, longitude, and altitude input by the operator.

(2) Eliminate all satellites with range squared greater than the range squared corresponding to a satellite at an elevation of 5 degrees.

(3) Order the remaining satellites from smallest range squared to largest range squared. This corresponds to ordering the satellites according to elevation from highest to lowest.

(4) Select the six satellites with the highest elevation and store in an array in the order of highest elevation to lowest elevation. If less than six satellites have elevations greater than 5 degrees then the six element array is filled with those visible satelites and zeroes are put in the remaining elements.

These tasks are performed in the module N2MSVS.

3.3.4.3.2 Satellite Selection During Steady-State

During steady-state operation, the satellite selection function reasses the visibility of the satellites every two minutes according to the following steps. The control of these tasks is performed in the module N1MSVT.

(1) If the current satellites being tracked were selected by the operator, no tasks are performed, i.e., these satellites will be used regardless of their elevation.

(2) If Master Control requests that a new satellite be added to the constellation, because less than six satellites are currently being tracked, or if Master Control requests that a satellite currently being tracked be replaced because it's elevation is less than 5 degrees or it has been lost from receiver track, then the satellite selection module N2MSVS is called and performs the following:

a. Compute the range squared at two different times for those satellites not currently being tracked and for which an almanac is in the data base. This is accomplished by calling N2MSVE for those satellites not currently being tracked.

b. Eliminate those satellites whose elevations are less than 5 degrees.

c. Determine whether each satellite is rising or setting by comparing the range squared at the two times.

D. Select the rising satellite with the lowest elevation as the replacement satellite. If no rising satellite is visible (elevation greater than 5 degrees), select the highest setting satellite as the replacement satellite.

(3) If a replacement SV is found, N2MSVP is called so that fit coefficients can be computed. Also the initial satellite clock correction based on almanac data

is computed.

(4) The final task of satellite selection during steady state is to compute the range squared for each satellite currently being tracked and determine if the satellite elevation is less than 5 degrees. If a satellite is found with elevation less than 5 degrees, Master Control is informed so that a replacement satellite can be requested the next time the satellite selection function is invoked. This task is performed in the module N1MSVT.

3.3.5 Receiver Aiding Function

In each 2 second Inner Loop time period, Master Control requests Navigation to provide aiding data to be used by the receiver when attempting acquisition or reacquisition of a satellite signal. Navigation provides two distinct types of aiding as follows:

(1) Navigation Aiding - The ranges and range rates computed to aid the receiver are based on the navigation solution, i.e., the estimated user state as output by the Kalman filter together with the computed satellite position and velocity are used to compute range and range rate.

(2) Receiver Self Aiding - The ranges and range rates used to aid the receiver are based on extrapolating the last receiver measurements forward in time to the desired aiding time. This type of aiding is almost totally independent of the

navigation solution. It does depend weakly on the navigation solution through a computation of range acceleration used in the extrapolation process.

Table 3.3-2 Identification of Receiver Aiding Type

SYSTEM CONDITION	TYPE OF AIDING
(1) Initial satellite acquisition	Navigation
(2) C/A Code reacquisition	Self
(3) P code reacquisition prior to navigation filter convergence	Self
(4) P code reacquisition when less than 4 satellites are being tracked	Self
(5) P code reacquisition after filter convergence and 4 or more satellites being tracked	Navigation
(6) New satellite acquisition during steady-state	Navigation
(7) P code reacquisition for filter average measurement residuals greater than 100 1/17 pchip	Self
(8) P code reacquisition for newly acquired satellite whose fit coefficients based on ephemeris data have not yet been computed	Self

The type of aiding used for particular system conditions is identified in Table 3.3-2. The aiding provided to the receiver in either case includes estimates of the following system variables:

(1) Range

(2) Range rate

(3) Clock bias between the user and the satellite

(4) Satellite 1.5 second epoch

(5) User 20 millisecond epoch corresponding to satellite 1.5 second epoch.

The range aiding is in units of 100 nanoseconds, thus the range is divided by the speed of light and multiplied by 1E7 before sending the aiding data to the receiver. Throughout the remaining discussion, range aiding will mean range converted to time units.

The receiver aiding tasks are performed in the module N2MAID except for the computations of range, range rate, and range acceleration which are accomplished in the module N2MRNG using current Kalman filter estimates of the user's state.

3.3.5.1 Navigation Aiding

Under conditions where the navigation filter is converged and is assumed to have a reasonably good estimate of the user state, or under conditions where no measurement

data on a particular satellite is available, navigation aiding is used to assist the receiver in acquiring or reacquiring the satellite signal.

The time for which aiding is required is computed and the module N2MRNG is called to compute range and range rate based upon the filters best estimate of the user's state and the position and velocity of the satellite as computed using the quadratic fit coefficients for the satellite orbit. The atmospheric range delay is added to the computed range and then the range and range rate are expressed in units of 100 nanoseconds and 1.040667 meters/sec respectively before passing the data to the receiver.

The bias between the user clock and the satellite clock is defined in Figure 3.3-4 and is computed from the equation:

$$TB = rb/C + TC + TS$$

whereas rb is the filter range bias state, C is the velocity of light, TC is a constant equal to the initial estimate of user clock bias, and TS is the satellite clock bias. The user to satellite time bias TB is passed to the receiver in units of 100 nanoseconds. The most recent satellite 1.5 second epoch and the corresponding user 20 millisecond epoch are also computed and sent to the receiver.

In the special system mode used for acquiring almanac data from a satellite, the aiding range and range rate

provided to the receiver are set to zero if aiding has been requested for a satellite for which the system does not presently have any almanac data. In this case, the receiver uses a special mode to search all frequencies and times when attempting satellite signal acquisition.

3.3.5.2 Self Aiding

Under conditions where a good receiver measurement has been processed in the past for a particular satellite, and the navigation estimate of user state is suspected to be poor, receiver self aiding is used to estimate the aiding parameters. The range self aiding is estimated by extrapolating the measured pseudo range forward in time according to the equation:

$$RS = TB - PR/C + RDOT * DT + (RA*DT**2)/2$$

where TB is the user to satellite clock bias, PR is the pseudo range count, C is the speed of light, RDOT is the measured range rate, RA is the range acceleration computed in the module N2MRNG, and DT is the time interval over which the measurement is extrapolated. The value of RS is then compared with the estimated range computed in navigation aiding in order to determine the extrapolated range to within 10 milliseconds of the computed range. This insures that the correct number of FTF clock counts have been included in the total estimate of range aiding.

The computation of user to satellite clock bias, satellite 1.5 second epoch, and corresponding user 20 millisecond epoch are computed in the same manner as described in paragraph 3.3.5.1.

3.3.6 Supplemental Functions

Several more minor functions are also performed by the Navigation Subsystem. They are described briefly in the next few paragraphs.

3.3.6.1 Initialization

Whenever the system is commanded by the operator to acquire satellites and compute a fix, the navigation filter state variables and certain system parameters are initialized. The initialization of the position of the user is done in the module N1MSVT which is the first Navigation Subsystem module to be activated. The Master Control Subsystem computes the user's x, y, z earth-centered, earth-fixed coordinates by transformation of the operator's CDU input of his position. The position components of the user state vector is initialized when these values are passed to the Navigation Subsystem. The initial range to the center of the earth is also computed at this time in the event that degraded mode operation is required.

The velocity components of the user's state, the range bias and range bias rate states, and the filter covariance states are initialized in the module N1MINT. The velocity

states and the range bias rate state are initialized to zero. The range bias state is initialized as zero; however, an estimate of the initial user time bias is computed after the first satellite measurement is made by assuming a zero measurement residual and solving the resulting equation for time bias. The resulting equation is given by:

TC = RC/C - 0.02 * (USER FTF-SV FTF) + PR/C-TS

where the variables used have defined previously in sections 3.3.2.1 and 3.3.3.1. This initial estimate of user time bias is then added to the time equivalent of the range bias state whenever the total user time bias is to be estimated.

The diagonal of the covariance matrix is initialized in units of 1/17 pchip but equivalent to the following:

Position Terms = (25Km)**2

Velocity Terms = (8.33 meters/sec)**2

Range Bias Term = (30Km)**2

Range Bias Rate Term = (0.545 meters/sec)**2

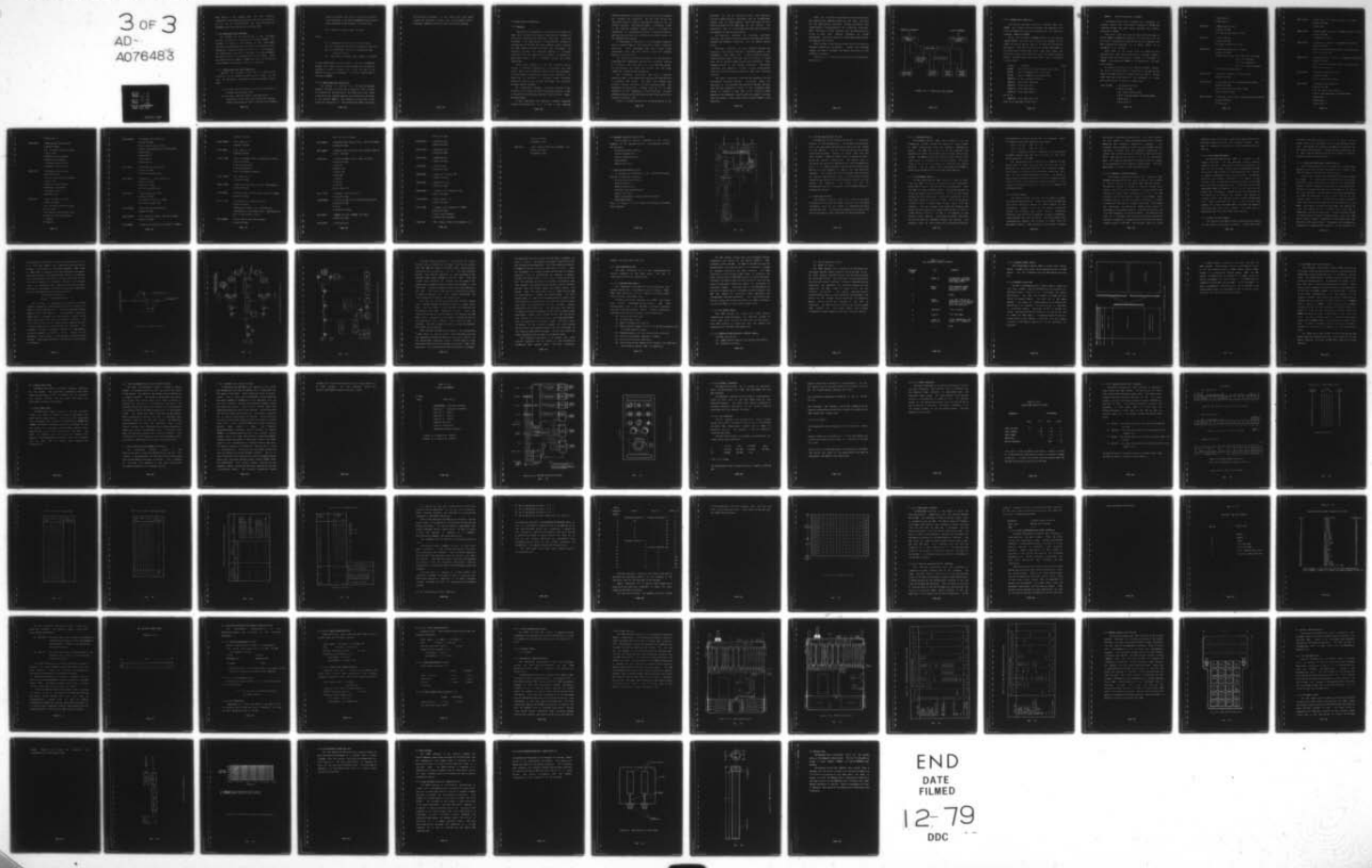
The off diagonal terms are initialized to zero.

The correlation time constants used in the transition matrices, the process noise covariance terms, and the variance of the measurement noise are initialized in the module NIMMIT.

In the case of a system warm start after the system has

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GLOBAL POSITIONING SYSTEMS (GPS). MANPACK/VEHICULAR USER EQUIPM--ETC(U)
AUG 79 F04701-75-C-0181
UNCLASSIFIED SAMSO-SD-TR-79-13-VOL-2 NL

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been placed in the standby mode, the user position components of the state and the user time bias (including TC and rb) are not reinitialized. All other variables and parameters are reinitialized as just described.

3.3.6.2 Spherical Error Estimate

An estimate of the uncertainty in the estimated position of the user is computed in the module N1MNFL. This estimate is based on the average of the measurement residuals and estimated bias errors due to multipath errors, atmospheric correction modeling errors, etc. The average of the measurement residuals is computed in the module N2MAID, and the bias error is estimated to be 10.737 meters. These two quantities are summed in N1MNFL and output to the CDU as the estimated uncertainty in the user's position.

3.3.6.3 Stationary User State Smoothing

Whenever the operator knows that the MVUE will be stationary, he can command a stationary user mode via the CDU. The Navigation Subsystem performs two tasks in this mode.

(1) The user velocity states are reset to zero prior to propagating the state vector.

(2) The user's position state is smoothed by an exponential filter with a 30 second time constant before outputting the data to the CDU via the Master

Control Subsystem. The reset of the velocity states is accomplished in the module N2MNEG and the position state smoothing filter equation is of the form:

$$\underline{P}(t) = \underline{P}(t-dt) + 0.067 * (\underline{PE} - \underline{P}(t-dt))$$

where

$\underline{P}(t)$ = Smoothed user position vector at time t

$\underline{P}(t-dt)$ = Smoothed user position vector at time t-dt

$\underline{PE}$ = Current Kalman filter best estimate of user position vector

dt = Time interval between state updates = 2 seconds

In the implementation of this filter, only the difference between the state and an initial estimate of the state is smoothed in order to preserve the filter accuracy using REAL*4 floating point arithmetic. This task is performed in the module N2MNEG.

3.3.6.4 Range Rate Bias Monitoring

The operator is informed via a CDU warning message whenever the MVUE oscillator has a range bias rate in excess of 10 meters/sec absolute value. The range bias rate state is monitored and compared against the 10 meter/sec threshold in the module N2MAID. The comparison is made only if the filter has converged, i.e., the average measurement residuals

are less than 100 meters. If the range bias rate state exceeds the threshold, a flag is set, and the Master Control subsystem commands the CDU to issue the warning message.

3.4 MVUE EXECUTIVE SUBSYSTEM

3.4.1 General

The Executive Subsystem is a collection of programs and data sets designed to allow the 'Applications' software in the various processors to operate as real-time, concurrent processes. The Applications (or Operational) software is that portion of the GPS real-time software which executes the GPS mission-oriented functions and algorithms. The Executive provides the interface between (1) processor interrupts and the applications software, (2) between the applications tasks, and (3) between calling and called subprograms.

Three major features of the GPS Executive are as follows: (1) Maximum commonality of procedures and data blocks among the different classes of GPS user equipment; (2) High degree of modularity in each Local Executive; (3) Simplicity and security of interfaces among individual modules of the Executive, as well as between the Executive and Applications software.

All operational software (including portions of the Executive) is divided into the following heirarchies, listed in the order of decreasing execution control levels: Tasks, and Subprograms.

A Task represents the smallest software component visible to the Executive, i.e., a task is the smallest

software entity which the Executive will explicitly schedule and dispatch for execution. At any time during the real-time process, a task is considered as being in one of several possible, well-defined states. Futhermore, a task is the smallest software element which is allowed to communicate to the Executive Control via Executive Service Routines and thus explicitly influence the future course of the computational process.

A Subprogram (or Subroutine) is the software component which is below a task in the Executive control hierarchy structure. Since subprograms may call (invoke) other subprograms, they may form several levels of software modules in this structure.

The Executive activates the tasks in all the processor subsystems and subsequently controls the necessary sharing of processor time that must occur in a real-time system. For this purpose, the tasks are divided into two large categories, foreground and background.

The foreground priorities each have a required execution rate, in the sense that they must be executed once in a certain time period. The tasks are ordered into priority classes according to their execution rates. The background priorities use processor time as it is made available by the completion of the foreground. They are ordered according to the desirability that they receive this left-over processor time.

