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OVERVIEW OF THE INSTRUMENT CONTROL AND DATA REDUCTION SOFTWARE IN THE SANDIA DATA ACQUISITION SYSTEM AT THE NEVADA TEST SITE

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ABSTRACT

Sandia National Laboratories has developed a sophisticated custom digital data acquisition system to record data from a wide variety of experiments conducted on nuclear weapons effects tests at the Nevada Test Site (NTS). Software is a critical part of this data acquisition system. In particular software has been developed to support an instrumentation/experiment setup database, interactive and automated instrument control, remote data readout and processing, plotting, interactive data analysis, and automated calibration. Some software is also used as firmware in custom subsystems incorporating embedded microprocessors. The software operations are distributed across the nearly 40 computer nodes that comprise the NTS Wide Area Computer Network. This report is an overview of the software developed to support this data acquisition system. The report also provides a brief description of the computer network and the various recording systems used.

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1. Introduction

Sandia National Laboratories has developed an extensive data acquisition system to record data from a wide variety of experiments conducted on nuclear weapons effects tests at the Nevada Test Site (NTS). These experiments are typically conducted using nuclear devices detonated in either N-tunnel or P-tunnel in Area 12 at NTS. All of the data recorded by the NTS data acquisition system are time domain waveforms of signal amplitudes.

This report is an overview of the software developed to support this data acquisition system. The report also provides a brief description of the computer network and the various recording systems used. The document describes the software system as it existed and evolved starting with DISKO ELM test in September 1989 through the SENTINEL exercise in December 1994.

2. Recording Hardware and Computer Network

The Sandia NTS data acquisition system contains the following principal hardware subsystems:

- SANDUS/SANDACE - low/mid frequency underground analog-digital system
- Tektronix 7912 - high frequency analog-digital recording system
- Tektronix 7103 - high frequency analog oscilloscopes
- High density digital tape recorders (HDDR)
- Mass Memory solid state memory digital data recorders
- Wideband fiber optic analog data links
- High speed digital fiber optic data links
- Ethernet digital fiber optic data links
- AUTOCAL - 7912 automatic calibration subsystem
- AUTOSIM - automated signal simulation subsystem
- Computer network
- LeCroy 6880 high frequency data recorders (No longer supported)
- LeCroy 7242B data recorders
- ACE - local controllers/network interface for recording subsystems
- Tektronix RTD720 - high frequency data recorders (DNA-owned)

A simplified block diagram of the recording system configuration used on a typical NTS event is shown in Fig. 1. Low and mid frequency signals are recorded underground in SANDUS [1] and SANDACE recording systems. The digitized data are sent to an aboveground Record Facility [2] over 20 Mbit/sec high speed digital fiber optic data links using Pulse Code Modulation (PCM) synchronous formatted bit streams. These data streams are recorded in both Mass Memory [3] and HDDR [4] systems located in Bldg. 909 in Area 12 which is approximately 7 km from the underground recording locations.

