Network Control System Development

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The development of the DSN Network Control System (NCS) has been authorized to provide centralized computer control and monitoring of Deep Space Station equipment status and data flow. The NCS is being implemented with an interim capability for current spacecraft-support requirements. A final NCS, providing future spacecraft-support requirements, will be implemented by a complex of mini-computers with dedicated subsystem functional capability.

I. Introduction

This is the fourth report describing the JPL Deep Space Network (DSN) Network Control System (NCS). The NCS provides centralized computer control and monitoring of all the JPL Deep Space Stations' (DSS) equipment and data flow status. The previous reports described (1) project plan and resources, (2) system functions and interface requirements, (3) data flow and hardware allocations, and (4) detailed descriptions of hardware and software development progress, for the interim and final NCS. This report discusses recent progress in hardware and software activities, and provides a detailed description of the interim NCS hardware implementation. The interim NCS will be utilized from July 1973 until July 1974, when the final NCS will become operational.

II. Final NCS Hardware Implementation

The final NCS hardware documentation is being prepared for procurement and system implementation. The final NCS data flow requirements are shown in Fig. 1.

Planning for the procurement of the mini-processors has been completed. A Source Evaluation Board has been appointed and procurement actions have been initiated.

Budget revisions and planning have been completed for inclusion of a third Sigma-5 computer for phase-over of Sigma-5 computers from the interim to the final NCS.

An operational mode for the NCS Ground Communications Facility (GCF) log has been defined. Detailed interface requirements are in preparation for logging formats, and for recall to Mission Control and Computing Center (MCCC) and to Remote Mission Operations Control (RMOC).

Detailed NCS equipment specifications have been completed for the following:

(1) Mini-computers.

(2) Cartridge disk file.

(3) GCF log disk file.

(4) Magnetic tape/controller.

(5) High-speed printer.

(6) Low-speed printer.

(7) Card reader.

(8) Operator terminal.

(9) Block transfer interface.

(10) Standard interface.

III. Final NCS Facilities

The location of the Network Data Processing Area (NDPA) for the final NCS installation is planned for JPL Building 202. An area adjacent to the interim NCS has been identified for the final system. The facility location is suitable for the final NCS installation and will allow an optimum transfer of Sigma-5 midi-computers from the interim to the final system. The proximity will also facilitate development of final NCS Real-Time Monitor/Network Support Controller (RTM/NSC) hardware and software interfaces.

Definition of equipment locations for Operations and for display data processing equipments of the Network Operations Control Area (NOCA) in JPL Building 230 is nearing completion. Facility locations will be coordinated with existing GCF modem equipments, and with MCCC data processing and display systems providing direct Mission Operation Control (MOC) for various spacecraft projects.

IV. Final NCS Software Implementation

The requirements for all NCS software subsystems are being analyzed for detailed software development. The system baseline design document has been completed. Detailed design requirements are in preparation for each functional subsystem.

V. Interim NCS Facility

The modification of JPL Building 202 and installation of the interim NCS facility are complete. The facility documentation revisions are in preparation for power, building construction, air conditioning, equipment layouts, and signal cabling from external equipments.

VI. Interim NCS Software

Several requirements for software changes have been received in conjunction with MCCC project services revisions. A key change provided for revised command/configuration capability to be included in the interim NCS.

The baseline design requirement specification for the interim NCS software is complete.

Detailed software design is essentially complete for all subsystem function modules, and in preparation for formal review.

The software-module coding is in progress. The testing of software diagnostics is in progress as part of the test plan for hardware and software. A formal test plan for hardware and software will be implemented for acceptance testing and transfer to Operations.

The software data flow diagrams for the real-time data processing in the PDP-8 and Sigma-5 processors have been completed. A detailed description of the system software will be provided in a subsequent report.

VII. Interim NCS Hardware Summary

The two Sigma-5 processor systems (real-time and off-line) and most peripherals have been installed. Both systems have been tested with basic diagnostic software, except for some peripherals on the off-line system.

