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DEVELOPMENT OF A COMPUTERIZED NUCLEAR MATERIALS CONTROL AND ACCOUNTING SYSTEM FOR A FUEL REPROCESSING PLANT

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ABSTRACT

A computerized nuclear materials control and accounting system (CNMCAS) for a fuel reprocessing plant is being developed by Allied-General Nuclear Services at the Barnwell Nuclear Fuel Plant. Development work includes on-line demonstration of near real-time measurement, measurement control, accounting, and processing monitoring/process surveillance activities during test process runs using natural uranium. A technique for estimating in-process inventory is also being developed. This paper describes development work performed and planned, plus significant design features required to integrate CNMCAS into an advanced safeguards system.

* * * * * * * *

Introduction

A computerized nuclear materials control and accounting system (CNMCAS) is being developed by Allied-General Nuclear Services at the Barnwell Nuclear Fuel Plant (BNFP). The objective of the CNMCAS development work is a system to provide an effective level of control and accounting for strategic special nuclear material in a typical, large-scale nuclear fuel reprocessing plant, which:

- Will satisfy both national and international requirements;
- Incorporate and demonstrate "state-of-the-art" safeguards techniques, equipment, instrumentation, etc., being developed at various U. S. sites;
- Will, by design, become an integral part of an advanced safeguards system.

The development of a computerized nuclear materials control and accounting system for a nuclear fuel reprocessing facility is a complex undertaking. Due to the complexity of the system, it must be developed and implemented by subsystem elements in planned stages over an extended period of time. CNMCAS development work has been split into two major, complementary activities:

- Conceptual design studies directed at describing the hardware configuration and software required for the total system,

- On-line demonstration to test and evaluate installed hardware and software concepts.

Both the conceptual design studies and the on-line demonstrations rely on the CNMCAS development system currently installed at the BNFP.

CNMCAS Conceptual Design Studies

During FY 1978, a preliminary conceptual design was prepared using the BNFP as a test bed.[1] Highlights of the preliminary conceptual design are described below.

The CNMCAS will represent a modular network of computers, communications equipment, and data collection, storage, and retrieval devices to demonstrate sophisticated, automated nuclear materials management capability. As conceived, the CNMCAS will be composed of several interrelated "software" subsystems. These subsystems include:

(1) A measurement subsystem to accumulate data required for determining nuclear material quantities,

(2) A nuclear materials accounting subsystem to provide real-time accounting of nuclear materials,

(3) A measurement control subsystem to check the quality of measurement data and generate measurement uncertainty statistics,

(4) An item and seal control subsystem to maintain the status of all discrete nuclear material items and tamper-safing seals on a current basis,

(5) A physical inventory subsystem to determine the quantities of nuclear materials contained in the facility,

(6) A process monitoring/process surveillance subsystem to monitor dynamic and static process locations for verification of nuclear materials control, and

(7) Subsystems to interface the CNMCAS with the Nuclear Materials Management and Safeguards System (or other external agency) and a Safeguards Coordination Center.

The CNMCAS also incorporates a Laboratory Data System (LDS), which provides analytical information and a remote data acquisition system to collect measurement and monitoring data from process instrumentation. Figure 1 presents the interfaces between the CNMCAS subsystems.

The conceptual design is periodically reviewed and revised based on the results of CNMCAS demonstrations and more detailed analysis of the requirements of the system. A revision of the conceptual design is currently in progress and will be issued as an FY 1979 report.

CNMCAS Development System

The CNMCAS development system currently installed at the BNFP is composed of three main components:

(1) CNMCAS central processing unit (CPU) plus input/output terminals and mass data storage devices

(2) Remote data acquisition system

(3) Laboratory data system.

The basic hardware configuration for the current CNMCAS development system is presented in Figure 2. Note that all equipment shown will be incorporated in the final CNMCAS hardware configuration, although specific functions may be revised.