Since it is often necessary for a program module to be

available for use by concurrent tasks, the Executive provides a means by which reentrancy may be accomplished without loss of data integrity. Each concurrent use of a routine accesses its own data area for the routine. The executive's role is to allocate this area and provide the base address to the calling routine.

The Executive performs the processor self-test functions and logs errors arising both from these and other hardware and software conditions, such as memory parity errors.

Processor interrupts are also handled through the Executive. The primary interrupt in the MVUE system is the Fundamental Time Frame (FTF), a 20-millisecond counter. There are other timer interrupts, also occuring at a fixed rate, which perform scheduling and synchronization. These transfer control to the process dispatcher. Additional interrupts are generally involved in error reporting and return to whichever task was executing when the interrupt occurred.

The major scheduling functions are handled in the 20 millisecond interrupt handler. Priorities ready for execution in the upcoming time period are marked, and each task that was supposed to finish in the preceding 20-ms period is checked to see that it did. Control is then passed to the dispatcher, which starts the highest priority task thus marked. This is the key functional element in the Executive.

There are utilities called Executive Service Routines which perform oft-repeated scheduling and other functions for the applications processes. Process activation, stop (deactivation), and waiting are the scheduling functions. Other functions include granting and relinquishing sole access to data sets, passing arguments to called subprograms, providing reentrant linkage where appropriate, and logging error reports.

Also included in the Executive are service routines for software floating point arithmetic , integer and extended integer arithmetic packages, and memory allocation for the different processors.

Figure 3.4.1-1 contains the high-level flow diagram for the executive.

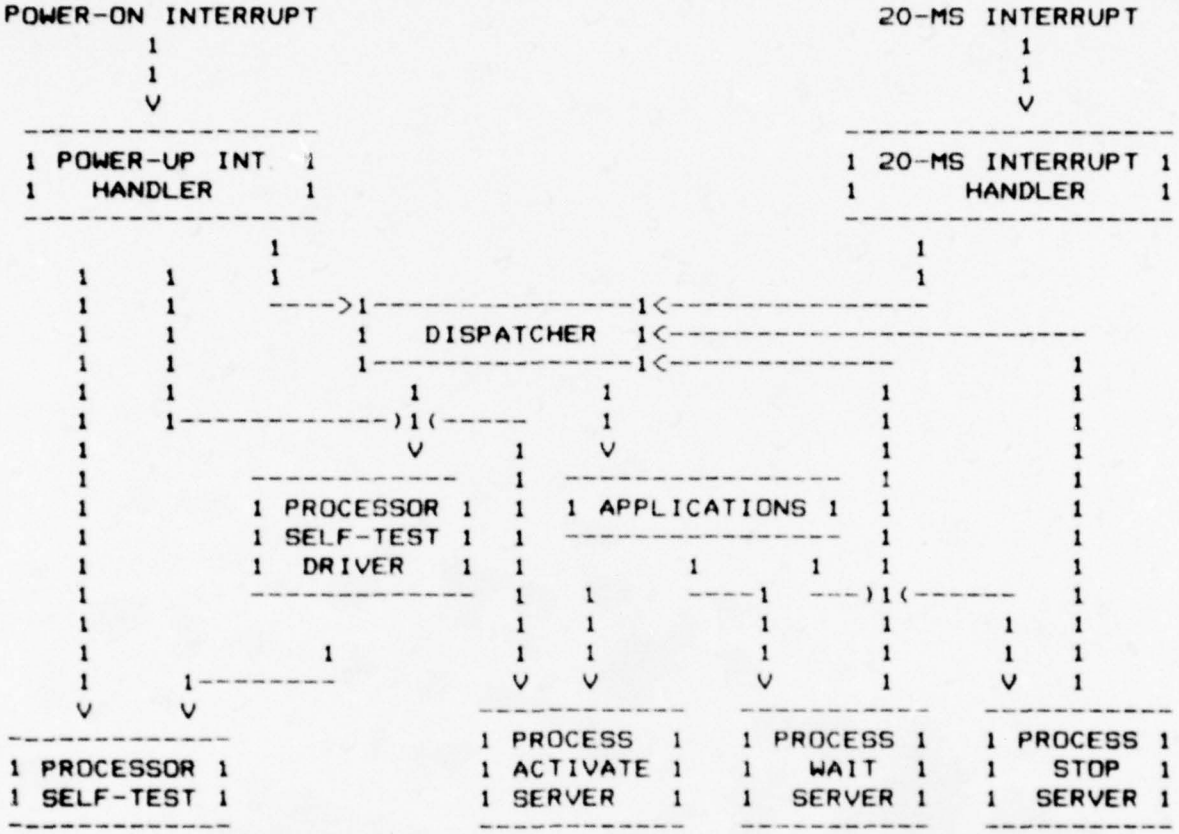


FIGURE 3.4.1-1 EXECUTIVE FLOW DIAGRAM

3.4.2 System Error Reporting

This section describes the error recording data set, XERROR, the format of errors recorded, and contains a list of all the MVUE errors which are reported to the executive programs, X3ERR and X3ERRA.

Errors are recorded in XERROR starting in the location labeled XEBUFS. The first word of each error message is the number of words to follow. That is, if there are three error descriptors, then the first word will contain the number 5. The second word contains the Error Code word (ECW), and third word contains the 20-ms FTF count. The remaining words contain the applicable error descriptors. This is a 28 word circular buffer.

Location	Contents	Word
XEDROP	No. of errors dropped because buffer full	1
XEPTRF	Word in XEBUFS to be filled next	2
XEPTRE	Word in XEBUFS to be emptied next	3
XEBUFS+0	N, No. of words to follow	4
XEBUFS+1	ECW, Error Code Word	5
XEBUFS+2	20-ms FTF count	6
XEBUFS+3	Error Descriptor 1	7
XEBUFS+4	Error Descriptor 2	8
and so on,		
XEBUFS+N	Error Descriptor N-2	4+N

Other error messages follow up to:

XEBUFE Follows last word in XEBUFS

To determine the current contents, the information to consider starts with the location contained in XEPTRE and continues through the word which precedes the location contained in XEPTRF.

The Error Code Word and the descriptors are sent to either X3ERR or X3ERRA as arguments. The first two bits of the Error Code Word are supplied by the error handler, and they indicate the subsystem: 01 is master state; 10 is navigation; 11 is receiver.

When there is not enough room to record all of a reported error, then none of the error is recorded. However, the fact that there was an error dropped is indicated in XEDROP. The contents of XEDROP is incremented by 1 for each error dropped.

A listing of the errors which may be reported follows. The Error Code Word (ECW) is listed first, followed by the name of the module which initiated the error report. On the right hand side a description of the arguments is listed with a description of the error listed first.

0101 X1IPOW	1	Processor self test
	2	20-ms FTF(LSW)
	3	No useful words follow
	4	Error code generated from X2TST/X2TFP
	5	Descriptor 1
	6	Descriptor 2

7 Descriptor 3

8 Descriptor 4

0102 X1IM 1 Memory parity error

2 20-ms FTF(LSW)

3 PC when parity trap occurred

0103 X1II 1 I-bus time out

2 20-ms FTF(LSW)

3 PC when time-out occurred

0105 X1IFS 1 FPAU returned an error status

2 20-ms FTF(LSW)

3 FPAU status word; bits 0 and 4 to 15 unused

bit 1 on, overflow

bit 2 on, underflow

bit 3 on, invalid operand

4 PC of interrupted module

0106 X1IT01 1 No active process in 1-ms priority

2 20-ms FTF(LSW)

0107 X1IT05 1 5-ms prior overrun incomplete last period

2 20-ms FTF(LSW)

3 Ptr to priority of overrun task

4 PC of overrun task

0207 X1IT05 1 5-ms seq. out of order, 5-ms not eq 3 from 20-ms

2 20-ms FTF(LSW)

3 5-ms count

0307 X1IT05
1 5-ms count > 3 count/int seq out of sync
2 20-ms FTF(LSW)
3 5-ms count

0208 X1IT20
1 20-ms update count not = XC0020 (sys out of sync)
2 20-ms FTF(LSW)
3 Update 20-ms count

0308 X1IT20
1 20-ms prior overrun, incomplete last period
2 20-ms FTF(LSW)
3 Ptr to priority(XLEVEL block) of overrun proc
4 PC of overrun proc

0408 X1IT20
1 Background prior overrun, incomplete last period
2 20-ms FTF(LSW)
3 Ptr to priority(XLEVEL block) of overrun proc
4 PC of overrun proc

0109 X1INT2
1 Unwanted interrupt level 2
2 20-ms FTF(LSW)
3 PC of interrupted module

010C X1TST
1 Processor self-test error
2 20-ms FTF(LSW)
3 No of useful words follow
4 Error code generated from X2TST/X2TFP
5 Descriptor 1
6 Descriptor 2
7 Descriptor 3

	8	Descriptor 4
010D X2TST	1	ROM checksum test failure
	2	20-ms FTF(LSW)
	3	No of useful words following
	4	Error code
	5	ROM block start address
	6	ROM block end address
	7	Expected checksum value
	8	Computed checksum value
020D X2TST	1	RAM memory test failure
	2	20-ms FTF(LSW)
	3	No of useful words following
	4	Error code
	5	RAM block start address
	6	RAM block end address
	7	Bad RAM location
	8	Bad RAM value
030D X2TST	1	Basic arithmetic failure
	2	20-ms FTF(LSW)
	3	No of useful words following
	4	Error code
	5	CZC mask for arith/logic test
	6	Value on which CZC applied
	7	(ignore)
	8	(ignore)

010E	X2IPOW	1 Processor self test error
		2 20-ms FTF(LSW)
		3 No. of useful words follow
		4 Error code generated from X2TST/X2TFP
		5 Descriptor 1
		6 Descriptor 2
		7 Descriptor 3
		8 Descriptor 4
0111	X3ACT	1 More than two args passed
		2 20-ms FTF(LSW)
		3 PC of activating task
0211	X3ACT	1 Receiver no. > max receiver no.
		2 20-ms FTF(LSW)
		3 Receiver number
		4 PC of activating task
0311	X3ACT	1 Task already activated
		2 20-ms FTF(LSW)
		3 pointer to process in XPROC
		4 PC of activating task
0113	X3CANC	1 More than two args passed
		2 20-ms FTF(LSW)
0213	X3CANC	1 No. receivers greater than max allowed
		2 20-ms FTF(LSW)
0115	X3REQ	1 Time out on gaining sole access to common

2 20-ms FTF(LSW)

0215 X3REQ 1 No. args not = 1

2 20-ms FTF(LSW)

0116 X3REL 1 No. args not = 1

2 20-ms FTF(LSW)

011A F RQMY 1 No. of arguments does not agree with caller

2 20-ms FTF(LSW)

3 calling program PC

4 Called program PC

5 No. of arguments expected

011D X3TIMM 1 No. args not = 1

2 20-ms FTF(LSW)

021D X3TIMM 1 Modulus not positive value for time request

2 20-ms FTF(LSW)

011E IASHFT 1 Overflow when shifting left, sign bit changed

2 20-ms FTF(LSW)

011F F ritp 1 Floating point interpreter error

2 20-ms FTF(LSW)

3 Status word (B0=div by 0, B1=overflow,
B2=underflow, B3=illegal instr., B4=code error)

4 PC of instruction in error

0120 X3ERRA 1 Error reports have been dropped

2 20-ms FTF(LSW)

	3	No. of errors dropped
0121 EASHFT	1	Overflow when shifting left, sign bit changed
	2	20-ms FTF(LSW)
0221 EASHFT	1	Absolute value of shift count greater than 15
	2	20-ms FTF(LSW)
0126 EXINT	1	Divisor greater than or equal to 2**16
	2	20-ms FTF(LSW)
	3	(ignore)
	4	MSW of arg
	5	LSW of arg
	6	EXINT WP
	7	(ignore)
	8	(ignore)
	9	User WP
	10	User return PC
012c X1INT7	1	Unwanted interrupt level 7
	2	20-ms FTF(LSW)
0158 M2RMOD	1	Invalid SV status for RCVR mode definition
	2	20-ms FTF(LSW)
	3	SV ID
	4	Invalid SV status
0196 R2PCK	1	RMSFLG not zero (M2DBPR not ready)
	2	20-ms FTF(LSW)
0197 R1PIN	1	Overflow error

		2 20-ms FTF(LSW)
0297	R1PIN	1 Overflow error
		2 20-ms FTF(LSW)
0397	R1PIN	1 Overflow error
		2 20-ms FTF(LSW)
0497	R1PIN	1 OVERFLOW error
		2 20-ms FTF(LSW)
0198	R1RM0	1 Slope >=7fff
		2 20-ms FTF(LSW)
0298	R1RM0	1 Slope <=5 or slope >=80
		2 20-ms FTF(LSW)
0398	R1RM0	1 Negative divisor
		2 20-ms FTF(LSW)
0498	R1RM0	1 Invalid 11/12 frequency flag
		2 20-ms FTF(LSW)
01C4	R2XSPM	1 Pass counter >= 4
		2 20-ms FTF(LSW)
01CC	ATAN2	1 Illegal input arguments to ATAN2
		2 20-ms FTF(LSW)
		3 first input argument
		4 second input argument
01CD	COS	1 Abs. value of COS input argument > 16

2 20-ms FTF(LSW)

3 argument value

O1CE SIN 1 Abs. value of SIN input argument > 16

2 20-ms FTF(LSW)

3 argument value

4.0 HARDWARE SUBSYSTEM DESCRIPTION

The following is detailed breakdown of the various segments of the hardware portion. The breakdown includes the following:

Receiver/Processor Section

Control Display Unit

Vehicle Installation Kit

MVUE Antenna

Battery Pack Unit

4.1 RECEIVER/PROCESSOR SECTION

As pointed out previously the Receiver/Processor Section includes the following:

RF Pre-Conditioning Section

Receiver Section

Data Processing Unit

External Input/Output Module

Master Oscillator

MVUE Instrumentation System Interface Module

MVUE POWER SUPPLY

Refer to Figure 4.1-1 for a Receiver/Processor Functional Block Diagram.