The PDP-8 processors are installed and tested with input/output (I/O) interface buffers. The PDP-8 to Sigma-5 link via data sets has been tested for routine data transfers. The GCF hardware interface to the PDP-8 has been tested locally at the PDP-8, and will soon be tested remotely to the GCF Central Communications Terminal (CCT) in Building 230.

The design and the hardware assembly are complete for remote display equipments in the NOCA. These are scheduled for installation in the recently allocated NCS NOCA of the JPL Space Flight Operations Facility (SFOF).

VIII. Interim Network Control System Equipment Description

A. General

The interim Network Control System will be operational from July 1973 to July 1974, at which time the final or full-capability Network Control System will replace the interim system. This description is of the interim system hardware configuration only. Descriptions of the final system hardware will appear in subsequent articles.

The interim Network Control System equipment is divided into three primary functional areas: (1) the GCF Interface Assembly, (2) the Data Processing Assembly, and (3) the Display Assembly. A simplified hardware block diagram showing the equipment locations is presented in Fig. 2. A brief functional description of each follows.

(1) The *GCF Interface Assembly* area performs multiplexing/demultiplexing functions to provide an interface between the Ground Communications Facility (GCF) high-speed and wideband data lines and the Data Processing Assembly area.

(2) The *Data Processing Assembly* area utilizes two medium-scale computers to meet the data handling and computational requirements of the interim NCS. These computers are provided with peripherals and interface equipment for communicating to the GCF interface and the display areas. The data processing area also contains equipments to provide Greenwich Mean Time (GMT) timing references to the computers.

(3) The *Display Assembly* area contains a set of remote peripherals which interface with the computers located in the data processing area. These peripherals provide the mission operations personnel with devices to (a) display data and alarms gathered in the data processing area, and (b) control the program operating modes of the interim NCS software.

Detailed hardware descriptions are provided below for the three interim NCS major functional areas shown in Fig. 3.

B. GCF Interface Area

The GCF interface area is located in the basement of Building 230. The function of this assembly is to interface GCF communications lines with the interim NCS data processing area. The interface consists of six high-speed data (HSD) links to/from the DSN Deep Space Stations (DSSs). A single wideband (WB) receive line from a DSS may be substituted for one of the six HSD links. The six high-speed channels are input to a small general-purpose computer via special interface adapter hardware (transmit/receive buffer). The adapter transforms the standard RS-232-type GCF interface to a computer-compatible format.

Data blocks originated at the DSSs are input to the computer using up to six HSD lines. Data are then multiplexed via software in the computer and formatted for output as a single wideband data stream to the interim NCS data processing area. Interface adapter hardware is utilized to transform the computer interface to a standard RS-232-type interface that is compatible with the data sets used for the wideband data link to the data processing area.

Data originated in the data processing area are transmitted as a single data stream on the wideband link to the GCF interface computer. These data are then demultiplexed and formatted by software in the PDP-8 computer for transmission via the interface adapter on the six high-speed data lines to the DSSs.

The major hardware subassemblies contained in the GCF interface are as follows:

(1) *PDP-8 Mini-Computers.* Two PDP-8L computers are provided to perform software multiplexing/demultiplexing and data formatting functions. One CPU is used "on-line" to process the communications data. The second processor serves as a spare which can be switched into the system in the event of failure of the primary computer. Each PDP-8 contains 8K words of memory, 20 channels of priority interrupt, and power fail-safe hardware. A high-speed paper tape reader and I/O console teletype are supplied as peripherals.

(2) *Transmit/Receive Buffer Assembly* (Interface adapter hardware). The PDP-8L Transmit/Receive Buffer Assembly is implemented in the interim NCS GCF interface area to provide an I/O interface of mini-computer PDP-8L with:

   (a) The NASCOM GCF high-speed data (HSD) and wideband data (WBD) lines.

   (b) The WBD link to the data processing area.

   The assembly will accept E1A RS-232 interface and perform a handshaking operation for data transfer to/from the HSD and WBD lines. The data bits are assembled/disassembled in two 24-bit buffers. Data transfer between buffers and PDP-8L is initiated from an I/O interrupt and is accomplished by I/O transfer micro-instructions. The assembly contains:

   (a) Six DSS HSD transmit/receive channels at 4.8 kbps.