The CNMCAS CPU incorporates a real-time operating system, RSX11M, and software for the demonstration programs is prepared using BASIC-PLUS 2 language. Critical software elements include the communication links between the CNMCAS CPU and the LDS and the remote data acquisition system. These links transmit sample requests, receive analytical results, and request and receive measurement data.

The Laboratory Data System has been successfully operated for about three years. It consists basically of a PDP 11/35 computer with 128 K of memory, two mag tape transports, two disk drives, and a line printer. Various input/output (I/O) devices are located throughout the laboratories, the plant areas, and in the process control rooms. The LDS is based on the Resource Sharing-Time Sharing (RSTS/E) operating system using the BASIC-PLUS language processor. All incoming samples are logged into the system, and as samples are analyzed, the data are entered and the results are calculated by the system. After the analyst approves a result, this information is available to any terminal on the system. When all constituents for a sample have been completed, a final report is printed on the line printer. Many types of laboratory instruments, some equipped with their own dedicated minicomputers, are interfaced to the system.

The heart of process and accountability measurement data collection for CNMCAS is the remote data acquisition (RTP) system. The system is composed of a PDP 11/04 preprocessor servicing multiple analog and digital controllers which are connected to instrument signal outputs. A significant portion of the measurement equipment in a reprocessing facility incorporates pressure differential sensors and transmitters with 4 to 20 milliamp output signals. In addition, process temperatures are monitored by signals from thermocouples. On-line monitors are also connected to the system. The digital output of the Ruska precision pressure gauges is currently processed by the system via digital controllers. Figure 3 presents a schematic of the remote data acquisition system.

Several hundred instruments are currently interfaced to the remote data acquisition system. The system scans the instrument signals at a rate of up

to forty per second. To smooth inherent randomness, readings for certain instruments are accumulated and averaged. The rate at which the system scans the signals is hardware dependent. The order in which the instruments are scanned is software-controlled.

To effect real-time data acquisition plus the averaging function, the instruments connected to the remote data acquisition system are divided into scan groups. The system monitors these groups per software-controlled sequences or scan modes. The basic scan mode includes all the instruments in the system. This mode stores only the most recent measurement data and discards previous data from storage.

Higher level scan modes interrupt the basic scan mode at preset intervals to monitor specific instrument groups for programmed time periods. The measurement data accumulated for each instrument in these scan modes are averaged to eliminate random instrument signal fluctuations and the averaged values are stored. The higher level scan modes retain several readings for each instrument to allow rate-of-change analyses by the CNMCAS. The PDP 11/04 preprocessor is programmed in machine language.

CNMCAS Demonstration Programs

CNMCAS development work conducted and planned during FY 1978 and FY 1979 includes on-line demonstration programs in conjunction with integrated test runs at the BNFP using natural uranyl nitrate solution. These demonstrations carried selected elements of the measurement, accounting, measurement control, and process monitoring/process surveillance subsystems through basic stages of development and implementation, i.e.,

- Software descriptions and specifications
- Software preparation
- Hardware procurement and installation
- Software/hardware on-line testing.

A uranium input/output demonstration program was first conducted in FY 1978[2] with an advanced demonstration following in FY 1979. These demonstrations used the CNMCAS development system for the measurement, accounting, and measurement control functions required for the following process steps:

- Input uranium feed
- Product uranium generated
- Liquid waste discarded.

The demonstrations produced the following significant achievements:

- Computer-controlled scanning of several hundred process and specialized accountability (Ruska DDR-6000 precision pressure gauge) instrument signals at various frequencies and durations,

- Storage and conversion of instrument signals to engineering units,

- Computer-coordination of measurement/transfer activities,

- Real-time comparison of redundant measurements using control limits to flag measurement anomalies,

- Generation of measurement/transfer batch summary reports,

- Automated transmission of sample requests and analytical results,

- Real-time accounting for individual points within a material balance area (MBA) and MBA transfers; use of preliminary data and fully automated report generation including material balance reports, and

- Interfacing of random and systematic error variances with quantity data to provide limit-of-error information for each material balance component and the total material balance.