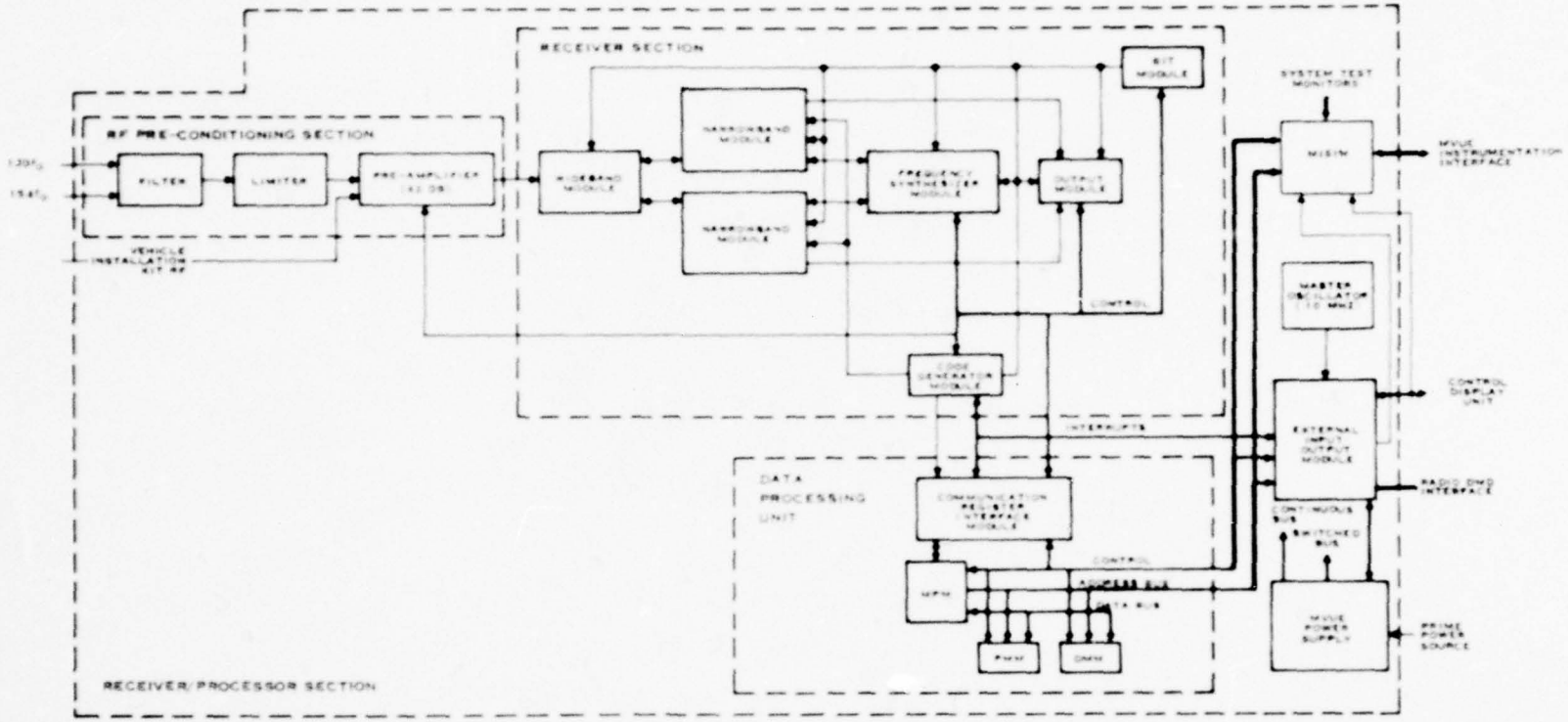


Figure 4.1-1. Receiver/Processor Functional Block Diagram

4.1.1 RF PRE CONDITIONING SECTION

The Receiver RF Pre-Conditioning Section is connected directly to the antenna ports. The hardware provides gain (42 $\pm$ 1 dB) and establishes the Noise Figure for the system (5.0 dB nominal). The RF Pre-Conditioning unit accepts inputs from two areas. One set of inputs come from the local antenna (154Fo and 120Fo) which correspond to the L1 and L2 SV carriers respectively. The second input is sourced by the Vehicule Installation Kit (VIK) Pre-Amplifier which is in essence hardware like the RF Pre-Cinditioning Section, but this hardware is remote from the Receiver/ Processor. This signal from the VIK Pre-Amplifier thus does not require amplification, and, it therefore must only be routed through the RF Pre-Conditioning Section when the user desires VIK operation. The output of the RF Pre-Conditioning Unit is forwarded to the Wideband Module of the Receiver Section.

4.1.2 RECEIVER SECTION

The Receiver Section under the control of the Data Processing Unit provides the means to extract the necessary information from the SV signals to determine the users position and time. The following paragraphs will delve into the various modules that constitute the Receiver Section.

4.1.2.1 WIDEBAND MODUULE

The Wideband Module (WBM) down converts L1 or L2 frequencies to 18Fo + 10 MHz (IF) using L.O. inputs (136Fo or 102Fo respectively) from the Frequency Synthesizer Module. The WBM has a gain of 43 dB (nominal) 3 dB bandwidth of 15 MHz, and contains the first AGC loop for the system. The WBM also receives a Built-In-Test Module test input which is utilized for fault isolation. This test input is on L1 or L2 carrier to exercise the entire Receiver. The IF signal that is generated by the WBM is buffered and forwarded to the two Narrowband Modules.

4.1.2.2 NARROWBAND MODULES

The Narrowband Modules (NBM) receive IF (18Fo +10 MHz) from the WBM. In its first function it mixes (correlates) either NRZ P-code or C/A code from the code generator, with the WBM IF down converted signal. The module proceeds to filter and amplify the correlated IF. The IF is then routed through two down conversions. The first involves an L.O. of 17Fo which yields an IF of Fo + 10 MHz. Prior to the second conversion the Fo + 10 MHz signal is power split into two channels. The two signals thus formed are routed to the second conversion which is accomplished with an L.O. of Fo + 10 MHz and an L.O of Fo + 10 MHz + 90 degrees in two distinct mixer devices. From these two mixers, the error (E) and the data (D) baseband signals are derived. The absolute value of the E channel and the absolute value of

the quadrature D channel are derived. A correlation output is formed utilizing the equations shown below.

$3(|E| + 1/2\ |D|)$ FOR $|E| > |D|$

$3(|D| + 1/2\ |E|)$ FOR $|D| > |E|$

This correllation output corresponds to the code phase alignment response when the code is injected at the first mixing operation in the NBM.

The appropriate sum is routed out by comparator driven select logic to control the 2nd AGC function and to be monitored by the Output Module as the correlation voltage. The E signal is buffered out as the Phase Locked Loop (PLL) error to the Frequency Synthesizer Module. The signal is also differentiated and buffered out as the Frequency Locked Loop (FLL) error to the Frequency Synthesizer Module. The D signal is filtered to extract 50 Hz data to be sampled by the Output Module.

4.1.2.3 OUTPUT MODULE

The Output Module receives the correlation voltages from the Narrowband Modules. These correlation voltages are digitized in the Output Module to allow peaking of the correlation voltage. Prior to the digital conversion process the processor may invoke various integration intervals over which the correlation voltage is integrated. These include 1 ms, 5 ms, and 20 ms. The Output Module also integrates and samples the filtered D signal from the Narrowband Module. Under processor control data is sampled

and stored in the Data Processing Unit. The Output Module can also perform a range rate measurement which involves measuring the Frequency Synthesizer frequency. The processor merely enables a counter to count between two key time marks. A signal from the Frequency Synthesizer is enabled and counted during the interval defined by the time marks. When the receiver section is in an SV acquisition mode, the Frequency Synthesizer frequency except for system errors represents an SV's doppler shifted signal. Thus this measurement is termed a range rate measurement.

4.1.2.4 FREQUENCY SYTHESIZER MODULE

The Frequency Synthesizer Module (FSM) comprises that hardware necessary to provide local oscillator (L.O) signals to various portions of the system (WBM, NBM, OM, and etc). The Receiver system is termed a coherent system which implies that all LO's are frequency or phase locked to the received SV signal when operating on an SV. The FSM receives both the FLL and PLL signals from the NBMs. Under processor control, the FSM can be set to function in either a frequency locked mode or a phase locked mode. These modes are determined by monitoring system errors which is performed by the system processor. The FSM can also be set to a fixed frequency via a D/A converter. The processor can load in a frequency word and select the D/A converter to provide a voltage to a Voltage Controlled Crystal Oscillator (VCXO) resident in the FSM. The processor, when in a fixed

frequency mode, can invoke a range measurement operation in the Output Module to verify the frequency setting. This type of operation is involved in a VCXO calibration and in VCXO set.

4.1.2.4 CODE GENERATOR MODULE

The Code Generator Module (CGM) is involved in two primary functions. The CGM generates various codes on command by the DPU. These codes include the P-code and C/A code for all SV types. These codes are generated with FSM clocks which implies that all codes generated are coherent or doppler compensated by the received signal. The DPU may shift the code (forward or backward) with respect to the received code to peak the Correlation Voltage from the NBM which receives the generated code. The CGM can also provide range measurement information. After having acquired and peaked the Correlation Voltage on some P-code the DPU has the capability to measure the elapsed time between an internal 20-ms time mark and a 20-ms doppler shifted data clock. When incorporated with the Z count derived from sampled 50-Hz data, the measurement represents the range to an SV with some time bias included. The time bais is associated with the users chosen time interval.

4.1.2.6 BUILT-IN-TEST MODULE

The Built-In-Test Module (BITM) generates test signals for the system to allow fault isolation. The DPU may invoke

the BITM to generate either an L1 or an L2 pseudo replica signal which are modulated by an X1 code and Barker Code only. The signals are routed to the WBM to be inputted like RF from the antenna ports. The DPU proceeds to activate an X1 code from the CGM and acquires this signal in a similar fashion to that of acquiring SV's.

4.1.2.7 RECEIVER OPERATIONAL CHARACTERISTICS

The following discussion will summarize in a high level manner the various functions performed by the receiver now that the modules have been discussed briefly.

The receiver acquires and coherenthy tracks an incoming SV signal. For signal power to be detected, the receiver must first of all be aligned by the DPU to the appropriate doppler shifted frequency associated with the desired SV. The DPU is provided with some prior knowledge as to which SV's are available. The DPU arms the Frequency Synthesizer such that the VCXO within is set to within 125 Hz of the desired signal carrier. The DPU then activates the CGM to inject the C/A-code associated with the desired SV into the NBM's. Each NBM is injected with the same code, however the codes are spaced by 1/2 a C/A-BIT cell or chip. One is termed Early while the other Late. The DPU activates the OM to digitize the Correlation Voltage signals from each NBM after having allowed integration of the signals over some DPU controlled time interval. The samples thus obtained are compared to a predetermined threshold. If the threshold is

not exceeded the DPU alters the CGM code phase by 16/17 th's of a chip and repeats the integration and digitization process. This process is continously repeated (1089 times or 1023 chips if required) until the threshold is exceeded. When the threshold is exceeded the DPU invokes a different code shifting algorithm, which involves code shifts of 1/17 of a chip, to peak the Correlation Voltage to a maximum value. In performing the peaking function the processor utilizes an enhancement technique (Early-Late Alqorithm) which is represented by the following equation:

Discrimination Function

$$\frac{L - E}{L + E} = \text{Correlation Factor} = r$$

This function is represented in Figure 4.1.2-1 where complete alignment is repressented at the zero crossing (or center) of the response curve. The DPU accumulates several samples of the code phase vs discriminator value and establishes a straight line approximation value to the center linear portion of the discriminator function. The code phase is then set to a phase position nearest the zero crossing establishing a coarse centering of the code. This alignment technique, hereafter refered as code peaking, yields an alignment to within $\pm$ 50 ns. Figure 4.1.2-2 represents those areas in the Receiver involved in this process. These areas form what is termed the code loop when in operation.

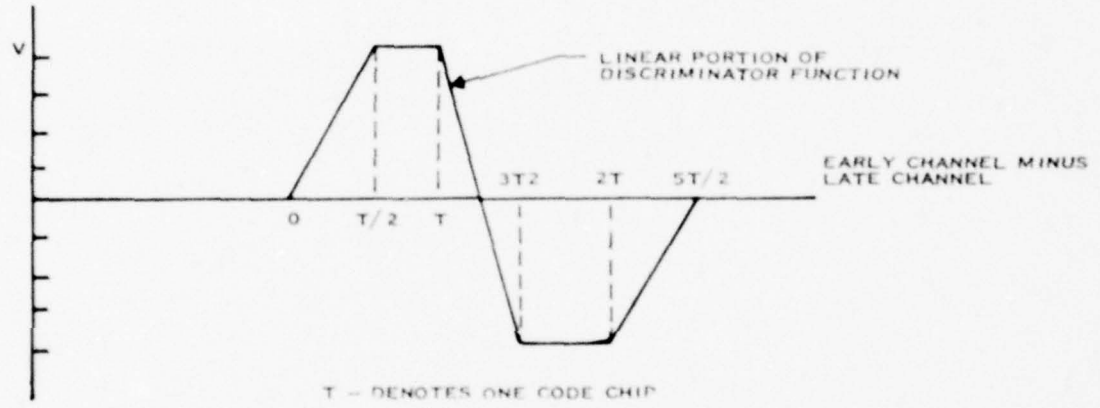


Figure 4.1.2-1. Correlation Factor (r)