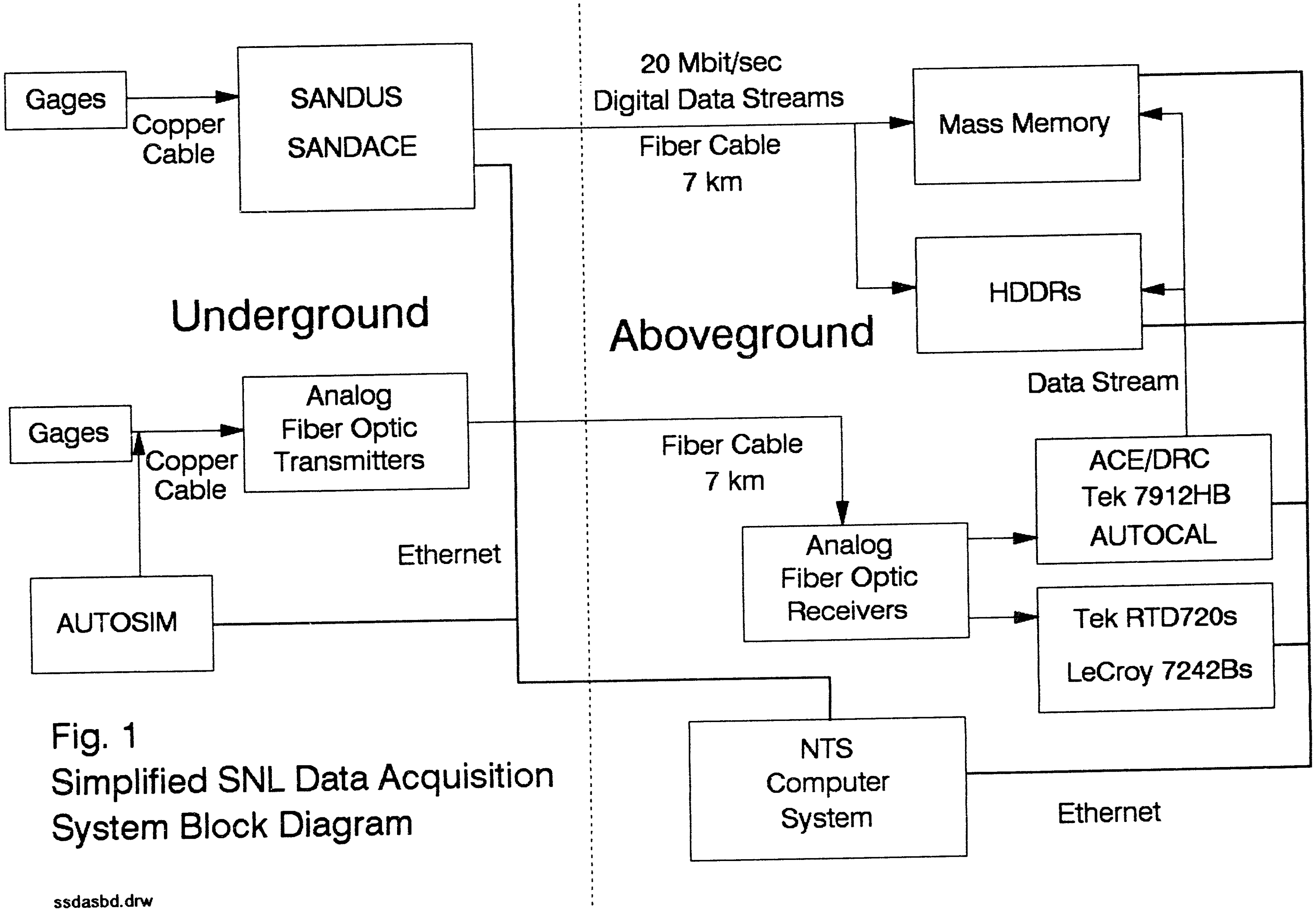


Fig. 1
Simplified SNL Data Acquisition System Block Diagram

ssdasbd.drw

High frequency signals are sent to Bldg. 909 via wideband analog fiber optic data links similar to those described in [5]. The signals are recorded by either Tektronix 7912HB [6], Tektronix RTD720 [7], or LeCroy 7242B waveform recorders. The 7912 system was originally designed to work underground. Thus it sends its data over high speed digital data links to the Record facility to also be recorded by the Mass Memory and HDDR systems. The RTD720s and the 7242Bs send their data directly to the computer network via IEEE 488 General Purpose Instrumentation Bus (GPIB) interfaces. In the past we have also recorded high frequency data underground using LeCroy 6880 waveform recorders. Even though 6880s are no longer supported, a description of the control and readout software will be included for the sake of completeness. Some high frequency signals are also recorded by Tektronix 7103 oscilloscopes using cameras and photographic film. These film records are digitized offline and transferred to the computer network via DEC TK-50 tapes.