   (b) One DSS WBD transmit/receive channel at 50 kbps.

(c) One WBD transmit/receive channel to the data processing area at 50 kbps.

All transmit receive channels are functionally identical and contained in eight identical logic modules. The assembly is packaged using JPL Hi-Rel standard integrated circuits and mounting hardware.

(3) *Block Demultiplexer.* The interim NCS utilizes two block demultiplexers (BDXRs) in the GCF interface area.

(a) BDXR 1 is connected in the wideband receive line from the DSSs for the purpose of (i) stripping filler blocks from the data stream before entry into receive buffer, and (ii) generating a data block detected (DBD) signal for the PDP-8 buffer.

(b) BDXR 2 is connected in the wideband receive line from the data processing area for the purpose of indicating sync and supplying the DBD signal to the receive buffer at the PDP-8L.

(4) *Filler Multiplexer.* The filler multiplexer (mux) allows the interim NCS to transmit data to a DSS interleaved with data generated at a remote MOC. The filler mux operates by allowing all HSD blocks originated at a remote MOC to pass directly through the assembly and be transmitted to the DSSs via GCF lines. When a remote MOC is not transmitting data blocks and filler data are being inserted on the lines, the filler mux detects the presence of the filler blocks and substitutes locally generated data blocks routed via a BMXR from either the interim NCS or MCCC. Should no local data be available for transmission, the BMXR will insert filler blocks for transmission from the interim NCS to the DSS. In all cases, data blocks from the remote MOC shall have the highest priority and will not be interrupted by local data. The filler mux capability is patched into a GCF line to a DSS when it is required to operate with a remote MOC. The filler mux is spared on the assembly level and the spare unit may be connected into system in the event of a failure.

(5) *Data Set.* A Model 401 data set is provided for wideband communications between the GCF interface area in Building 230 and data processing area in Building 202. Two data sets are provided; the second 401 serves as a backup link to Building 202.

C. Data Processing Area

The data processing area is the focal point for data handling, computation and data generation for the interim NCS. The data processing area is located in Building 202, Room 101. The equipment consists of:

(1) Two medium-scale digital computers.

(2) Peripherals for each of the computers.

(3) Interim NCS timing equipment.

(4) Interface hardware to allow the computers to communicate with GCF interface and display areas.

The two computers perform unique tasks for interim NCS application. One machine is identified as the real-time processing system, while the other is identified as the background processor. The real-time system performs the processing of data blocks from the DSS via wideband interface from the GCF interface area. The processing is done as the blocks are received and consists of such tasks as GCF data block accountability, logging blocks containing metric data on magnetic tape, monitoring DSS command configuration and formatting of alarm and status messages for transmission to the display area. The real-time machine also has the capability to transmit data blocks to the DSSs. These messages consist of prediction data, test data blocks, and command configuration control information. The real-time machine must perform time-critical tasks in response to data input from the DSSs and must transmit data to the DSSs at specified times.

The background system runs batch-type programs in support of the real-time system, but is not electrically connected into the real-time system. The tasks performed are not time-critical with respect to when they are performed. An example of a background application is the calculation of station observable metric prediction data from spacecraft ephemeris data. An output magnetic tape is written containing the generated prediction data. This tape is then hand-carried from the background machine to the real-time machine. It is read into the real-time machine and stored in memory for transmission to the DSSs at a designated time.

The two computer systems may reverse their roles in the interim NCS by simply changing software and patching the desired real-time machine into the GCF interface and display area. In the event of a failure of one of the computer systems, the remaining computer becomes the real-time machine. The background tasks are temporarily discontinued until repairs are made on the faulty computer.

The equipment complement in the interim NCS data processing area consists of the following items.

(1) *Real-Time and Background Computer Systems.* The two computer systems are identical so that they may perform either task. They are composed of the following equipment.

(a) *Central Processing Unit.* Xerox Data Systems Sigma-5 computer with 48K of 32-bit memory words, hardware floating point arithmetic, power fail-safe, and 16 channels of priority interrupt. The CPU is supplied with an I/O teletype and paper tape reader/punch.

(b) *Disk.* A three-megabyte random access disk (RAD) and controller are provided for auxiliary memory.