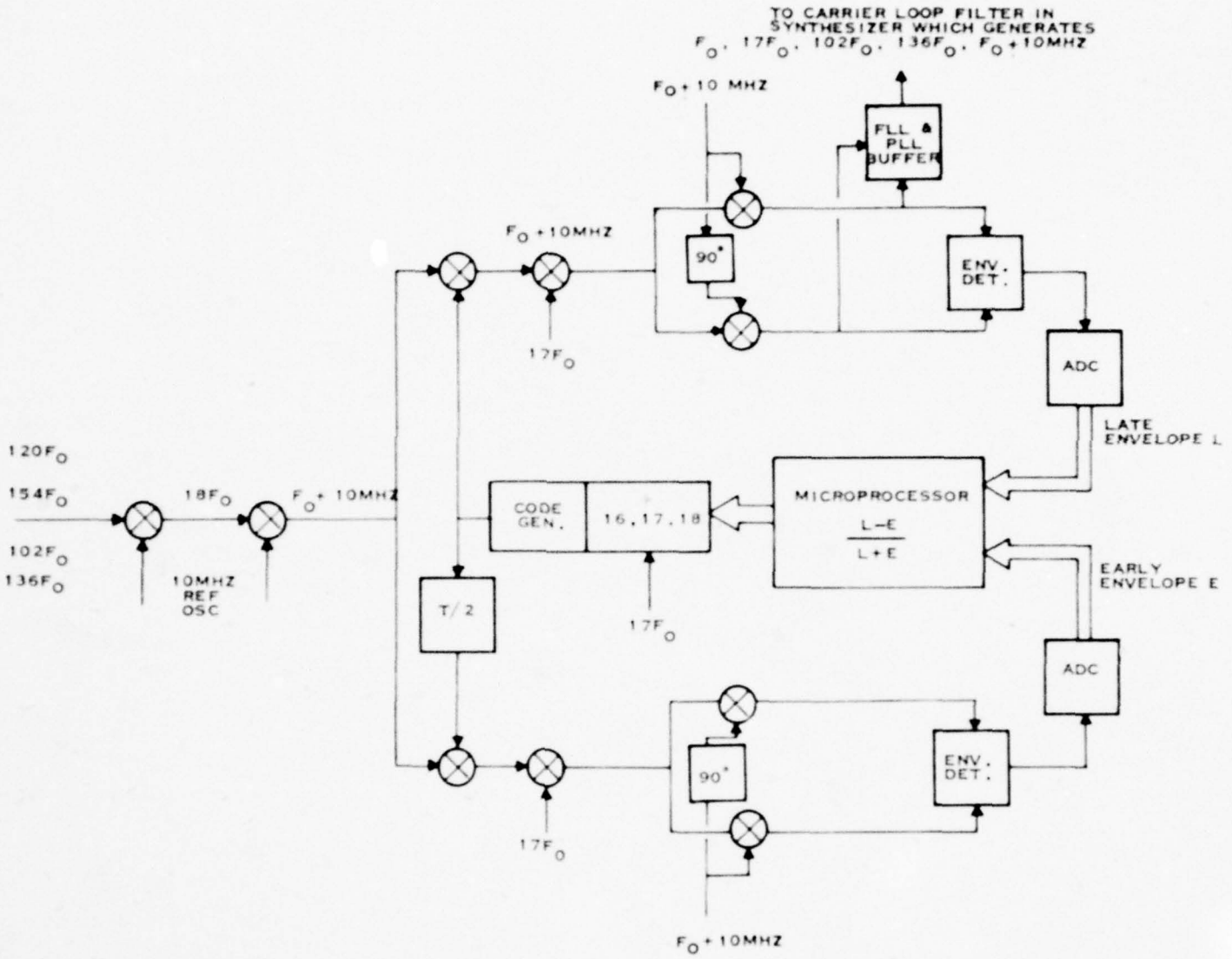


Figure 4.1.2-2. Functional Diagram of Code Loop

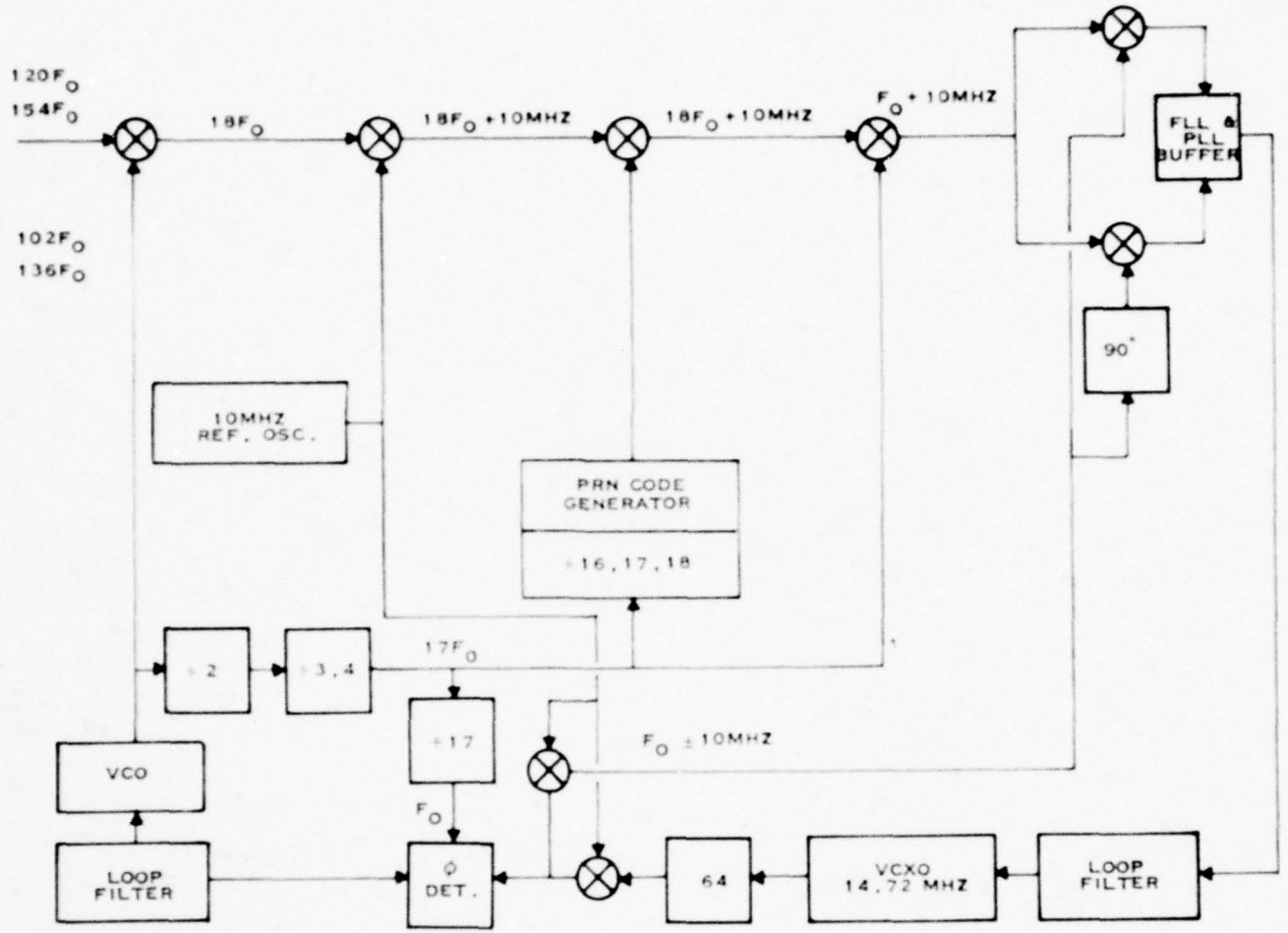


Figure 4.1.2-3. Functional Diagram of Carrier Loop

Once the coarse centering is accomplished the Costas Carrier Loop is closed in an FLL mode. Thus the FLL signals from the NBM are routed to the FSM'S VCXO. Electronically the loop error is nulled to ± 15 Hz. The DPU performs another code peaking operation to take advantage of the enhanced signal level created by the FLL mode. The DPU follows this operation by invoking the PLL mode in the Costas Loop by enabling the PLL signal from the NBM to the FSM'S VCXO. The DPU proceeds to perform one last peaking of the code. The carrier loop which is invoked at this point is shown in Figure 4.1.2-3. This diagram emphasizes the various modules involved in the carrier loop.

The DPU has at this point acquired C/A code in phase lock. The DPU proceeds to determine where to sample 50-Hz data. The C/A Epochs (1-ms intervals) are monitored for coincidence with data transition points. Once the transition points (bit cell boundaries) are defined, the CGM Data Clock is aligned such that data is sampled at the end of a typical bit cell interval. Once this Bit Sync is attained, the DPU decodes the data such that the Handover Word (HOW) can be obtained.

With the HOW, the CGM can be armed to the appropriate P-code phase to acquire P-code. Since the data clock Bit sync operation aligned the data clock to within ± 50 ns of the appropriate transition point, the DPU loads a P-code phase associated with a future data clock point. When that particular clock pulse arrives the P-code shift is enabled.

This operation will thus yield a P-code phase alignment to within ± 50 ns. The processor proceeds to peak the P-code with the Early-Late algorithm. This final peaking yields an alignment to within 1/17 of a P-code chip (~ 6.0 ns). With the alignment of P-code, the DPU now performs the ranging operation. This is accomplished by enabling a doppler shifted 17Fo signal (17Fo (1 ± V/C)) to a counter within the CGM. The interval over which this signal is counted is that time between a Bit Synced Data Clock and a 20-ms Time Mark derived from the 10-MHz Master Oscillator within the system. When this particular count is summed with the HOW the resulting sum is termed the pseudo-range. The term pseudo-range is used since the measurement includes a user clock bias which is brought about by the fact that the 20-ms Time Marks are asynchronous to the coherent signals generated by the Costas Loop. The code phase, also, may not correspond to perfect alignment at the time the pseudo-range measurement is made, since, the DPU control over the CGM can only resolve to 1/17 of a P-chip. The range measurement, thus, is subjected to a "vernier range" correction which corresponds to the differnce between the zero-crossing derived by the code-peaking operation and the code phase at the time the measurement was made. The DPU thus stores the range information and proceeds to subsequent tasks.

The preceding discussion is a general one, other receiver sequences can be invoked by the processor to accomplish other similar tasks. The basic functions,

however, are those described here.

4.1.3 DATA PROCESSING UNIT

The Data Processing Unit is the computational and control component for the MVUE system. The DPU is subdivided into the following modules.

4.1.3.1 MICROPROCESSOR MODULE

The components of the MPM are the microprocessor unit, address decode logic, programmable read-only memory (PROM), PROM power switching circuitry, random-access memory (RAM), clock circuitry, and buffer logic.

The basic functional component of the MPM is the single chip, 16-bit, Integrated-Injection-Logic, SBP 9900 microprocessor unit. The SBP 9900 is software compatible with the TI 990 minicomputer family. General operational characteristics the microprocessor unit exhibits are:

(A) 16-bit instruction word

(B) 2.75 MHz basic clock

(C) Memory-to-memory architecture

(D) Memory address capability for up to 32,768 sixteen-bit word or 65,536 eight-bit bytes

(E) Separate memory, I/O, and interrupt bus structure

(F) Use of 16 work-space registers in memory

(G) Up to 16 prioritized interrupts

(H) Instruction-driven communication register unit (CRU) and direct memory address (DMA) I/O capability

The MPM address decode logic performs memory address recognition and decode for the memory (PROM or RAM) contained within the MPM. The PROM on the MPM provides the microprocessor unit with 512 words of nonvolatile storage for program instruction and data constants. The PROM switching circuitry minimizes MPM power by disabling the power source from all MPM PROM devices not being addressed. The RAM on the MPM provides the microprocessor unit with 256 words of high-speed read/write memory for allocation as work-space memory. The buffer logic on the MPM memory bus provides the mechanism for information transfer between the MPM and memory for instruction fetch operations and storage/data retrieval operations. The instruction-driven CRU bus, along with the microprocessor unit DMA I/O feature, provides the MPM with input/output capabilities.

4.1.3.2 DATA MEMORY MODULE

Each DMM provides the system with 4,096 words of random-access read/write memory for temporary storage of 17-bit data words (16 bits for data and 1 bit for parity). Each DMM contains a single-port data and address bus compatible with the MPM local memory bus.

4.1.3.3 COMMUNICATIONS REGISTER INTERFACE MODULE

The CRIM consists of:

(A) Communication register unit decoder and buffers

(B) Interrupt circuitry

(C) Parity generator/checker

(D) Reset circuitry

The CRIM decodes bits 3 through 5 of the address bus into eight register select lines for use by any CRU device. The other address and CRU control lines are also buffered for use by CRU devices. The interrupt circuitry synchonizes the interrupt stimuli, provides interrupt masking/clearing capability, and generates the interrupt request and code signals for the MPM. (refer to Table 4.1.3-1 for the Interrupt priorities). The parity generator/checker performs parity checks on read operations and generates the parity bit for storage during operations to read/write memory. Parity errors are signaled to the DPU as interrupts. The reset circuitry receives the various system reset stimuli (e.g., from power supply) and provides corresponding reset signals to the other processor modules.

TABLE 4.1.3-1
DPU INTERRUPT PRIORITY RANKING

INTERRUPT LEVEL	TYPE	COMMENTS
0	POWER ON	NON-MASKABLE INTERRUPT INVOKED BY POWER GOOD FROM POWER SUPPLY
1	PARITY ERROR	CRIM GENERATES CHECK PARITY ON ALL RAMS READ/WRITE CYCLES
2	--	SPARE
3	MEMORY TIME-OUT	LOCAL BUS TIME OUT IS GENERATED BY CRIM ANYTIME MORE THAN 4 WAIT STATES OCCUR ON LOCAL BUS
4	1MS EPOCH	1 MS C/A COPCH
5	5 MS TM	5 MS TIME MARK
6	20 MS FTF RCVR LRU	20 MS FUNDAMENTAL TIME FRAME (FTF) INTERRUPT
7	_____	SPARE

4.1.3.4 PROGRAM MEMORY MODULE

The Program Memory Module (PMM) is a Read Only Memory module. 16,384 16 bit words can be addressed within the PMM module. The unit interfaces onto the MPM address and data bus.

4.1.3.5 MEMORY ALLOCATION

The DPU is implemented with a memory paging capability such that greater than 32,768 addresses are available for addressing space. Figure 4.1.3-1 illustrates the memory partitioning. The lower 8K of memory is termed the root section of program memory. The next 16K is the paged segment. Two pages of program memory can be enabled for addressing in this segment. The following 6K is dedicated to scratchpad memory. Addresses 30,720 to 32,000 are unused. Addresses 32,000 to 32,768 are utilized by the MPM for PROM and RAM memory. The memory paging function is accomplished via CRU commands to the EIOM. With this paging function, a total memory capacity of 47,872 addresses are available.

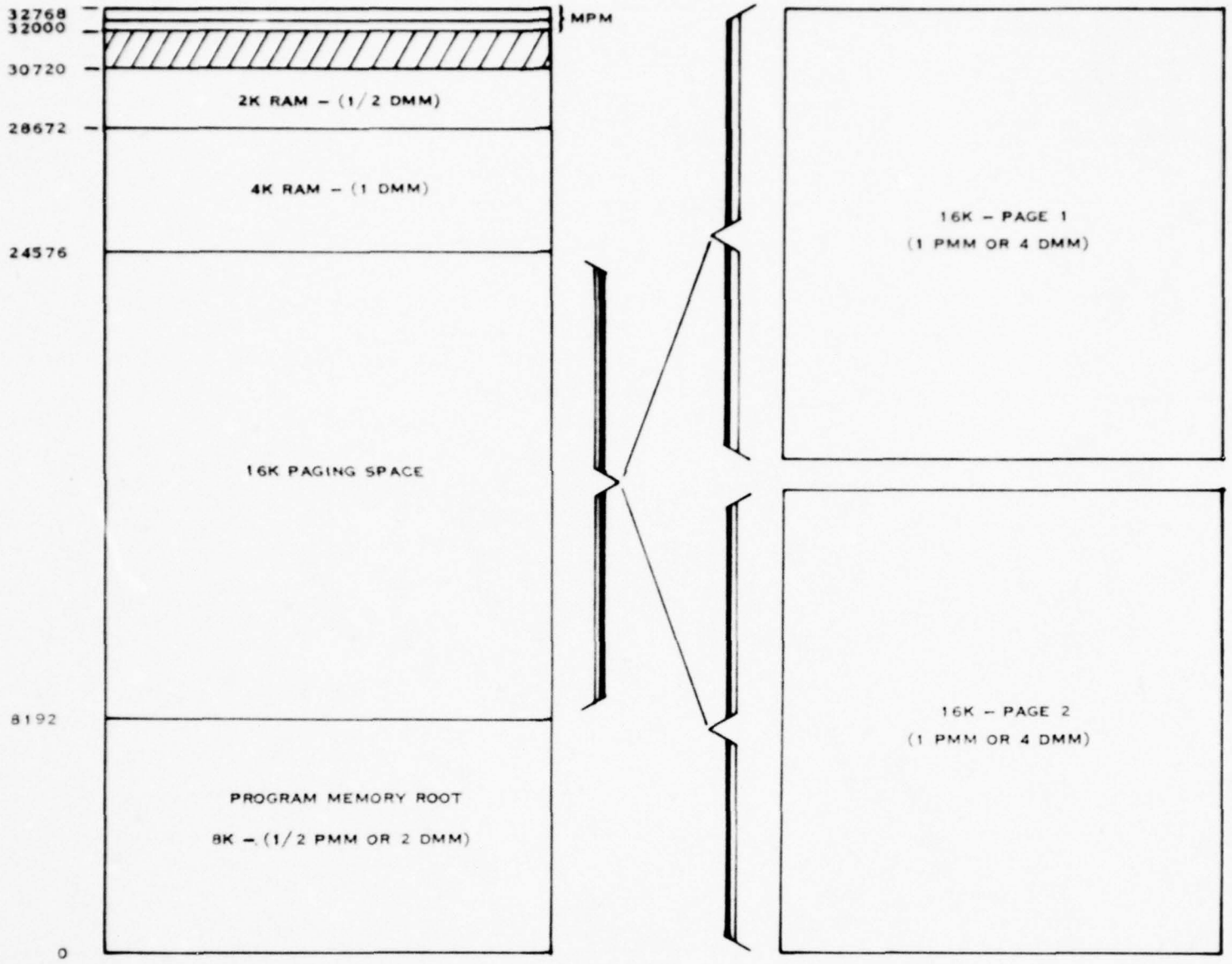


Figure 4.1.3-1. MVUE Memory Paging (2 pages)

The MVUE system is avaivable in two types, the RAM and PROM systems. These systems, as also illustrated by Figure 4.1.3-1, are either strictly a Data Memory Module (DMM) system or a combination Program Memory (PMM) and DMM system. The RAM system is composed of 12 DMM's with one module programmed for 2K utilization. The PROM system is composed of three PMM's and two DMM's. One of the DMM's is again programmed for 2K utilization. One of the PMM's (the Program Memory Root) is programmed for 8K utilization while the other two constitute the two 16K pages.

4.1.4 EXTERNAL INPUT/OUTPUT MODULE

The External Input/Output Module (EIOM) functions as the primary interface with external devices and provides the system with unique system functions to accomplish various tasks. The EIOM provides interface signals to the CDU and the Digital Message Device. It generates key system clocks and time marks from the systems Master Oscillator. Power supply control emanates from the EIOM when a user desires to set the unit to STANDBY, WARMUP, and the ON modes. Included in the EIOMs implementation is a time keeping circuit (Digital Counter) which allows the system to keep track of elasped time to a resolution of 20 ms while in a STANDBY mode or while in WARMUP. When coming out of a STANDBY situation the DPU can read the elapsed time which allows an update of time for the reacquistion process. When in a WARMUP situation the timer is monitored for the 13.66 min point. At this instant power is enabled to the entire system, as the WARMUP mode is non-operating limited power mode. As power is enabled a level 0 interrupt is issued to the DPU to initialize the system into the appropriate state.

The EIOM also allows the DPU to select the appropriate memory page for program executions. This capability allows memory capacity to exceed the SBP 9900s capacity of 32,768 addresses.

4.1.5 MASTER OSCILLATOR

The Master Oscillator is a 10 MHz frequency reference for the system. The oscillator possesses a short term stability less than 2×10^{-9} (1σ) over a 10 sec interval. The signals derived from the Master Oscillator are distributed throughout the system.