Comprehensive process monitoring and process surveillance are extremely important elements of an integrated safeguards system in a nuclear fuel reprocessing plant. A process monitoring/process surveillance (PM/PS) demonstration program is currently in progress at the BNFP. The primary objective of this demonstration is to test and evaluate potential PM/PS functions to be incorporated in the CNMCAS. Functions being tested include:

- Process alarm monitoring
- Physical inventory monitoring
- Transfer flow direction confirmation
- Solution quantity transferred versus received comparison
- Simulated plutonium nitrate storage including theft/diversion tests.

The process alarm function operated satisfactorily since early in the FY 1979 integrated uranium run. Current alarm display, printout, storage on disk, and historical alarm printout from disk storage have been demonstrated. Methods for making best use of these data are being evaluated.

The physical inventory monitoring function was demonstrated during the final inventory. CNMCAS continuously monitored each vessel as it was isolated for inventory to ensure that liquid levels remained static until the inventory was completed.

The product quantity transferred versus input quantity received comparison was demonstrated in the Separations Facility. The remaining PM/PS functions will be demonstrated in the plutonium product areas during August 1979.

An in-process inventory demonstration program directed at developing a technique for near real-time estimation of measurable process holdup was performed. The estimation is based on real-time liquid level, density and temperature measurements integrated with calculated flowsheet and/or analytical values for density, and uranium and acid concentrations. Major process holdup and surge vessels are incorporated in the demonstration. The demonstration is part of the basic work required to achieve the long-term goal of real-time inventory capability in a large fuel reprocessing plant. Results

indicate the program was a satisfactory first step toward this long-term goal.

CNMCAS Development Plans - Near Term

In the near-term the CNMCAS conceptual design will be revised. Major items to be addressed in the revision include:

- Incorporation of the real-time operating system (RSX11M) which replaced the original time-sharing system (RSTS/E),
- Updated computer hardware requirements and configuration incorporating CNMCAS demonstration experience,
- Addition of computer security features,
- Expansion of CNMCAS subsystem design descriptions based on FY 1978 and FY 1979 demonstration results, and
- Enhancements to the remote data acquisition system.

Tentative CPU requirements have been developed which reflect the need for redundancy and separating software development work from the operating system. These requirements are summarized below:

- Remote Data Acquisition System
  - Upgrade Existing PDP 11/04 to a PDP 11/34
- CNMCAS Central CPU's
  - PDP 11/60 #1 - Separations Controller
  - PDP 11/60 #2 - Master Data Base Controller
  - PDP 11/60 #3 - Redundancy and Development Work
  - PDP 11/60 #4 - Redundancy and Development Work
- Fuel Receiving and Storage Station
  - PDP 11/34 - FRSS Controller
- Laboratory Data System
  - PDP 11/35 #1 - Existing CPU
  - PDP 11/35 #2 - Redundancy and Development Work (existing CNMCAS CPU)

A conceptual CNMCAS hardware configuration is shown in Figure 4.