The 7912, SANDACE, and LeCroy 6880 recording subsystems are controlled by a Alternate Common Equipment (ACE) chassis [8]. The ACE is a VME-based subsystem controller using both commercial and custom modules. The ACE controller modules were purchased from Force Inc. and use a Motorola 68000 microprocessor. The ACE can communicate with data recording equipment and the computer network via the following interfaces: RS-232/422, ethernet (custom protocol), GPIB, custom command link, and a custom data link.

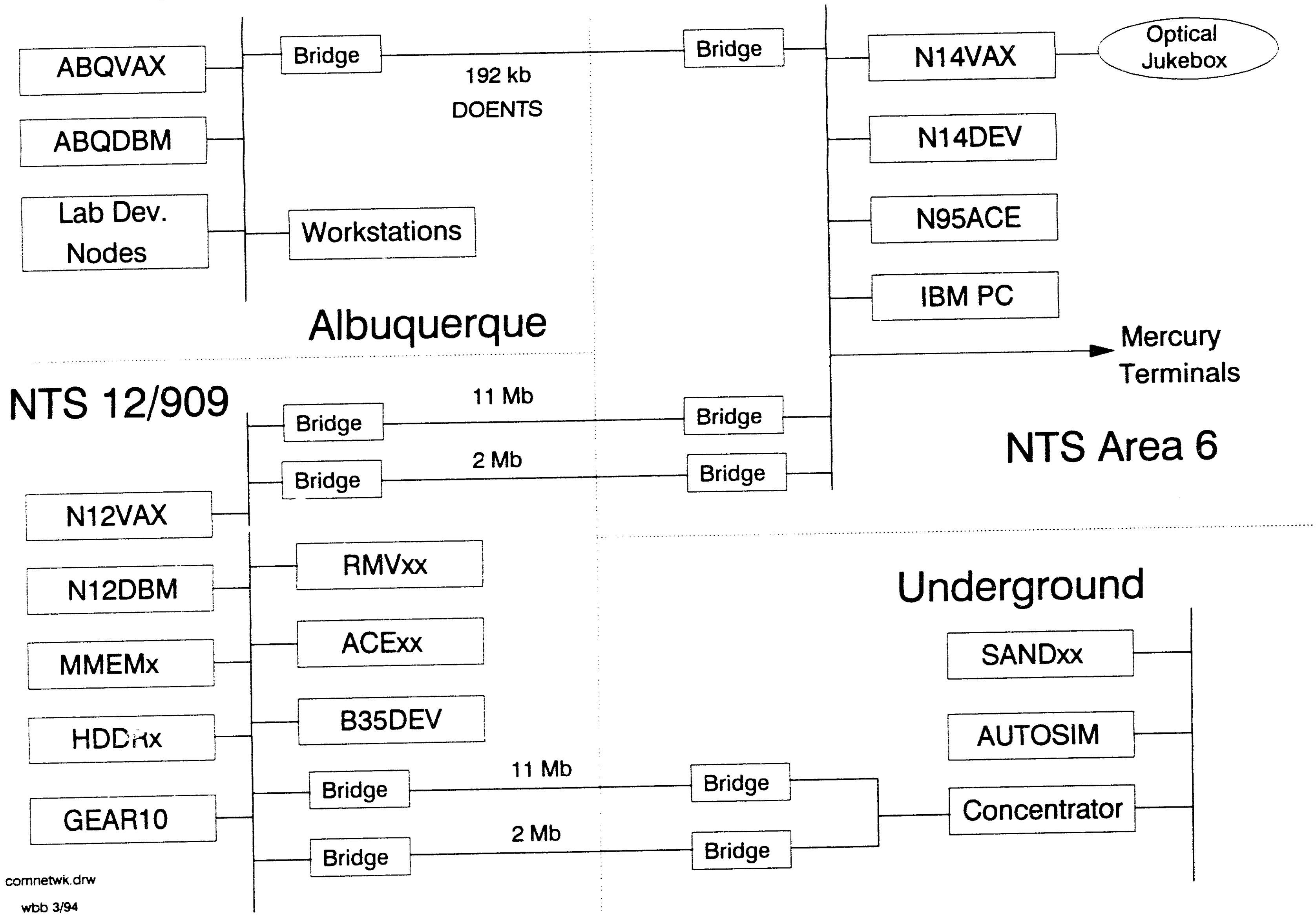
Some of the major components of the data acquisition system are described in more detail in the following sections.