(c) *Magnetic Tape Units.* Three 9-track, 800-bpi, 75-ips, magnetic tape units and controller are provided for loading external programs, and for logging of DSS data. A single 7-track magnetic transport and controller are provided to load data and program tapes generated on other computers that only have 7-track output capability.

(d) *Line Printer.* A line printer capable of printing 600 lines per minute and controller are provided. The printer is utilized to provide data dumps which are used to assist in troubleshooting network problems.

(e) *Card Reader.* A 400-card per minute card reader allows for the loading of standards and limits data cards and control messages. The card reader is also used for loading of program cards when program compilations are required.

(f) *Cathode-Ray Tube Console.* A cathrode-ray tube (CRT) display, keyboard, and hard copy device console is provided as an interactive terminal and display device for the INCS. The CRT display is used to provide alarms and status information of the DSN. The keyboard is used to call up various display formats and input program control messages.

(g) *Communications Controllers.* Four communications controllers are provided with each computer system to interface with the GCF and the display areas. The communications controllers convert the parallel data words and control signals on the Sigma-5 I/O bus to an RS-232 compatible serial data stream interface. The four serial data streams' outputs/inputs of the controllers are routed from each computer to a patch panel. At the patch panel, by appropriate patching, either one of the Sigma-5 computer systems may be connected in as the real-time system. The four communications controllers are used in the following manner:

(i) *GCF Interface.* This communications controller provides a full duplex, synchronous, 50K-bit data rate RS-232-type interface to a wideband data set. The wideband data set transmits and receives data to/from the PDP-8 computer located at the GCF interface area.

(ii) *Display CRT Interface.* A half-duplex synchronous, 7.2K-bit data rate communications controller provides an RS-232 interface to the CRT console in the display area.

(iii) *Line Printer Interface.* A full-duplex synchronous, 2.4K-bit data rate communications controller provides an RS-232 interface to the line printer located in the display area.

(iv) *TTY Interface.* This communications controller provides a half-duplex asynchronous 110-baud character interface (RS-232 compatible) to the teletype unit located in the display area.

The communications controllers interface to the other interim NCS areas by data sets or in the case of the line printer and CRT console by line drivers. In all areas the interface is a serial data stream and electrically compatible with the standard RS-232 interface.

(2) *Timing Assembly.* The data processing area has a rack of equipment to provide timing references to the computers. The Interim Timing Assembly is self-contained and derives its time base from a General Technology Corporation Model 304B rubidium frequency standard. This standard generates a 1-MHz sine wave which is accurate to approximately 1 part in 10^{11}. An identical unit is available for backup in case of failure of the on-line unit. Each frequency standard feeds an Astrodata Model 6190-629 Time Code Generator which produces the following outputs:

(a) A 30-bit parallel binary-coded decimal (BCD) word consisting of days, hours, minutes, and seconds.

(b) A 27-bit parallel binary word consisting of hours, minutes, seconds, and milliseconds.

(c) A NASA 36-bit serial code modulated on a 1-kHz carrier.

The NASA 36-bit time code is used to calibrate the time code generators against an identical code brought in by telephone line from the JPL Standards Laboratory. An oscilloscope, integral to the Timing Assembly, is used to monitor the 36-bit serial-code patterns as well as the phase of the 1-kHz carriers. The interim NCS time code generators are phase-shifted to bring them into agreement with the JPL Standards Laboratory code pattern.

The parallel BCD and binary outputs from the two time code generators as well as pulse outputs are input to an Inversion and Switching Assembly (ISA). This unit contains input receivers and switching logic to select inputs from either one of the time code generators and provide individually buffered outputs to the two Sigma-5 computers and to the two wall-mounted remote displays. The second time code generator serves as a backup unit and is switched into the system at the ISA in the event of a failure of the primary system.

Both computers can read the BCD and/or binary words into CPU general registers for availability to the software. The 1-pps and 1-kpps pulses are provided to the external priority interrupt systems of both computers.