4.1.6 MVUE POWER SUPPLY

The MVUE Power Supply converts a 24 VDC (nominal) signal from either a battery or a 24 volt generator into eight distinct power buss'es. The buss'es are subdivided into switchable and continous busses. While in WARMUP and STANDBY, the MVUE's switchable busses are inhibited to set the system to a low power consuming mode. While in this mode only key circuits will be set to the "ON" mode. The EIOM, for example, will have only the standby timer powered. Scratchpad memory associated with the processor will be kept "ON" to retain data required for reacquisition.

4.1.7 MVUE INSTRUMENTATION SYSTEM INTERFACE MODULE

The MVUE Instrumentation System Interface Module (MISIM) is the means by which a user can monitor the status of the system. The status of the system can be outputed by a number of methods. The system is implemented with analog and digital test points which are either buffered or selected for monitor on a multiplexer test point. The available analog test points are inputted into a multiplexer such that any one can be made available thru a multiplexer buffer. The MISIM also makes available the Maintenance Panel interface which allows the user to intervene with processor execution as the need arises. The MISIM also makes available two other key interfaces. One is the Control Display Unit interface which allows actuation of these lines via the instrumentation port. The second is the MVUE Instrumentation System (MIS) recording interface. This interface port allows dumping of key system parameters which are stored in RAM memory during normal system operation.

4.1.8 RECEIVER/PROCESSOR HARDWARE INTERFACES

The operational software resident in the Receiver/Processor drives all hardware within the unit. All control is accomplished via the CRU structure associated with the SBP 9900 at the heart of the DPU. Thus, software by utilizing the repetoire of CRU type instructions activates and monitors all hardware activity.

4.1.8.1 INTERNAL CRU SYSTEM STRUCTURE

In employing the SBP 9900's CRU capability, the system was implemented such that the address bus is subdivided into four major 4 bit fields. These fields are the R, M, B and L fields. The R field bits are the MSB's, which determine what major segment of hardware is to be addressed such as one of N receiver section since some GPS systems include more than one receiver. Table 4.1.8-1 defines what each state associated with the R field defines. The M field bits are the next lower order three bits. This field is reserved for a specific module within a receiver. The B field bits are utilized to define a Byte of seven bits within a module while the L field, the three LSBs, are utilized to define a specific latch within a Byte. The Receiver Hardware/Software Interface Control Document TI Drawing 2009817 is a detailed description of the receiver control signals while the EIOM Specification Drawing No 2009714 contains those CRU operation associated within the EIOM. Figure 4.1.8-1 represents this interface from a high level. Not shown in diagram is the CRIM which decodes the R field of the address bus. The decodes are designated as CRR, and serve as enables to various hardware segments. The M, B, and L fields are then routed to the various hardware modules along with the other key CRU signals (CRUCK, CRUOUT, DATA, and CRUIN DATA). The control signals required by the Wideband Module and the two Narrowband Modules are decoded in the Output module. The Frequency Synthesizer module

decodes the L field while depending on the Output Module for B field decodes. The Code Generator Module and Built-In-Test Module decode the B and L fields.

TABLE 4.1.8-1

R FIELD ASSIGNMENTS

R Field State	Description
0	CARD READER or 733 data terminal
1	Receiver 1 (Only One For MVUE)*
2	Receiver 2 (Spare)
3	Receiver 3 (Spare)
4	Receiver 4 (Spare)
5	EIOM CRU Space **
6	Built-In-Test Module
7	Maintenance Panel Interface

* Refer to TI Drawing No. 2009817

** Refer to TI Drawing No. 2009714

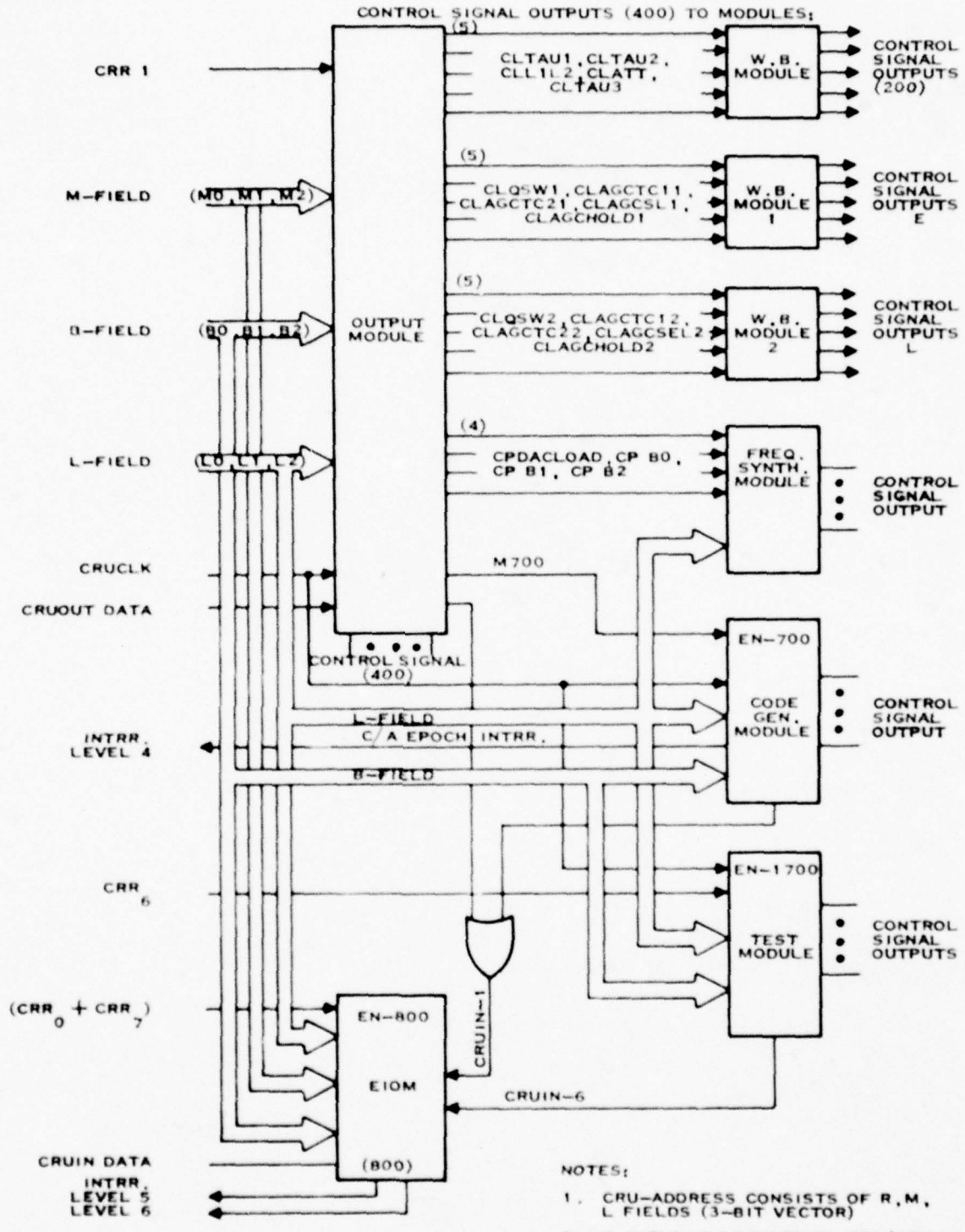


Figure 4.1.8-1. GPS MVME CRU Interface Diagram

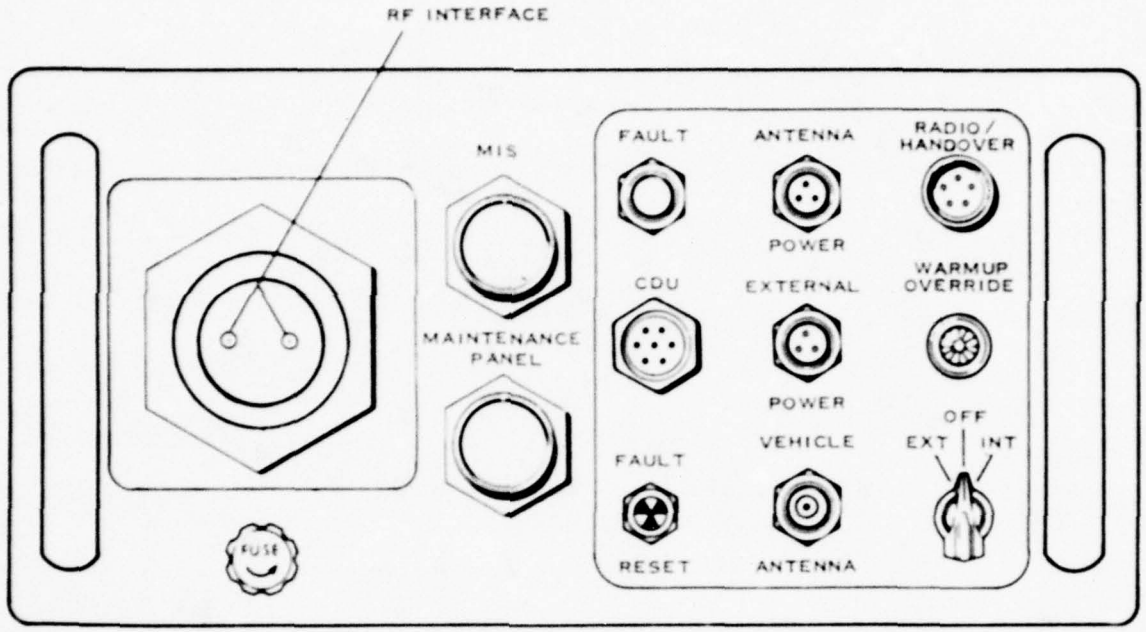


Figure 4.1.8-2. MVUE Top View

4.1.8.2 EXTERNAL INTERFACES

The Receiver/Processor has a variety of interfaces which include operator, RF, Power, CDU, Radio/DMD, VIK, and MIS Interface.

The Operators Interface to the system is illustrated by Figure 4.1.8-2, which is the TOP COVER VIEW of the Receiver/Processor. The MVUE Users Manual in Appendix A provides a detailed description of the various controls associated with this operator interface

4.1.8.2.1 RF INTERFACE

The RF Interface for the Receiver/Processor includes two RF inputs which correspond to the L1 and L2 (1575.42 MHz and 1227.6 MHz respectively) signals from a number of satellite vehicles. The typical L1 and L2 signals is characterized below

The Receiver/Processor is designed to operate with the signal levels specified below

	P(min)	(max)	C/A(MIN)	(max)
L1	-163 dBw	130 dBw	-163 dBw	130 dBw
L2	-166dBw	130 dBw	N/A	

Link 1 (L1) Signal

The transmitted center frequency of the L1 signal is 1575.42 MHz.

Doppler offset due to SV motion in approximately ± 4.8 KHz and doppler due to vehicular motion of 25.0 m/sec is ±0.131 KHz, for a total doppler variation of 9.9 KHz.

The in-phase and quadrature components of the L1 carrier will be

PSK modulated (±90 degrees) by the PRN P-CODE modulo two added to system data and the PRN C/A modulo two added to the same system data, respectively.

Link 2 (L2) Signal

The transmitted center frequency of the L2 signal is 1227.6 MHz.

Doppler offset due to SV motion is ± 3.7 KHz and doppler due to vehicular motion of 25.0 m/sec is ± .102 KHz, for a total of 7.6 KHz.

The L2 carrier are PSK modulated (± 90 degrees) by the PRN P code modulo two added to the system data or the PRN C/A coded modulo two added to the system data.

4.1.8.2.2 POWER INTERFACES

The Power Interfaces to the Receiver/Processor includes two input connectors. One connector, which is refered to as the External Power connector, is associated with the vehicular power modes. The specification for a typical source is characterized in Table 4.1.8-2. The EXT/INT switch on the Receiver/Processor top cover must be set to EXT to function in this mode. The second connector is on the bottom surface of the Receiver/Processor. The side opposite the Top Cover

TABLE 4.1.8-2

PRIME POWER SPECIFICATIONS

PARAMETER	REQUIREMENT			
	MIN	TYP	MAX	UNITS
INPUT VOLTAGE	20	24	30	V
INPUT CURRENT		2.50	3.75	A
INPUT POWER		60	75	W
RMS RIPPLE			1.0	V
RIPPLE FREQUENCY			500	HZ

This input is from the Battery Pack which contains Lithium or Nicad batteries generating DC power at a nominal voltage of 24 volts. In order to function from the battery mode the EXT/INT switch must be set to the INT mode.

4.1.8.2.3 CONTROL DISPLAY UNIT INTERFACE

The Control Display Unit (CDU) Interface is composed of power signals and logic signals. The CDU derives its power from the Receiver/Processor power supply. The power busses routed to the CDU include +5 VDC and -12 VDC. The logic signals utilized are those involved in serial transfers to and from the CDU. The Receiver/Processor controls the transfers in both cases, that is to say that, the Receiver/Processor clocks data to the CDU as well as clocking data out. The signals involved are those listed below.

A) CDUDIN - The serial data line utilized to send data to the CDU.

B) CDUCKIN - The clock associated with sending data on the CDUDIN line.

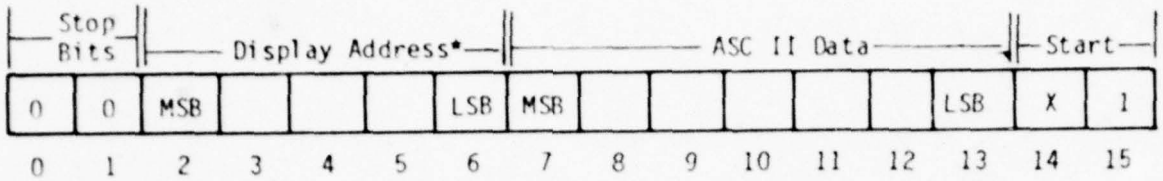
C) CDUDOT - The serial data line utilized to extract data from the CDU.

D) CDUCKOT - The clock associated with extracting data on the CDUDOT line.

The data formats for sending and receiving data to and from the CDU are shown in Figure 4.1.8-3 A and B.

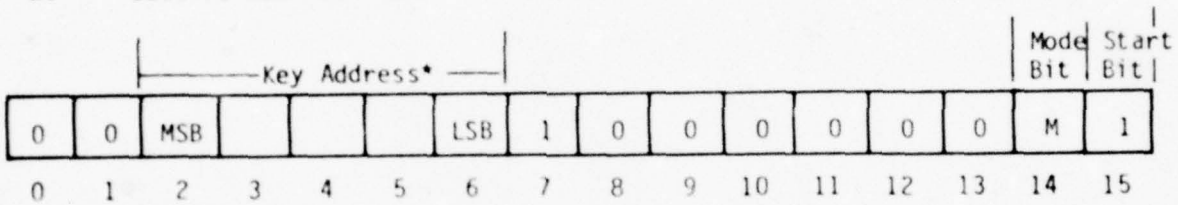
DATA FORMATS

A. Data Format To CDU



*Refer to Tables 4.1.8-3, 4 and 5 for data field formats.

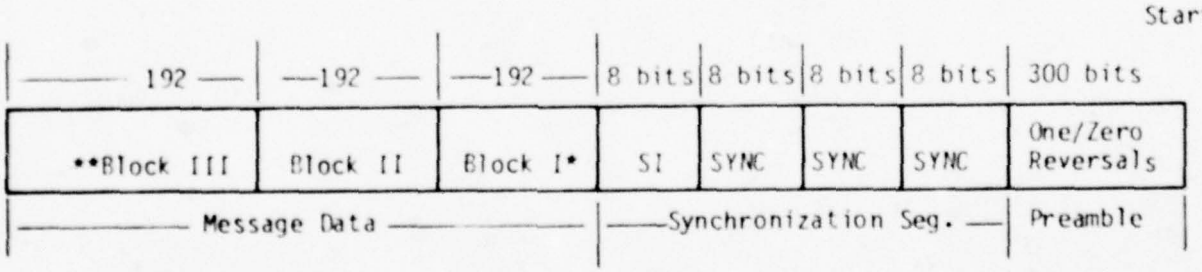
B. Data Format From CDU



*Refer to Table 4.1.8-6 for data field format.

Manual = 0
Auto = 1

C. DMD/Radio Data Format



*Refer to Data Block Contents description.