2.1 Computer Network

The computer network consists almost entirely of Digital Equipment Corp. (DEC) VAX computers running the VMS operating system [9]. A simplified block diagram of the network is shown in Fig. 2. The network has major facilities in Bldg. 962 in Area IV at SNL/New Mexico, in Bldgs. CP-14, CP-214, and CP-95 in Area 6 at NTS, and in Bldg. 909, adjacent trailers, and underground in Area 12 at NTS. The various sites are connected as a Wide Area Network (WAN) by various types of Bridges. Large machines, 6420s, and an 8350, are used for software development, overall recording system control, and data archiving and analysis. Smaller MicroVax IIs are used in recording subsystems for local interactive control. MicroVax IIs are also used in the Mass Memory and HDDR systems to transfer production data into the computer network.

The data acquisition and processing tasks require that many of the nodes and accounts in the NTS system have nonstandard and in some cases extraordinarily high VMS quotas and privileges. Determining and maintaining these quotas and privileges while maintaining adequate quality and security is a major challenge for the computer system management team.

Fig. 2 SNL NTS Wide Area Computer Network



Normally the computer network operates in an unclassified mode. Since some of the shot data is classified, the portions of the network in CP-14 and 909 and the encrypted WAN link between them are configured for classified operation for NTS events. The main part of the system at NTS is not connected to the SNL/New Mexico computers during this period. The system remains in this classified configuration for about 2 months after an event. The classified systems are then sanitized and the entire network is restored to unclassified operation.

Another important feature of the network is the use of RS-232/422-to-GPIB convertor boxes. These converters are used by the AUTOSIM software to control signal simulation pulse generators and precision system characterization waveform recorders throughout the tunnel complexes, in development laboratories, and in recording rooms.

In the past all users have worked on simple DEC VT-100, 200, and 300 series and Tektronix 4208 terminals. We have recently added a number of DEC VAX 4000/VLC window-based workstations to the network. We have also recently added a few NCD ethernet window terminals. We are converting to an X-window-based user environment.

2.2 SANDUS

The Sandia Digital Underground System (SANDUS) is a low and mid frequency analog and digital waveform recording system custom-developed inhouse for unattended operation in the severe underground environment at NTS [1]. Low frequency digitizing modules, TA591 [10], can record signals with bandwidths from DC to 100 kHz with either 8 bits resolution and 16k samples or 12 bits of resolution and 8k samples. In addition these modules can be configured as "real-time" channels and send continuous data to the uphole Record Facility. Mid frequency digitizing modules, TA592, can record signals with bandwidths up to 10 MHz and sample up to 50 Ms/sec with 8 bits of resolution and 16k samples. The TA592 modules incorporate two analog-to-digital converters (ADC). This dual ADC feature must be dealt with several places in the software.

Both of these recording modules may be used in either a SANDUS or a SANDACE recording subsystem. A SANDUS contains 128 channels and is controlled by a local DEC LSI-11 embedded microcontroller, the TA485A. SANDACE systems contain either 32 or 64 channels and are controlled by ACEs.

2.3 Tektronix 7912HBs

The Tektronix 7912HB waveform recorders can digitize analog signals with bandwidths up to 750 MHz. They are used at sample rates as fast as 5 ns/div which corresponds to approximately 100 ps/sample. The 7912 recording systems were originally designed to work underground. Since the 7912s have volatile memory (data is lost when power is removed), a custom device called the Data Retention Chassis (DRC) was designed to transfer data from the 7912s, store it in nonvolatile memory, and transfer it to the Record Facility via a 20 Mb/sec link before ground shock arrival at about 200 msec [11]. Each DRC can control up to 16 7912s. The 7912 systems are interfaced to the computer network for downloading settings and local control via ACEs which access the 7912s through the DRCs. Each ACE can control up to 64 7912s.