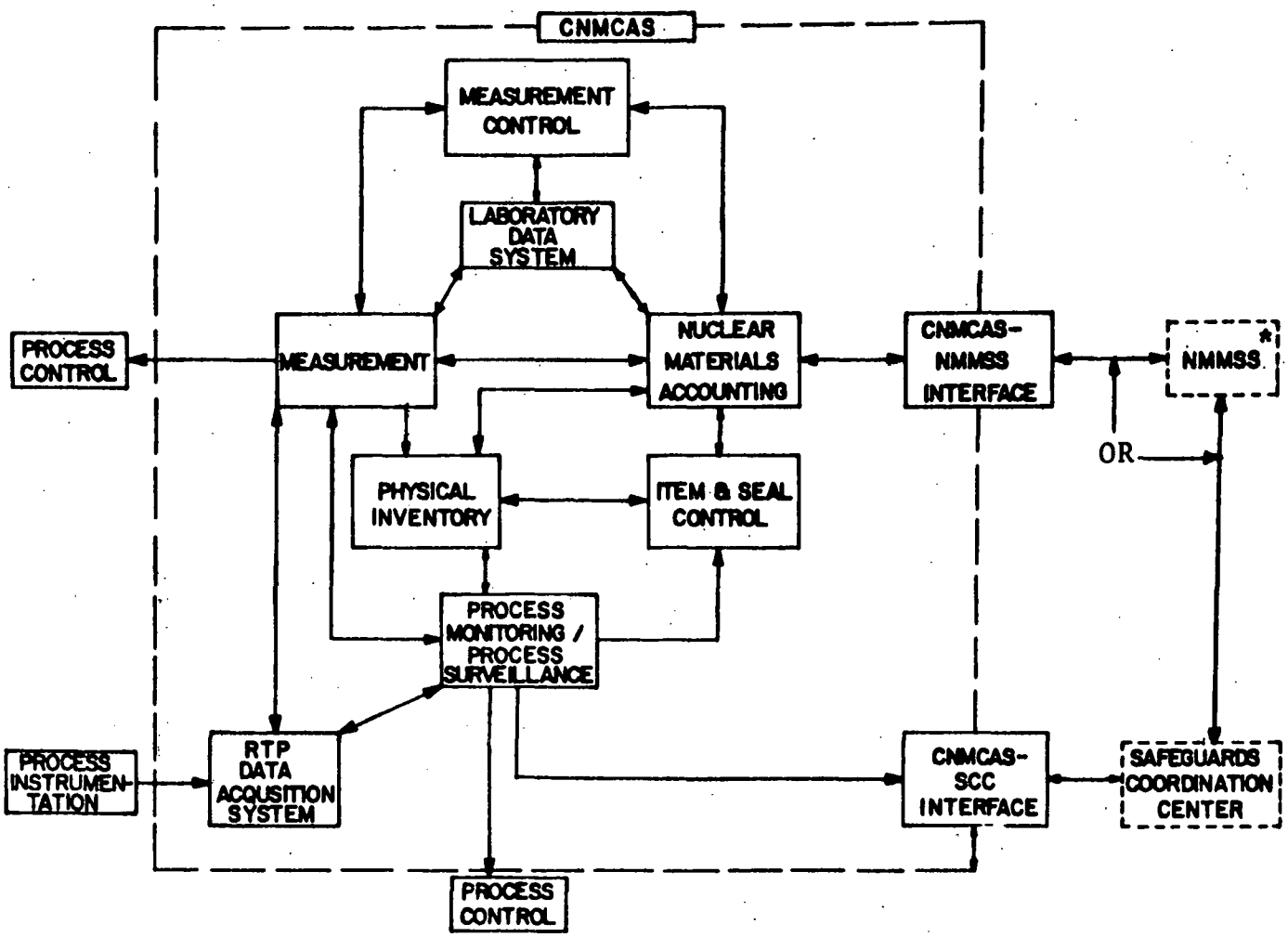
An integrated process run is not scheduled in FY 1980. Therefore, CNMCAS demonstration work will be directed at specific problems and new development areas. For example, considerable work is planned on in-process inventory estimation under ideal conditions.

The results of CNMCAS development work to date have justified the decision to proceed in planned stages rather that attempting to detail the design of the total system in one step. The experience and knowledge gained from the conceptual studies and on-line demonstrations will be invaluable in the continuing effort to develop and implement the CNMCAS.

References

(1) J. M. Crawford, M. H. Ehinger, C. Joseph, M. L. Madeen, "Conceptual Design of a Computerized Nuclear Materials Control and Accounting System (Preliminary Report)", AGNS-1040-2.2-18, May 1978.