**The last four characters in Block III are EOT's.

Figure 4.1.8-3. Serial CDU Data Formats

Table 4.1.8-3. Display Address Format

Display + Location	Binary MSB				LSB	Hex Decimal
1	0	0	0	0	1	01
2	0	0	0	1	0	02
3	0	0	0	1	1	03
4	0	0	1	0	0	04
5	0	0	1	0	1	05
6	0	0	1	1	0	06
7	0	0	1	1	1	07
8	0	1	0	0	0	08
9	0	1	0	0	1	09
10	0	1	0	1	0	0A
11	1	0	0	0	1	11
12	1	0	0	1	0	12
13	1	0	0	1	1	13
14	1	0	1	0	0	14
15	1	0	1	0	1	15
16	1	0	1	1	0	16
17	1	0	1	1	1	17
18	1	1	0	0	0	18
19	1	1	0	0	1	19
20	1	1	0	1	0	1A

+ Refer to Figure 4.2-1.

Table 4.1.8-4. ASC II Data Format

USASC II (MSB … LSB)							USASC II Character
1	0	0	0	0	0	0	@
1	0	0	0	0	0	1	A
1	0	0	0	0	1	0	B
1	0	0	0	0	1	1	C
1	0	0	0	1	0	0	D
1	0	0	0	1	0	1	E
1	0	0	0	1	1	0	F
1	0	0	0	1	1	1	G
1	0	0	1	0	0	0	H
1	0	0	1	0	0	1	I
1	0	0	1	0	1	0	J
1	0	0	1	0	1	1	K
1	0	0	1	1	0	0	L
1	0	0	1	1	0	1	M
1	0	0	1	1	1	0	N
1	0	0	1	1	1	1	O
1	0	1	0	0	0	0	P
1	0	1	0	0	0	1	Q
1	0	1	0	0	1	0	R
1	0	1	0	0	1	1	S
1	0	1	0	1	0	0	T
1	0	1	0	1	0	1	U
1	0	1	0	1	1	0	V
1	0	1	0	1	1	1	W
1	0	1	1	0	0	0	X
1	0	1	1	0	0	1	Y
1	0	1	1	0	1	0	Z
1	0	1	1	0	1	1	[
1	0	1	1	1	0	0	\
1	0	1	1	1	0	1	]
1	0	1	1	1	1	0	^
1	0	1	1	1	1	1	-
0	1	0	0	0	0	0	
0	1	0	0	0	0	1	!
0	1	0	0	0	1	0	"

Table 4.1.8-4. ASC II Data Format (Contd)

USASC II MSB						LSB	USASC II Character
0	1	0	0	0	1	1	#
0	1	0	0	1	0	0	$
0	1	0	0	1	0	1	%
0	1	0	0	1	1	0	&
0	1	0	0	1	1	1	'
0	1	0	1	0	0		(
0	1	0	1	0	0	1	)
0	1	0	1	0	1	0	*
0	1	0	1	0	1	1	+
0	1	0	1	1	0	0	,
0	1	0	1	1	0	1	-
0	1	0	1	1	1	0	.
0	1	0	1	1	1	1	/
0	1	1	0	0	0	0	0
0	1	1	0	0	0	1	1
0	1	1	0	0	1	0	2
0	1	1	0	0	1	1	3
0	1	1	0	1	0	0	4
0	1	1	0	1	0	1	5
0	1	1	0	1	1	0	6
0	1	1	0	1	1	1	7
0	1	1	1	0	0	0	8
0	1	1	1	0	0	1	9
0	1	1	1	0	1	0	:
0	1	1	1	0	1	1	;
0	1	1	1	1	0	0	<
0	1	1	1	1	0	1	=
0	1	1	1	1	1	0	>
0	1	1	1	1	1	1	?
0	0	0	0	1	0	0	EOT
0	0	1	0	1	1	0	SYN
0	0	0	1	1	1	1	SI

Table 4.1.8-5. Special Input User Commands To CDU

Display Address Field					ASC II Data Field							Description
MSB				LSB	MSB						LSB	
1	1	0	1	1	1	0	X	X	X	X	X	This code command induces CDU to clear all characters from the display. All LEDs off. Clears display and previous pattern lost.
0	1	0	1	1	1	0	X	X	X	X	X	This code command induces CDU to execute a test cycle. All LEDs ON.
1	1	1	0	0	1	0	X	X	X	X	X	This code command force CDU to inhibit power to as much logic as possible (Display Logic) without losing display data.
0	1	1	0	0	1	0	X	X	X	X	X	Forces CDU to enable power to display logic.

Table 4.1.8-6. Key Address Format

Key Location	Key Adress Code MSB LSB	
1*	0 0 1 0 1	ENT
2	Ø Ø 1 0 Ø	RAD
3	0 0 1 1 0	SEL
4	0 0 1 1 1	GRD
5	0 1 0 0 1	Upper Left
6	0 1 0 0 0	CLR
7	0 1 0 1 0	Upper Right
8	0 1 0 1 1	LAT
9	0 1 1 0 1	1
10	0 1 1 0 0	2
11	0 1 1 1 0	3
12	0 1 1 1 1	TIM
13	1 0 0 0 1	4
14	1 0 0 0 0	5
15	1 0 0 1 0	6
16	1 0 0 1 1	RNG
17	1 0 1 0 1	7
18	1 0 1 0 0	8
19	1 0 1 1 0	9
20	1 0 1 1 1	ALT
21	1 1 0 0 1	—
22	1 1 0 0 0	0
23	1 1 0 1 0	.
24	1 1 0 1 1	FIX

		Description
EPR	1 1 1 0 0	When an input data error is detected, the CDU will output this code to the user.
RAD	1 1 1 0 1	When RAD is depressed, the CDU will output this code to the user prior to transmitting DMD or Radio data.
STBY	1 1 1 1 1	CDU code when in STDBY

* Refer to Figure 4.2.-1

As implied by the data formats shown in the Figure transfers are accomploished via 16 bit clock intervals. These clocking intervals are attained by executing CRU operations in the EIOM's CRU space.

When a user depresses the RAD key on the CDU a special serial mode is invoked which involves both the CDU and the Receiver/Processor. This special format is associated with Digital Message Device Communication. As shown in Figure 4.1.8-3c the message is composed of a preamble, synchronization segment, and three data blocks.

The preamble shall be 300 bits of alternating ones and zeros.

The synchronization segment consists of four 8-bit ASCII characters, 7 bits of data from Table 4.1.8-4 and 1 bit of odd parity per character. The first three characters shall be ASCII SYN characters while the fourth is an ASCII SI character. These synchronization characters are separate and distinct from the succeeding data blocks. They are transmitted in serial form, MSB to LSB immediately after the preamble.

A data block is composed of sixteen twelve bit characters arranged vertically as shown in Figure 4.1.8-4. Each of the twelve bit characters is an ASCII character (7-bits) followed by five (5) odd parity bits formed as follows:

A) P1 is odd parity on the 7 data bits.

B) P2 is odd parity on bits 1, 3, 5, 7.

C) P3 is odd parity on bits 2, 3, 6, 7.

D) P4 is odd parity on bits 4, 5, 6, 7.

E) P5 is odd parity on bits 7 data bits and P thru P4.

The character produced is b1b2b3b4b5b6b7P1P2P3P4P5 where b1 thru b7 is the ASC II character with b7 the MSB and b1 the LSB. When the data blocks are transmitted, transmission will proceed in a left to right fashion starting at the top of the block as shown in Figure 4.1.8-4, such that all b1 bits for all sixteen characters are transmitted first followed by all b2 bits for all sixteen characters and proceeding in this manner through the P5 parity bits.

The three data blocks shall contain data as shown in the following list.

Block Character Number	Block I	Block II	Block III
1	Display Character 1+	Display Character 11	0
2	0*	" " 12	0
3	T	" " 13	0
4	I	" " 14	0
5	D	" " 15	0
6	B	" " 16	0
7	T	" " 17	0
8	Display Character 2	" " 18	0
9	" " 3	" " 19	0
10	" " 4	Display Character 20	0
11	" " 5	0	0
12	" " 6	0	0
13	" " 7	0	EOT
14	" " 8	0	EOT
15	" " 9	0	EOT
16	" " 10	0	EOT

+Display character 1 shall be controlled by the user to represent the destination address of the message or the identifier code for the receipent of the message.

*Block characters 2-7 of Block I shall always be as shown while the last four characters of Block III shall always be EOT ASCII characters.

The Receiver/Processor via commands previously issued

to the system will clock the formatted data from the CDU with one of three bit rates. These rates include 300, 600, and 1200 bits per second.

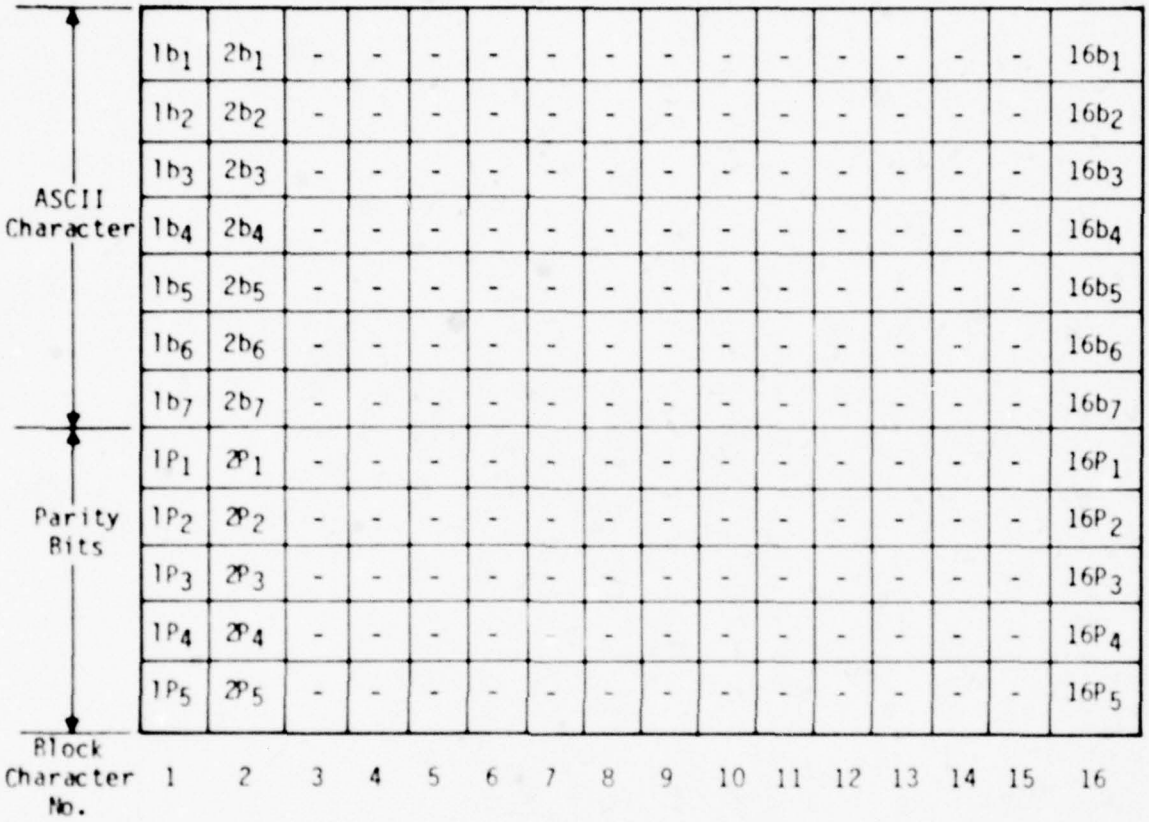


Figure 4.1.8-4. DMD/Radio Data Block

4.1.8.2.4 RADIO/DMD INTERFACE

The RADIO/DMD Interface is the means by which the Receiver/Processor communicates with the Digital Message Device DMD. The interface includes an analog signal which is compatible with the DMD. The analog signal is Frequency Shift Keyed (FSK) based on the information being extracted from the CDU when the RAD key is depressed. Thus the Receiver/Processor clocks the serial data from the CDU. The data is routed to the EIOM which converts the information to FSK data and buffered to the Radio/Handover connector. The FSK tones are 1200 and 2400 Hz while the bit rate is 300, 600, and 1200 baud. This interface port can also be connected to a radio (PRC-25 or 77). The tone would be routed to the connector on the radio normally reserved for the handset. This feature makes transmission of messages to remote DMD's possible.

4.1.8.2.5 VEHICULE INSTALLATION KIT INTERFACE

The Vehicule Installation Kit (VIK) Interface is composed of a power interface and an RF interface. The power interface merely consists of a 12 volt tap from the output of the Receiver/Processor internal power supply which is made available at the Antenna Power connector on the top cover of the Receiver/Processor. This connector is utilized to provide power to the VIK Pre-Amplifier section while the unit is in a vehicular mode. The RF interface is for the amplified L1/L2 signals from the VIK Pre-Amplifier. The RF

signal is injected in to the Vehicule Antenna BNC connector on the top cover of the Receiver/Processor the signal for this input is characterized below.

Bandwidth	± 25 MHz around L1 and L2
Power Level	-88 dBm (C/A) nominal
VSWR	1.5:1

4.1.8.2.6 MVUE INSTRUMENTATION SYSTEM INTERFACE

The MVUE Instrumentation System (MIS) Interface is subdivided into two major areas. These two areas include the Maintenance Panel interface and the MIS interface. The Maintenance Panel interface is those signals required to intervence with processor execution. Detail descriptions of each signal is provided in the module descriptions for the MISIM paragraph 6.3.3. The MIS interface is subdivided into test point monitoring, MIS recording, and CDU interfacing.

Test point monitoring involves calling out various analog test points and real time availability of other key system signals. Table 4.1.8-7 shows those signals that are available for real time monitor while Table 4.1.8-8 lists those signals that are available for monitor on a multiplexer. This table also lists the addresses associated with the various signals. These signals can be selected for real time monitor as well as converted to digital information by an A/D converter

within the Receiver/Processor

TABLE 4.1.8-7

MIS REAL TIME TEST POINTS

ITEM NO.	DESCRIPTION
1	ERROR A
2	ERROR B
3	X1AGO
4	5 MS TIME MARK
5	20 MS TIME MARK
6	10 MHZ (MASTER OSCILLATOR)
7	20.23 MHZ (FREQ SYNTH LO2)

TABLE 4.1.8-8

MULTIPLEXER SELECTABLE ANALOG TEST POINTS

ITEM	DESCRIPTION	ADDRESS(HEX)*
1	+5VDC	00
2	+12VDC	01
3	+15VDC	02
4	-5VDC	03
5	-12VDC	04
6	1.5VDC	05
7	-15VDC	06
8	5.2VDC	07
9	1ST AGC	08
10	AGC 2A	09
11	MUX DATA	0A
12	MUX COR1	0B
13	MUX COR2	0C
14	VCOIN	0D
15	VCXO TUNE	0E
16	LOOP IN	0F
17	AGC 2B	10
18	CODE	11
19	ERROR A	12
20	ERROR B	13
21	GND	14
22	SPARE 1	15
23	SPARE 2	16
24	SPARE 3	17
25	X1AGO	18
26	MEMPG	19
27	C/A EPOCH	1A
28	DATA CLOCK	1B
29	PROC CLOCK (2.75 MHZ)	1C

*THIS ADDRESS IS INJECTED INTO THE RECEIVER/PROCESSOR ON 5 LOGIC SIGNALS (ADDR 10-14) WHERE THE ADDR14 SIGNAL IN THE LSB

The MIS recording interface includes a two signal output only interface. The interface signals include the logic signals shown below:

A) DHO DATA - The serial data line utilized to send data from the Receiver/Processor to any instrumentation storage medium. Signal is sourced by the Receiver/Processor.

B) DHO CLK - The clock associated with sending data on the DHO DATA line. Signal is sourced by the Receiver/Processor.