The data from the 7912s consists of the locations of the top and the bottom of the trace defining the input analog signal as stored on a diode matrix inside the device's scan convertor tube [12]. The output data also contains locations of defects or spurious points in the diode matrix. Trace location data may be missing if signal transitions are too fast; or the trace is not positioned properly; or if the signal is deflected offscale. This data must be converted by the software into a usable waveform for further analysis.

7912 subsystems also contain a computer controlled calibration capability called AUTOCAL. The AUTOCAL hardware consists of precision DC, sinewave, and pulse signal generators and signal routing switches. The software that runs this calibration hardware is also called AUTOCAL.

2.4 Record Facility

The Record Facility is located in room 131 in Bldg. 909. It contains two major subsystems, the Mass Memory and High Density Digital Recorder (HDDR). The purpose of both is to record the 20 Mbit/sec high speed digital data streams sent from either SANDUS or ACE recording subsystems. From MISTY ECHO (Dec. 1988) through the HUNTERS TROPHY event (Sept. 1992) all production data from Sandia experiments have been collected using the Record Facility.

Mass Memory and HDDRs are used redundantly on NTS events. The data stream from each waveform recording subsystem is sent to each type of uphole recorder. Normally Mass Memory is designated prime for ACE systems, and HDDR is designated prime for SANDUS systems. As will become clearer later, the data streams processed by the Record Facility are the fundamental unit of reference for virtually all of the NTS data acquisition system software.

Normally the various recording subsystems continuously read the contents of memory from the waveform recorders and send the digital data to the Record Facility. This feature is referred to as a "live stream" and is very useful in debugging the system.

Mass Memory uses solid state memory systems provided by Dataram Inc. There are four Mass Memory subsystems called MMA thru MMD. Each can record up to four data streams designated MM1A, MM2A,...MM4D. Data from each Mass Memory subsystem is read into the computer network by a dedicated MicroVax II via a Dataram interface board. The software program DECOM is used to read and process Mass Memory Data.

The HDDRs are high speed digital tape recorders. The four tape recorder subsystems are designated HDDRA thru HDDRD. Each HDDR can record up to four high speed data streams designated HDDR1A, HDDR1B, ... HDDR4D. There is a MicroVax II used to control and read data from each HDDR subsystem. Data from HDDRs as well as from live data streams are read into the computer network via a combination of an EMR-8330 demultiplexer and a SNL developed TA667 Data Distributor. The EMR-8330 must be properly set up via computer-control over an RS-232 interface. The TA667 communicates with the MicroVAX II via a DEC DRQ-11 16-bit parallel interface controller. In addition each HDDR subsystem contains the following custom ancillary custom hardware: TA653 HDDR Control and Auxiliary Data Demultiplexer [13], TA652 HDDR Timing and Auxiliary Data Multiplexer [14], TA717 Function Interface [15], TA737 Function Matrix [16], and a TA668 Local Data Selector. The TA653 and TA717 can be controlled from the MicroVAX II via DRQ-11 interfaces. The software program FETCH is used to control all HDDR equipment and read the data.

2.5 GPIB Recording Subsystems

The Tektronix RTD720 and LeCroy 7242B high frequency data recording subsystems are designed for reliable operation only in the aboveground environment. Both control and data readout are accomplished using GPIB interfaces to either MicroVAX II or VAXstation 4000 VLC control computers. The relatively slow GPIB readout, reliance on disk-based local controllers, and lack of an interface to the NTS range-timing subsystem make these recording subsystems unsuitable for use underground. The RTD720s are owned by the Defense Nuclear Agency (DNA) and operated by Sandia in support of DNA experimenters. The RTD720 control software was developed for DNA and is described completely in [7]. The LeCroy 7242Bs are similar to the RTD720s in many respects. The RTD720 computer and software architecture has been modified to support the 7242Bs. We have begun work to include support for the Tektronix SCD5000 and SCD1000 waveform recorders in the GPIB software system.
Each major GPIB subsystem, e.g. all possible RTD720s, is controlled by a master node called GEARxx. GEAR stands for GPIB Ethernet Analog Recording node, and xx is the serial number, e.g. 10.