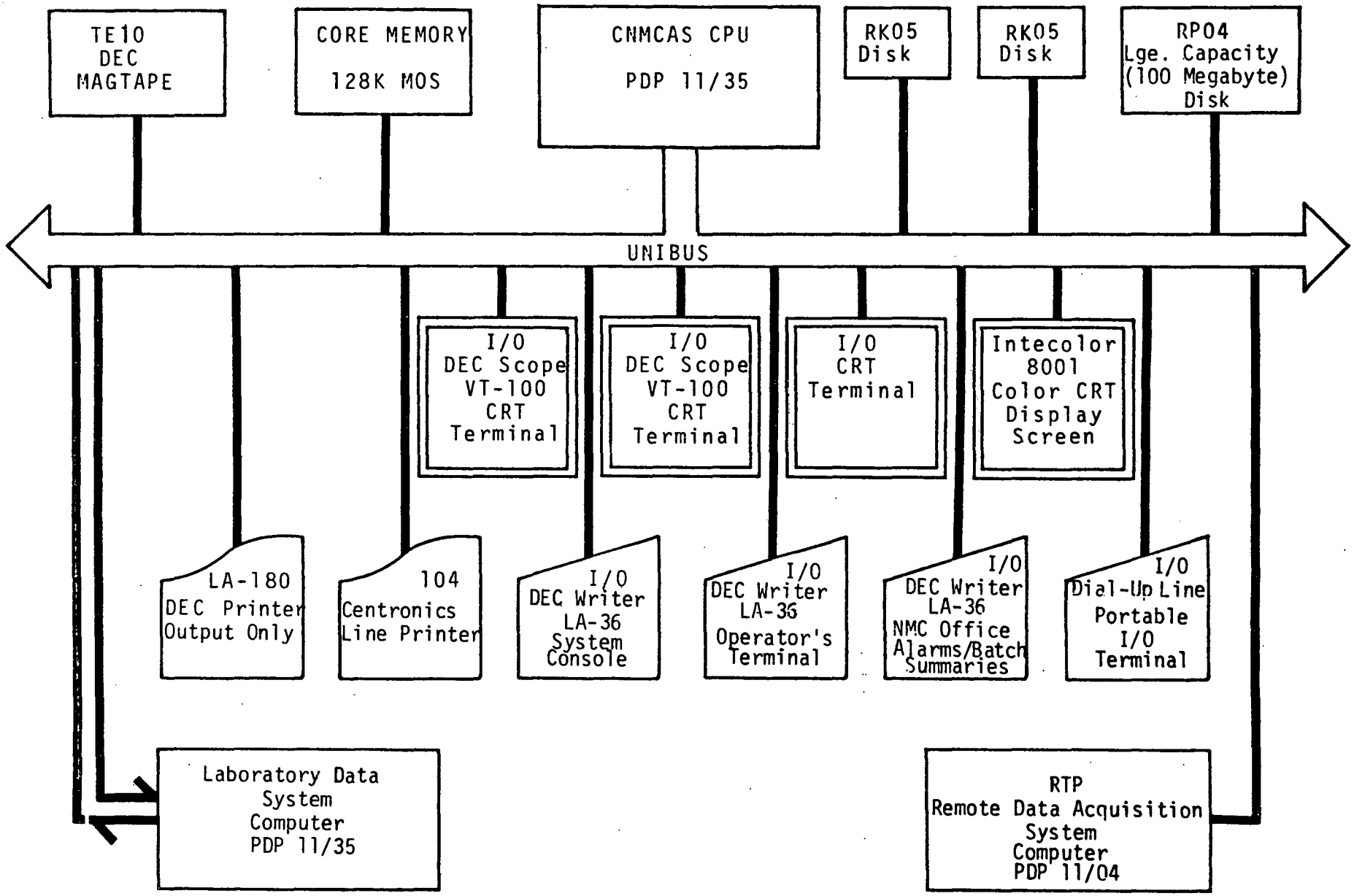
(2) J. M. Crawford, M. H. Ehinger, C. Joseph, M. L. Madeen, "Computerized Nuclear Material Control and Accounting System Development Evaluation Report - FY 1978", AGNS-1040-2.2-9, October 1978.