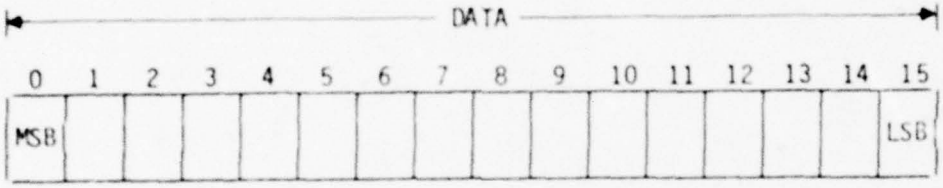
The data format utilized for MIS interface is shown in Figure 4.1.8-5. Data transfers are accomplished via 16 bit clock intervals. These clock intervals are attained by executing CRU operations in the EIOM's CRU space.

Operational software utilizes this interface port to send out key system parameters normally stored in scratchpad memory (RAM). The data available via this port is defined in the In-Plant Test portion of the final report.

The CDU interface formats have already been discussed in section 4.1.8.2.3. The signals associated with the CDU are merely routed through this port such that an instrumentation system could be used to monitor transmissions between the CDU and the Receiver/Processor or it could be used to emulates a CDU by communicating with the Receiver/Processor utilizing the same interface formats.

MIS INTERFACE WORD FORMAT

FIGURE 4.1.8-5



4.1.9 RECEIVER/PROCESSOR PERFORMANCE CHARACTERISTICS

The performance characteristics of the Receiver/Processor are discussed in the following paragraphs.

4.1.9.1 VERNIER MEASUREMENT ACCURACY

Assume: Code flop* and average of 16 measurements.

C/No = 35 dB, input signal level - 133 dBm, -163 dBW

full dynamics condition

P-Code	C/A Code
Accuracy (1σ)	Accuracy (1σ)
0.9 meter	9 meter

*Code flop refers to alternating NBM's to average out any electronic delays associated with each NBM path.

4.1.9.2 L1/L2 DIFFERENTIAL DELAY

Differential delays between L1 and L2 frequencies shall not drift more than:

(1σ) = 3.5 ns over 10 minute period after oscillator warm-up.

4.1.9.3 BIT ERROR RATE

Undetected bit error rate shall be less than 5×10^{-5} or P code at C/No = 35 dB and input = -163 dBw or C/A code at C/No = 35 dB and input = -163 dBw.

4.1.9.4 PLL TRACK CHARACTERISTICS

Phase lock loop - shall track with mean time to slip 10 minutes under the following condition:

Input signal = -163 dBW P_r = -163 dBW C/A

C/No = 35 dB P_r = 35 dB C/A

Off set code being tracked .31 chip

Frequency input dynamics at Fo

Lock Range = ± 68.2 Hz

Acceleration = 0.3414 Hz/sec

4.1.9.5 FLL ACQUISITION CHARACTERISTICS

Frequency lock loop -- shall acquire frequency lock within .025 ± .005 sec. when subjected to a step frequency response response of 100 Hz under the following conditions:

Input signal level = -130 dBm P_r

= -163 dBW C/A

Frequency error 125 Hz at phase detector.

Offset code being acquired .31 chip

Frequency input dynamics at Fo

Lock range = ± 68.2 Hz

Acceleration = ± 0.3414 Hz/sec

4.1.9.6 FLL TRACK CHARACTERISTICS

Frequency lock -- shall maintain weak hold on under the following conditions:

Input signal = -163 dBW P_i = -163 dBW C/A

C/No = 35 dB P_i = 35 dB C/A

Off set code being tracked 12 chip

Frequency input dynamics at Fo

Lock Range = ± 68.2 Hz

Acceleration = ± 2.7 Hz/sec

4.1.9.7 RANGE MEASUREMENT ACCURACY

Pseudo Range Accuracies (1σ)

	P-Code	C/A Code
Phase lock loop	.07 ns	.07 ns
Quantizing	1.66 ns	1.66 ns
Vernier correction	0.9 meter	9 meter

4.1.9.8 PSEUDO RANGE RATE ACCURACIES (1σ)

	P-Code	C/C/A Code
Total Accuracy For specified signal levels	0.2 m/s	0.2 m/s

4.1.9.9 VCXO CALIBRATION ACCURACY

The VCXO circuitry and control is capable of being calibrated to an RMS accuracy of 25 Hz referenced to the 154 Fo frequency for any desired setting over the range of Fo $\pm$ 69 Hz.

4.1.9.10 NOISE FIGURE

$\leq$ 5.5 dB max

4.1.10 MECHANICAL CHARACTERISTRICS

The Mechanical Configurations which are available include the RAM Receiver/Processor and the PROM Receiver/Processor shown in Figures 4.1.10-1 and 4.1.10-2 respectively.

The RAM Receiver/Processor a Random Access Memory (RAM) configuration which is electronically configurated with a Data Memory Module (DMM) case which contains RAM type memory hardware to store the operational program. The memory, therefore, is of a volatile nature implying the system cannot be powered to the off state without losing stored information. This particular configuration is also equipped with two DMM Buffer Boards to drive the additional bus load represented by the two halves of the DMM case. The final significant feature of the RAM configuration is that it can only be powered from an external power source. The top cover select switch, therefore, when switching between external and internal only selects an RF source and does not

control power source.

The PROM Receiver/Processor is a Programmable Read Only Memory configuration. The operational program is stored in read only memory and is not lost in a power down situation. This configuration can be configurated with a battery pack to power the unit for short periods of time. The unit can thus be powered in the internal as well as external mode. The unit does have one significant mechanical variation from the RAM configuration. This feature is associated with the master oscillator. The oscillator in the PROM configuration is mounted to one side wall of the housing to allow for maximum heat transfer from the oscillator module. The RAM configuration has its oscillator module mounted on a special bracket that is welded between the housing walls and toward the center of the housing. Tables 4.1.10-1 and 2 represent the current and power specifications for each module shown in Figure 4.1.10-1 and 2. The Top Cover View of the Receiver/ Processor is shown in Figure 4.1.8-3.

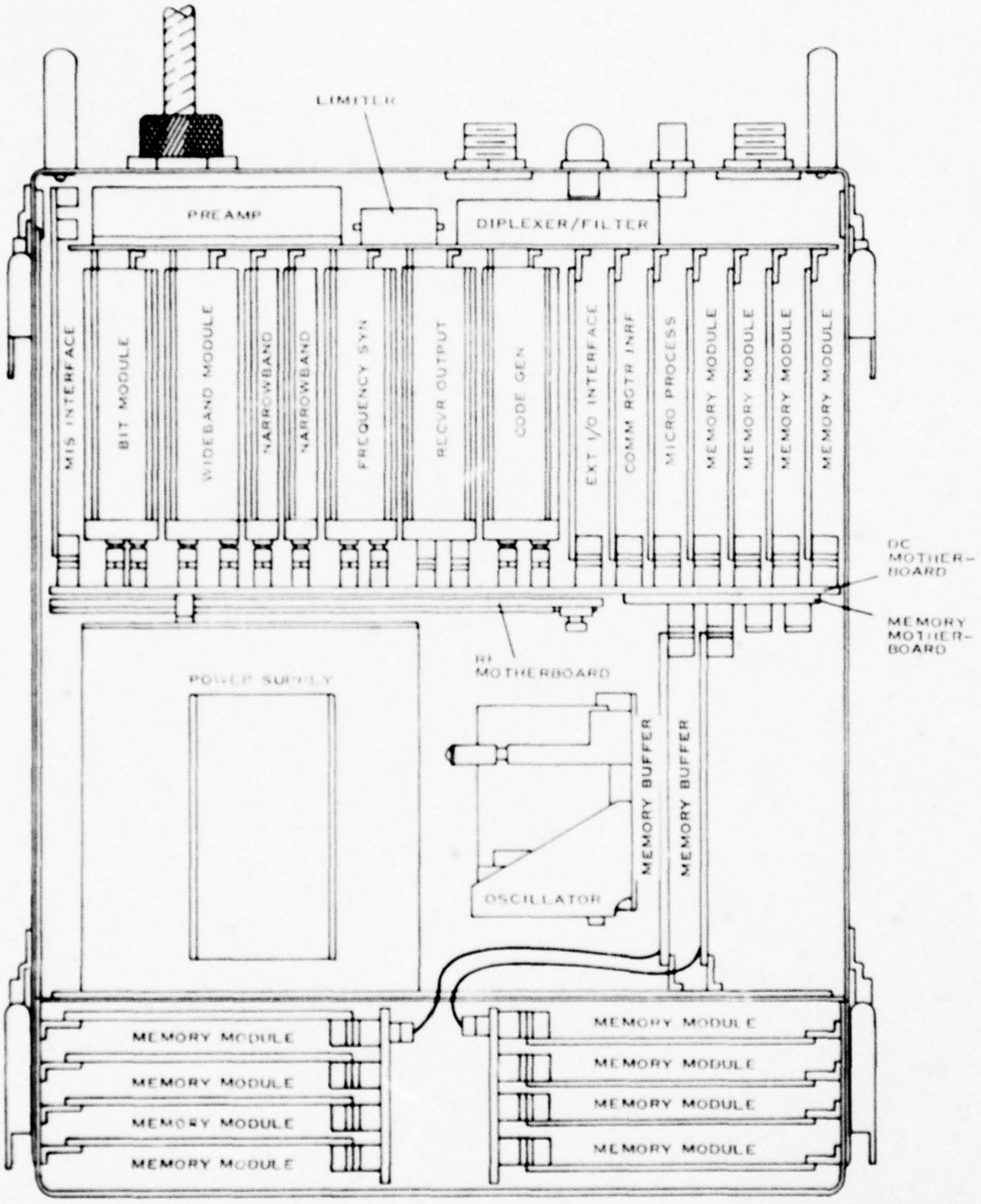


Figure 4.1.10-1. RAM Receiver/Processor

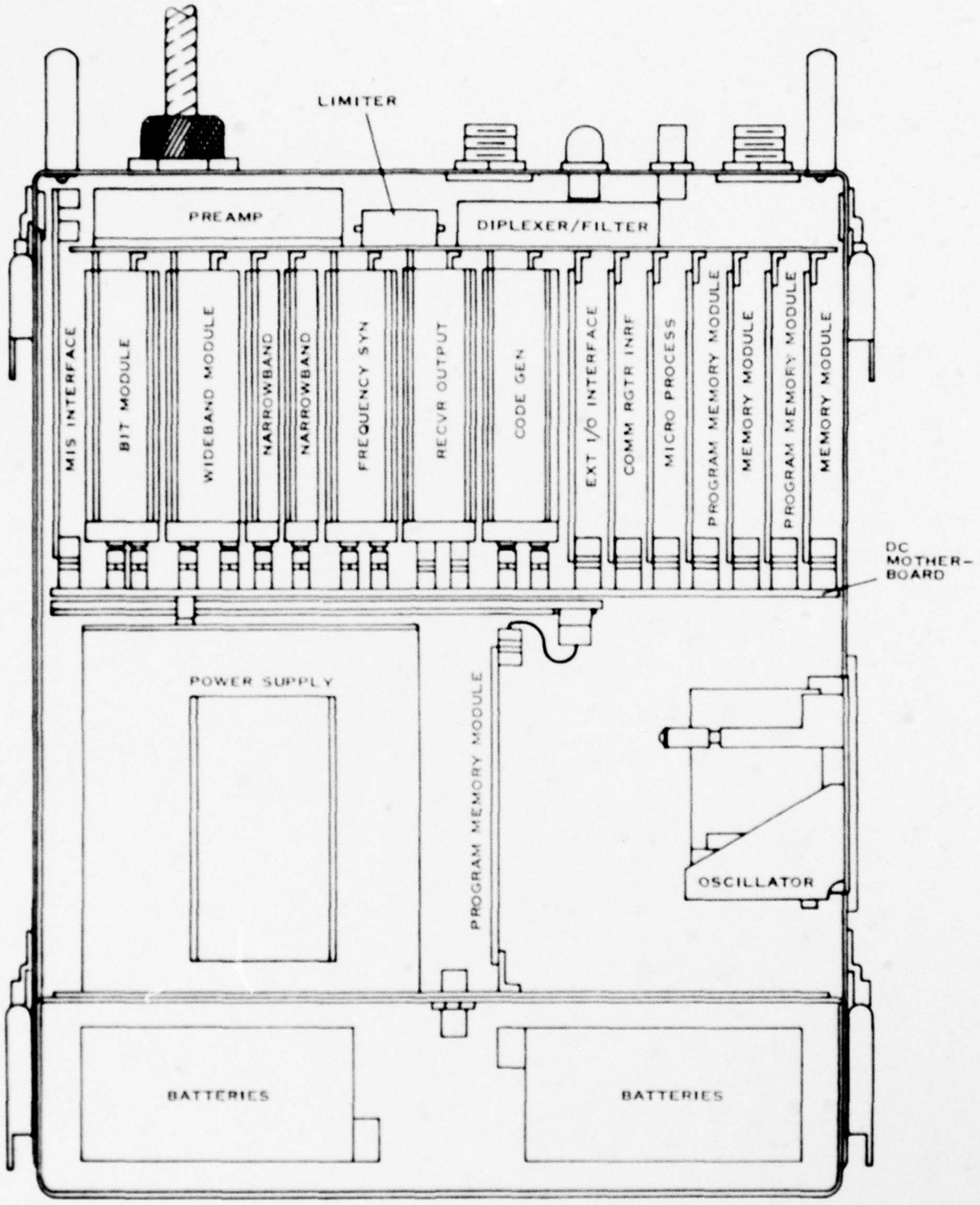


Figure 4.1.10-2. PROM Receiver/Processor

Table 4.1.10-1. MVUE RAM Receiver/Processor Power Estimates

Module Name	Qty	(Max current (ma) for each voltage) +1.5	+5.2 (RF)	+5.0 Logic	-5.0	+12.0	-12.0	+16.0	-16.0	+28	
Wideband	1		39.0	68.0	6.0	86.0	55.0				
Narrowband	1		21.0	37.0		43.0	27.0				
Narrowband	1		21.0	37.0		43.0	27.0				
Output	1			264.0	48.0	54.0	4.0				
Freq. Synth.	1		600.0		7.0	57.0			57.0		
Code Gen.	1			1150.0							
Bit Module	1		420.0		18.0	164.0					
ØSC Module	1							26.0		215.0	
EIØM	1			250.0							
Pre-Amp/SW (LRU)	1			10.0		150.0					
Pre-Amp/SW (Inst. K)	1					150.0					
DMM (addressed)	1			260.0	40.0	1060.0					
DMM (non-addressed)	1			260.0	40.0	160.0					
" "	1			260.0	40.0	160.0					
" "	1			260.0	40.0	160.0					
" "	1			260.0	40.0	160.0					
" "	1			260.0	40.0	160.0					
" "	1			260.0	40.0	160.0					
DMM (non-addressed)	1			260.0	40.0	160.0					
CPIM				880.0							
MPM		800.0		1560.0							
CDU				840.0			260.0				
Totals (Total buss current)		800.0	1100.0	7176.0	400.0	2927.0	373.0	26.0	57.0	215.0	
Totals (bus power)		1.21	5.72	35.9	2	34.8	4.5	.39	.86	6.	87.4

Table 4.1.10-2. MVUE RAM Receiver/Processor Power Estimates

Module Name	(Max current (ma) for each voltage)									
	+1.5	+5.2 (RF)	+5.0 Logic	-5.0	+12.0	-12.0	+16.0	-16.0	+28	
Wideband		39.0	68.0	6.0	86.0	55.0				
Narrowband		21.0	37.0		43.0	27.0				
Narrowband		21.0	37.0		43.0	27.0				
Output			264.0	48.0	54.0	4.0				
Freq. Synth.		600.0		7.0	57.0			57.0		
Code Gen.			1150.0							
Bit Module		420.0		18.0	164.0					
ØSC Module							26.0		215.0	
EIØM			250.0							
Pre-Amp/SW (LRU)			10		150.0					
Pre-Amp/SW (Inst. K)					150.0					
DMM (addressed) 25%			260.0	40.0	265.0					
PMM (16K)			256.0							
PMM (16K)			256.0							
CRIM			880.0							
MPM	800.0		876.0							
CDU			840.0			260.0				
Totals	800.0	1100.0	5184.0	120	1012	373.0	26.0	57.0	215.0	
Totals (bus power)	1.2	5.72	25.9	2.0	34.8	4.5	0.39	.86		75.37

4.2 CONTROL DISPLAY UNIT SECTION

The Control Display Unit (CDU) functions as the primary operator interface for control and monitor of the system. The CDU is utilized to display pertinent system information via two rows of 10 alphanumeric displays. Refer to Figure 4.2-1. The keyboard is a 6 x 4 three level alphanumeric keyboard. The processor resident within the CDU (TMS1301) interfaces with the DPU. The CDU processor accepts display commands from the DPU and proceeds to display the information as required. The CDU processor also monitors the keyboard for user inputs (depressed keys). When a key is registered the processor forms a code for the key and sends the message to the DPU. The CDU also performs one other key task. This task involves reformating the CDU display information to be compatable with a Digital Message Device (DMD). The transmission of the reformated data is extracted (clocked out) from the CDU by the Receiver/Processor section. The data is routed to the EIDM within the Receiver/Processor Section which converts the data to a Frequency Shift Keyed tone for output to either a PRC-25 or 77 radio or directly to a DMD.