GPIB-based recording systems have only been used for SNL advanced instrumentation development and production recording (using the RTD720s) for DNA experimenters. In the future we plan to use the LeCroy 7242Bs to record production SNL data.

3. Software System Overview

This section provides an overview of the overall NTS data acquisition software. The key subgroups of the overall software system are:

- Instrumentation Database
- Control-Account Software
- Dry Run/Shot day automated data processing software
- Interactive data reduction software (DSP)
- Interactive instrument control and setup software
- Utility programs

Each subgroup is described in more detail in following sections. The various data file formats are described in section 9. Finally a section on embedded microcontroller firmware is also included.

Fig. 3 shows a data flow diagram of the various major software components and data structures used in the SANDUS and ACE portions of the NTS data acquisition system. Fig. 4 shows a similar diagram for the GPIB recording subsystems.

The vast majority of the VAX software in the system is written in Fortran. The code uses VMS system calls extensively. The code also uses a number of DEC extensions to Fortran 77. In particular the STRUCTURE extension feature of VAX Fortran forms the basis of most of the programs in the system.

A number of procedures are written in VMS DCL language. These include CONTROL, SCHEDULER, and much of DSP.

3.1 Documentation

A number of SAND reports have been written describing various software programs. These are included in the references. Reference [7] contains a large amount of system software documentation. Other programs have good but less formal documentation. The type and location of the documentation for these other programs may be found in Appendix A.

4. Instrumentation Database and Instrument Control Files

The Instrumentation Database contains the following types of information: administrative data, instrument setup data, and data processing instructions. Administrative data consists of experimenter names, DNA experiment numbers, descriptions, etc. Instrument setup information contains all of the relevant programmable settings for all of the recording devices and ancillary equipment used in the the recording system. This section also includes all necessary hardware addressing information, e.g. data stream definitions, GPIB addresses, coax switch control paths, etc. Data processing instructions include such items as engineering unit conversions, software cable compensation information, plot axis limits, signal demultiplexing boundaries, etc.

The database is implemented using the Ingres relational database management software package. Access to the database is accomplished via an extensive database application software package written in Fortran and using Ingres enhanced Fortran database access statements. This application provides a number of customized screens for easy entry and modification of data by operators from terminals. The application also generates a variety of reports.

A major design decision by the software development team and management was that the Ingres Instrumentation Database only resides on a couple of network nodes (primary and backup). The information is propagated to the rest of the network via conventional VMS direct access flat files called Instrument Control Files (ICF). (ICFs used to be called "Tables"). Besides historical bias, the major reasons for this decision were that accessing the flat files would be much faster than Ingres database access, and Ingres licenses would not have to be purchased and maintained on the 35-40 nodes on the network. A major part of the database application software is to create ICFs from the database tables and in the case of high frequency recorders update the database from instrument setting data in the ICF. ICFs are described further in Section 9.2.

There is one ICF per Record Facility data stream. Also there is one ICF per GPIB bus for GPIB recording systems. ICFs are always stored in the directory DD:[TABLES] on whichever node they are needed.

For high frequency recording systems there are actually three independent databases for instrument settings and signal processing information. The first one is used for actual dry run and shot data. The other two support two kinds of special tests, Laser Calibration and Software Cable Compensation. These special tests often require different recorder settings from those used for actual data, e.g. gain, record boundaries, etc. All three sets of settings are included in each ICF.