* OR OTHER EXTERNAL AGENCY

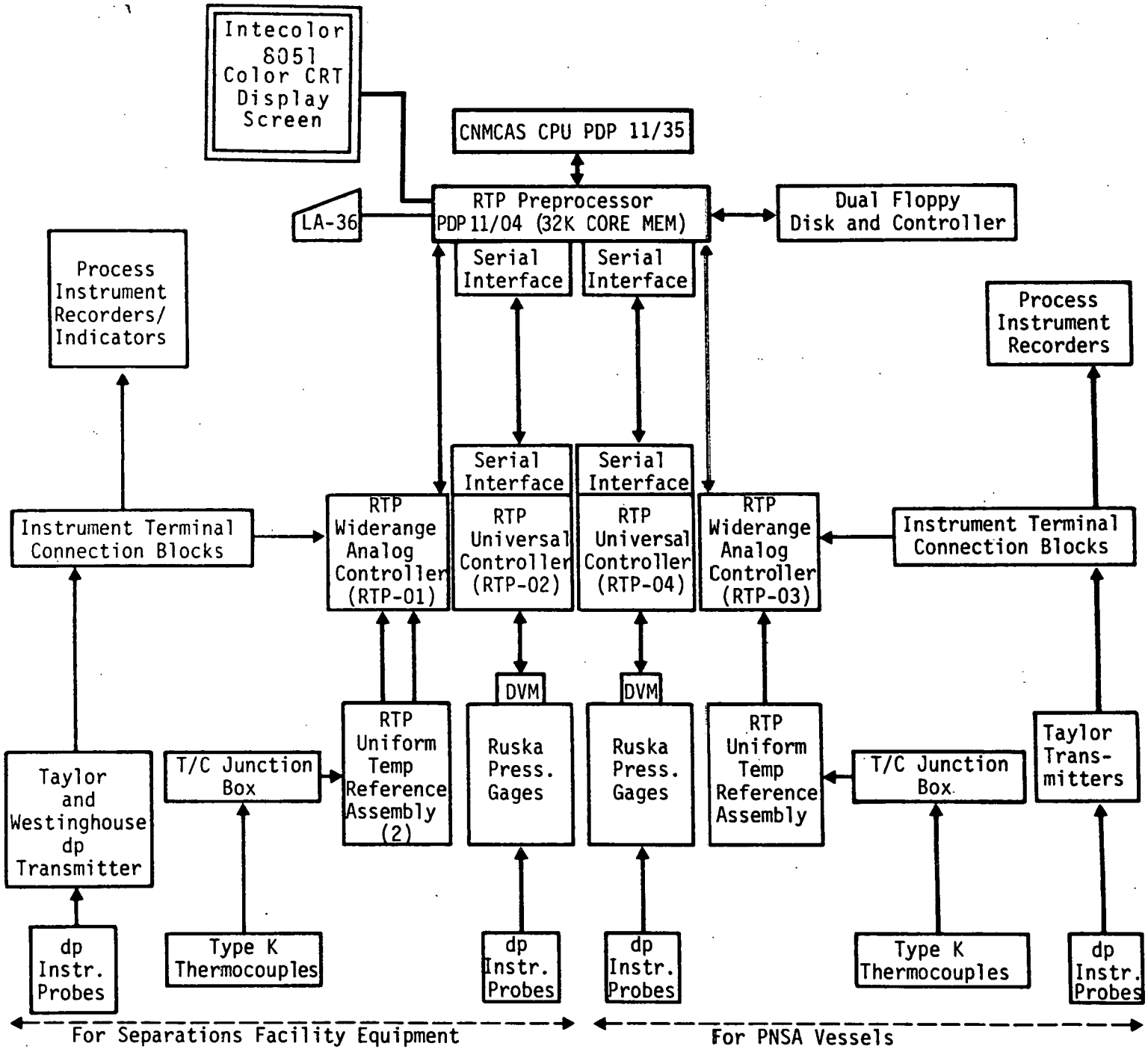
CNMCAS INTERFACES

FIGURE 1



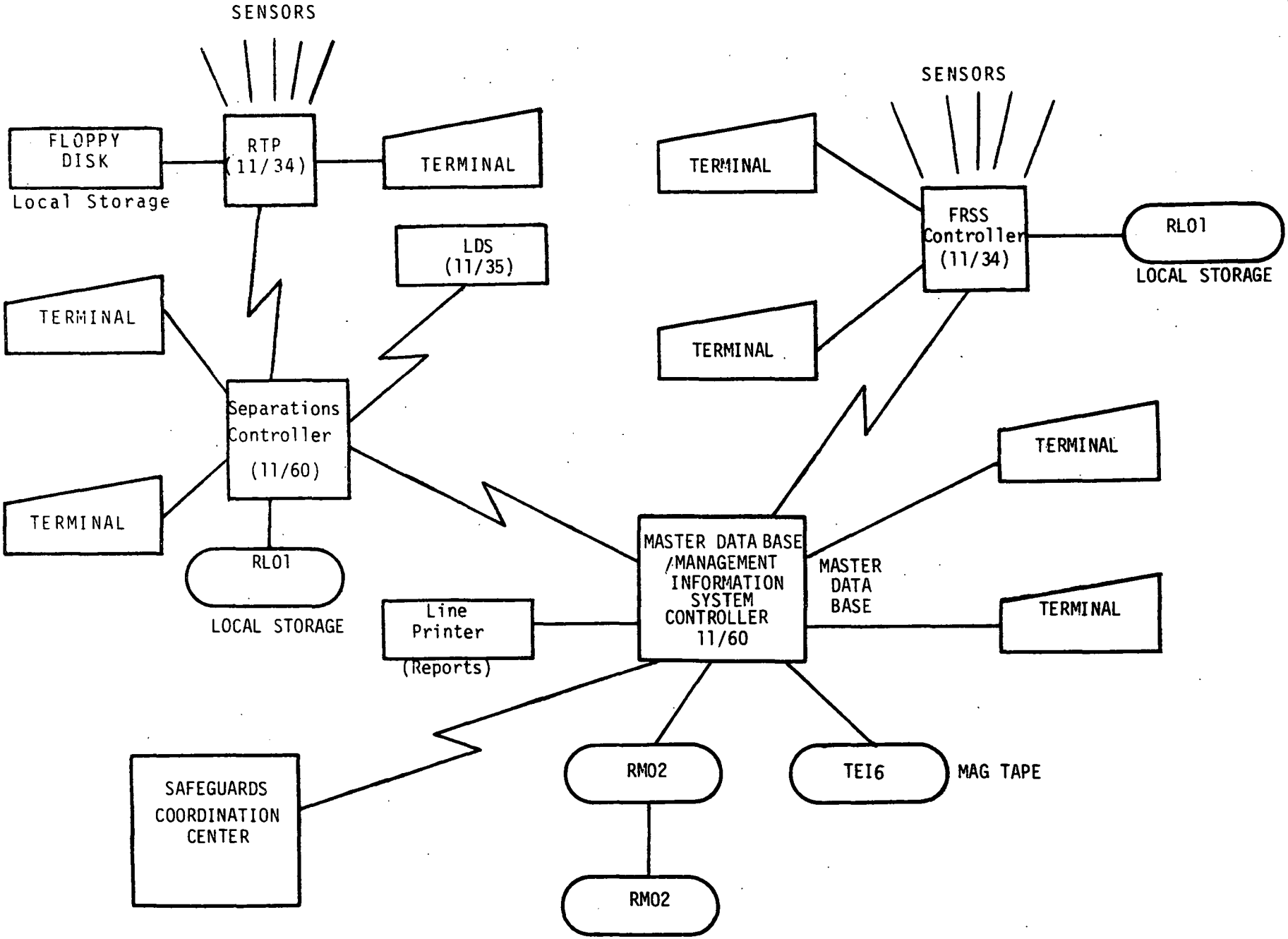
BASIC HARDWARE FOR CNMCAS SYSTEM

FIGURE 2



REMOTE DATA ACQUISITION (RTP) SYSTEM - FY 1979

FIGURE 3



CNMCAS SCHEMATIC - CONCEPTUAL

FIGURE 4

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