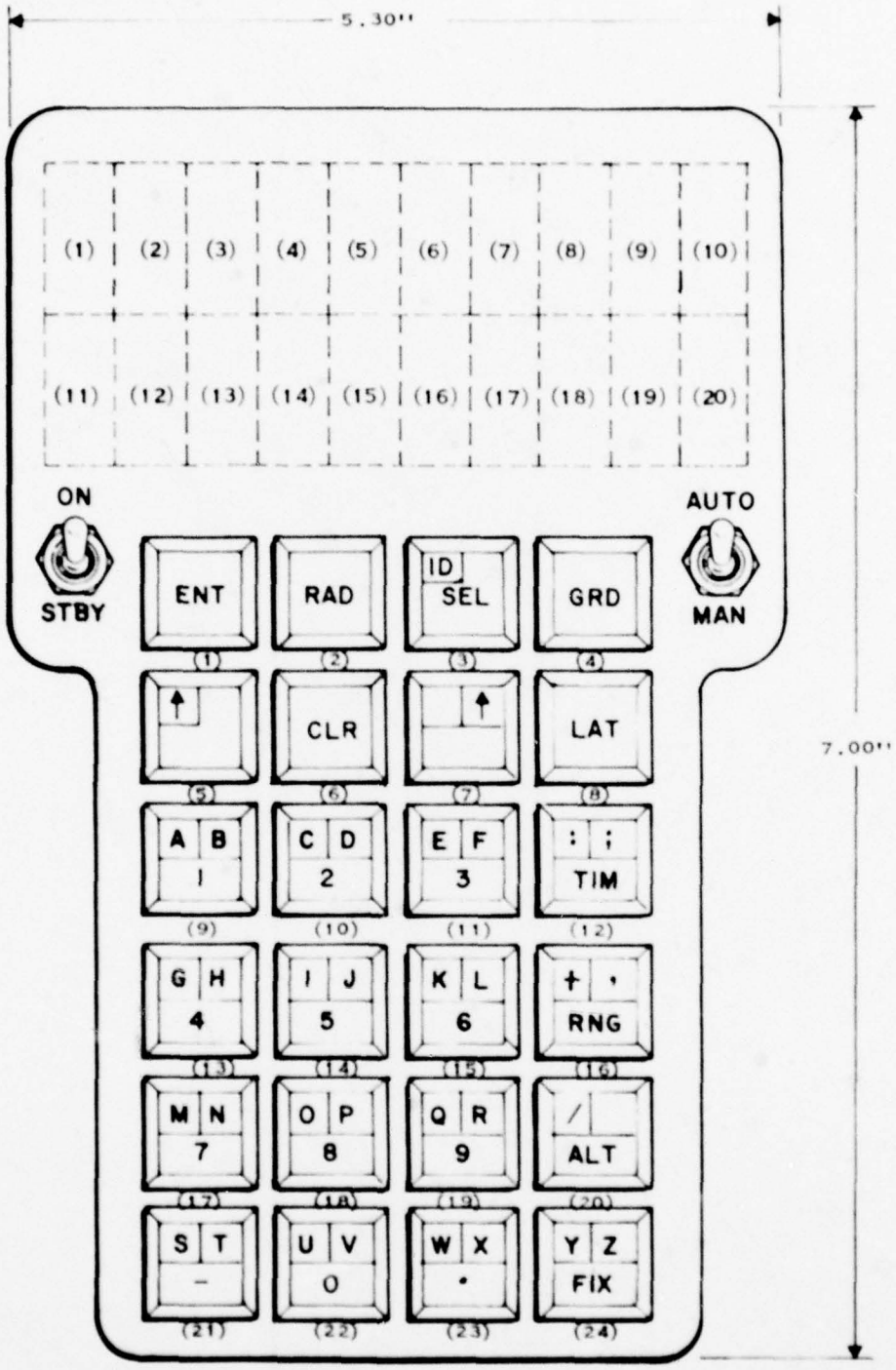


Figure 4.2-1. MVUE Control Display Unit

4.3 VEHICLE INSTALLATION KIT

The Vehicle Installation Kit (VIK) is composed of that equipment required to mount the MVUE Receiver/Processor in a vehicular mode. Figure 2.1-2 illustrates that equipment required for this mode of operation. The VIK includes a Pre-Amplifier Unit, a Power Filter Unit, and Mechanical Mounting Tray.

4.3.1 VIK PRE-AMPLIFIER

The VIK Pre-Amplifier functionally shown in Figure 4.3-1 is similar to the RF Pre-Conditioning hardware described in sections 4.1.1 and 6.1.1. The similarities are with the resident Diplexer/Filter, Limiter, and Pre-Amplifier gain. The VIK Pre-Amp has only one RF path while the RF Pre-Conditioning unit has two. This implies that the VIK Pre-Amplifier possesses no select control. The VIK Pre-Amp unit contains a Voltage Regulator (DC to DC) which regulates 16 VDC from the Receiver/Processor unit to 12 VDC to power the pre-amplifier.

4.3.2 VIK POWER FILTER

The VIK Power Filter is merely an EMI device designed to both prevent EMI signals from entering the MVUE system and prevent signals sourced by the MVUE system from entering other adjacent systems (if any). The Power Filter is designed to be connected in series with any external power source that a user may decide to connect to the MVUE

system. Figure 4.3-2 shows the insertion loss characteristics of the power filter.

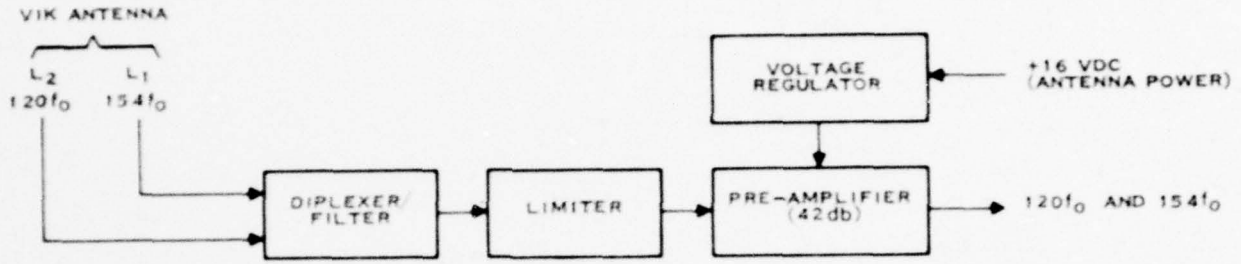
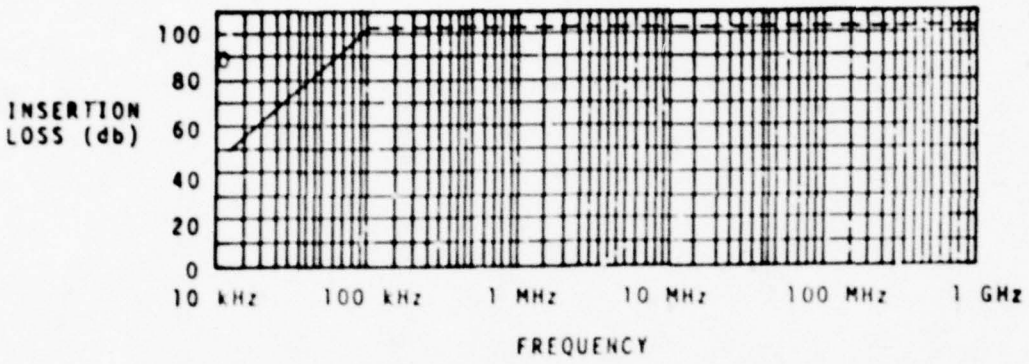


Figure 4.3-1. VIK Pre-Amplifier



1/ MEASURED IN A 50 OHM SYSTEM PER MIL-STD-220
2/ MEASURED UNDER A LOAD OF 10 AMPS @ 28 VOLTS

Figure 4.3-2. Power Filter Insertion Loss Characteristics

4.3.3 VIK MECHANICAL MOUNTING TRAY

The VIK Mechanical Mounting Tray is merely a means to mount the Receiver/Processor on a surface that is shock isolated from the typical vehicular environment the unit will function in. The Receiver/Processor is designed to mount on the tray less the Battery Pack. The only mode of operation is in the External mode with an external power source providing power.

4.4 MVUE ANTENNA

The MVUE Antenna is the interface between the electro-magnetic waves that originate at the satellites and the transmission line signal that is directed to the Receiver/Processor or to the VIK Pre- Amplifier when in a vehicular mode. The MVUE Antenna is composed of a combination of passive elements that are required to direct the radio frequency satillite transmissions onto a coaxial transmission medium.

4.4.1 MVUE ANTENNA ELECTRICAL CHARACTERISTICS

The MVUE Antenna is functionally characterized in Figure 4.4.1 and mechanically illustrated in Figure 4.4.2. The unit is subdivided into an L1 and an L2 receptor element enclosed in a radome for environmental protection. Each element has a Right Hand Circular Polarized (RHCP) far field pattern. The coverage for each element is omni-directional in the upper hemisphere. The lower hemisphere response is minimized to reduce multipath sensitivity. The gain of the antennas is such that at least 0 dBc (Gain referenced to a Right-Hand Circular Polarized Isotropic Radiator) for elevation angles above 10 degrees where the horizon is described by a 0 degree elevation angle. The gain specification are achieved over bandwidth of $\pm$ 10 MHz centered at L1 and L2 (1575.42 MHz and 1227.6 MHZ respectively).

4.4.2 MVUE ANTENNA MECHANICAL CHARACTERISTICS

The mechanical boresights of the antenna is directed toward zenith in an operational environment. The zenith is 0 degree declination or 90 degrees elevation. The extension that elevates the antenna (Antenna Support Assy) provides for zenith orientation when the host vehicle is on level terrain and zenith orientation when the Manpack configuration is at 0 degrees or 90 declinations.

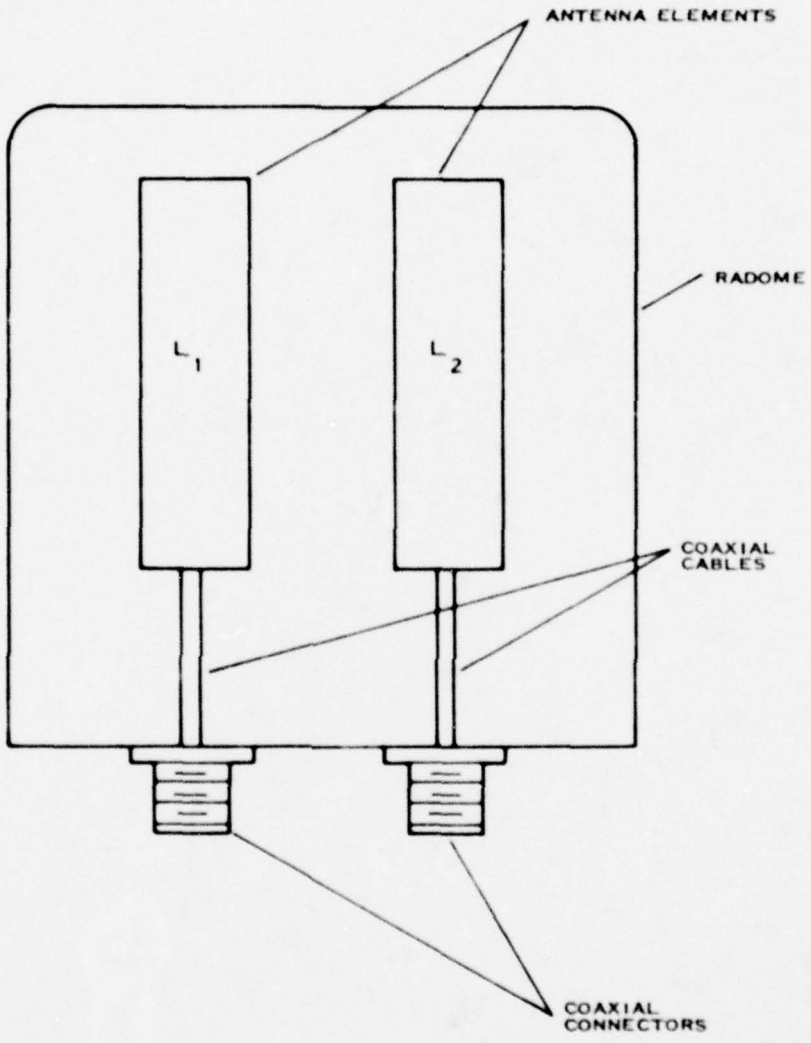


Figure 4.4-1. MVUE Antenna Functional Diagram

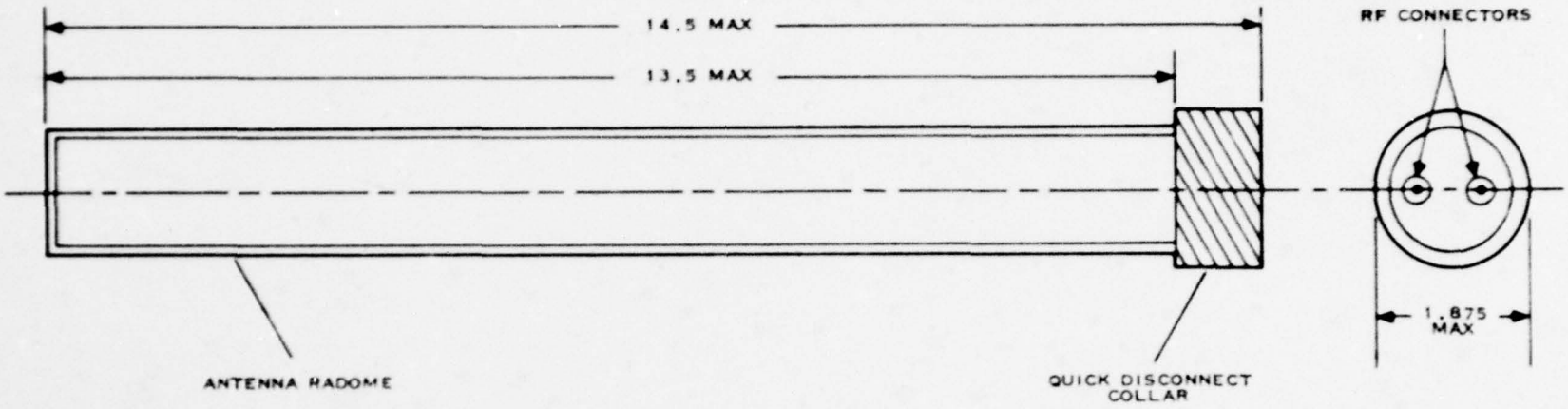


Figure 4.4.-2. MVUE Antenna Mechanical Outline

4.5 BATTERY PACK

The Battery Pack is the power source for the system while in the Manpack configuration. The unit is designed to accept a Nicol Cadmium (BB590) or Lithium (BB5590) type battery.

The battery life of the Battery Pack varies from a minimum of 1.75 hrs for a Nicad in a continous on mode to a 7 hr life for a Lithium in the same mode. As shown in Figure 4.1.10-2 the Battery Pack is designed to snap on to the lower section of the PROM Receiver/ Processor unit when Manpack operation is required. Refer to paragraph 6.3.5 for a detailed description of the Battery Pack electronics and interfaces.