D. Display Area

The display area peripherals are located in the operations area in Building 230. These peripherals interface with the real-time computer in the interim NCS data processing area. These peripherals are utilized by the operations personnel to input control information and to obtain display data from the interim NCS data processing area. In addition to the peripherals, an interface rack contains a data set for the TTY and line driver circuits for the line printer and CRT.

The display area is the location where control of the interim NCS is effected by the DSN operations personnel. The TTY unit provides a log of interim NCS status, DSIF status, and alarm information. The line printer is used to display selected data blocks received from the DSIF. The CRT/hard copy/keyboard is an interactive terminal to the real-time computer, and it is used for control of the operating modes of the software. The terminal also displays data which provide DSIF status and information useful to operation of the interim NCS.

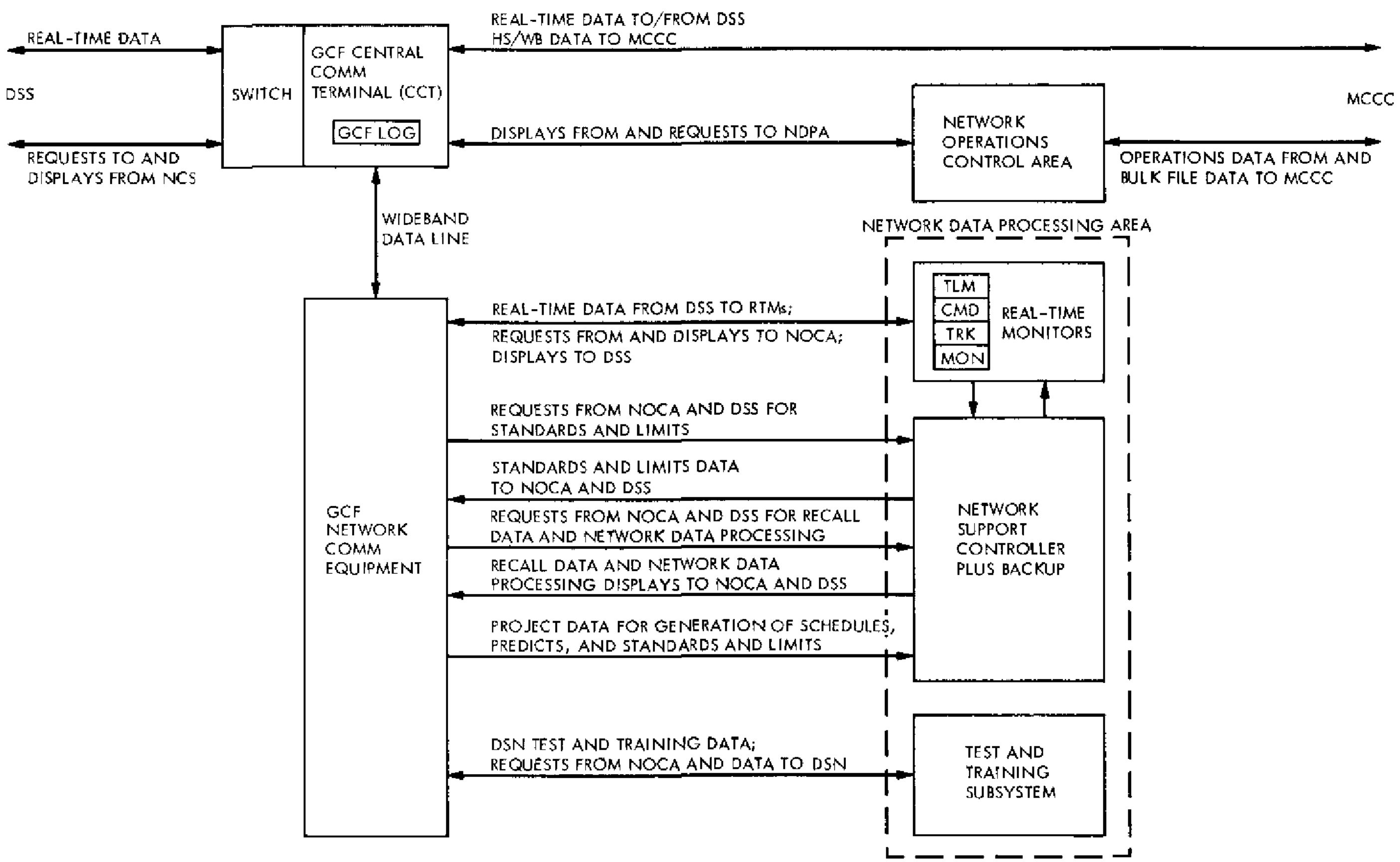


Fig. 1. NCS data and message flow requirements

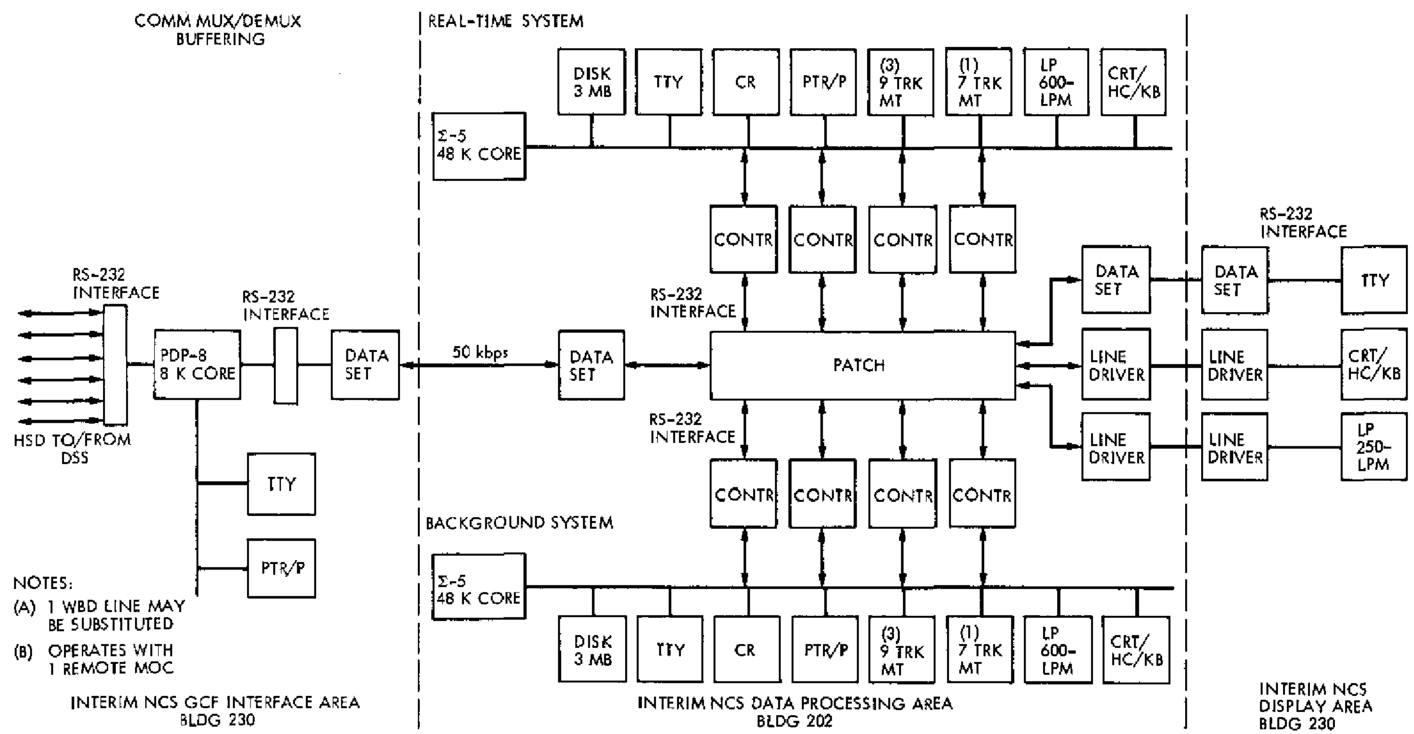
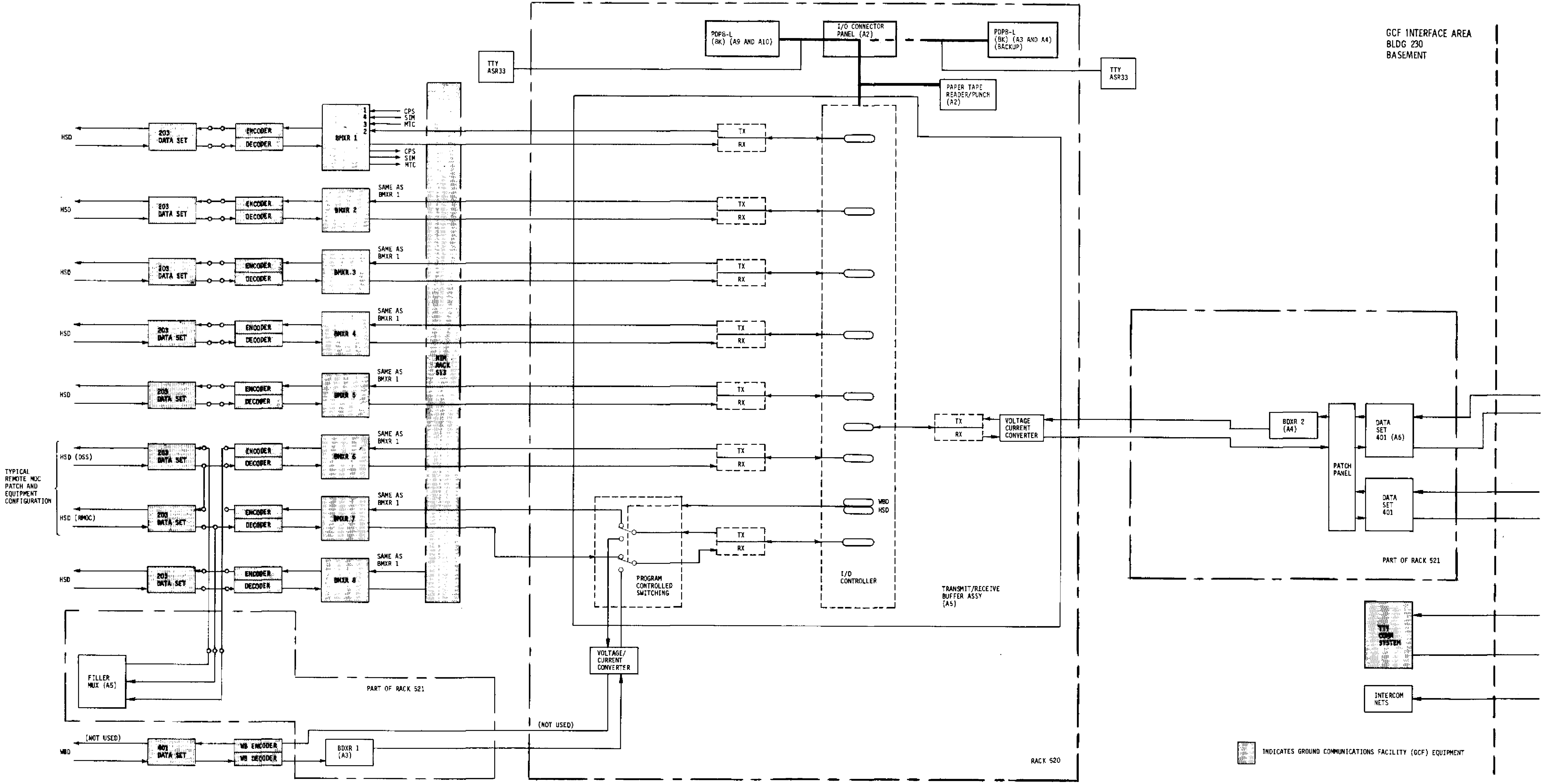


Fig. 2. Interim NCS hardware block diagram



GCF INTERFACE AREA
BLDG 230
BASEMENT
PDP8-L
(8K) (A9 AND A10)
I/O CONNECTOR
PANEL (A2)
PDP8-L
(8K) (A3 AND A4)
(BACKUP)
TTY
ASR33
TTY
ASR33
PAPER TAPE
READER/PUNCH
(A2)
HSD
203
DATA SET
ENCODER
DECODER
BMXR 1
CPS
SIM
MTC
CPS
SIM
MTC
SAME AS
BMXR 1
BMXR 2
BMXR 3
BMXR 4
BMXR 5
BMXR 6
BMXR 7
BMXR 8
TX
RX
HSD (DSS)
HSD (RMOC)
TYPICAL
REMOTE MOC
PATCH AND
EQUIPMENT
CONFIGURATION
WBD
HSD
PROGRAM
CONTROLLED
SWITCHING
I/O
CONTROLLER
TRANSMIT/RECEIVE
BUFFER ASSY
(A5)
VOLTAGE
CURRENT
CONVERTER
BDXR 2
(A4)
PATCH
PANEL
DATA
SET
401 (A6)
DATA
SET
401
PART OF RACK 521
TTY
COMM
SYSTEM
INTERCOM
NETS
FILLER
MUX (A5)
PART OF RACK 521
VOLTAGE/
CURRENT
CONVERTER
(NOT USED)
(NOT USED)
WBD
401
DATA SET
WB ENCODER
WB DECODER
BDXR 1
(A3)
RACK 520
INDICATES GROUND COMMUNICATIONS FACILITY (GCF) EQUIPMENT

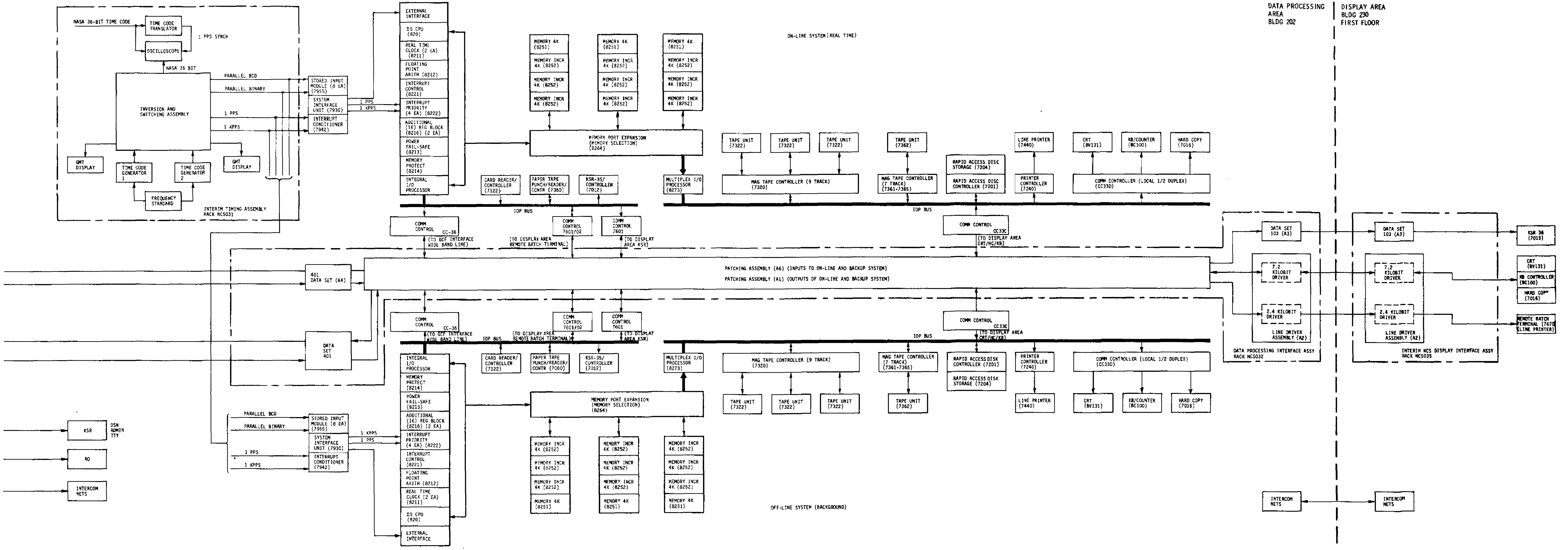


Fig. 3. Interim NCS detailed hardware block diagram