Fig. 3 SNL NTS DAS Software Data Flow Diagram

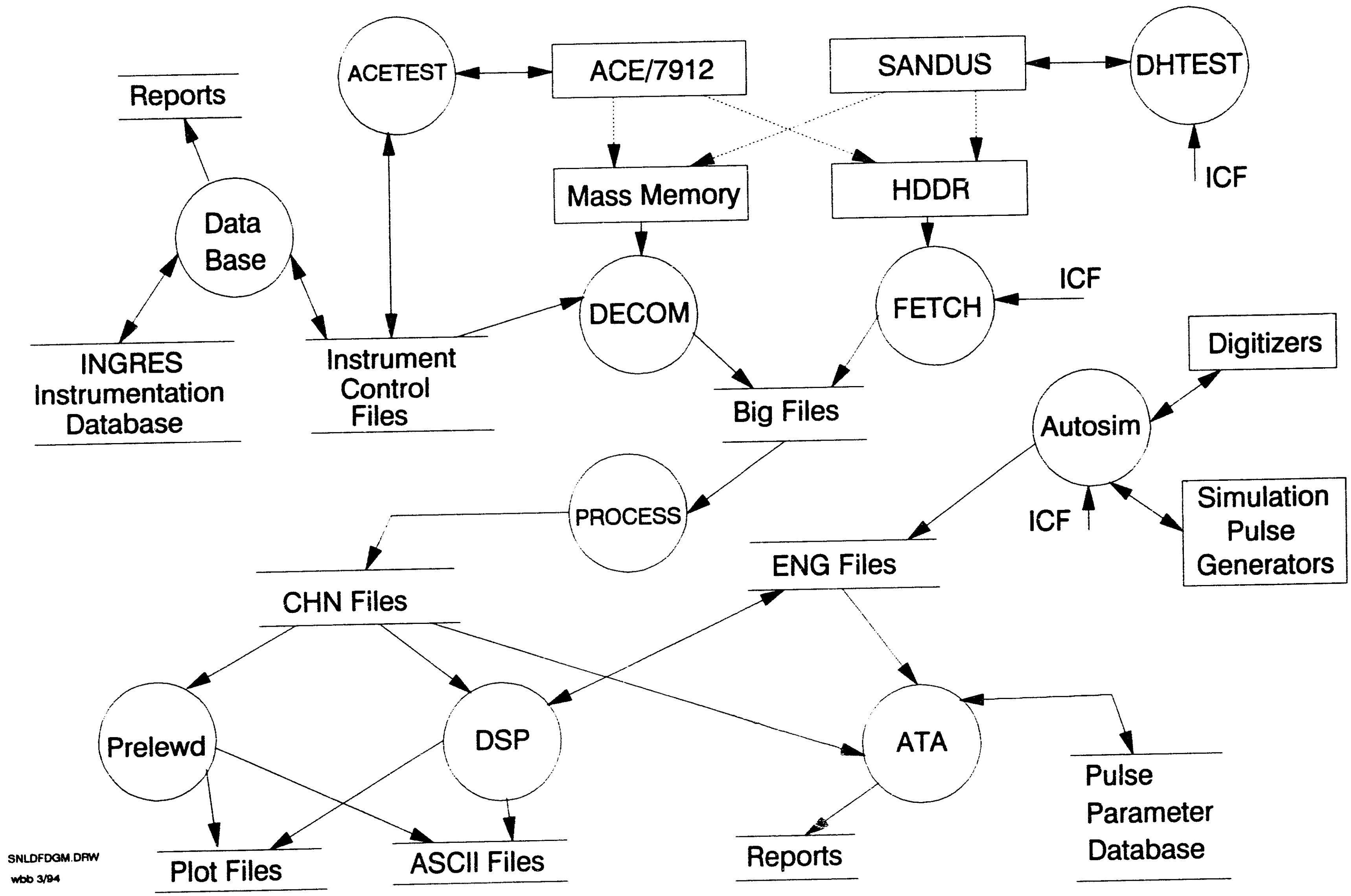
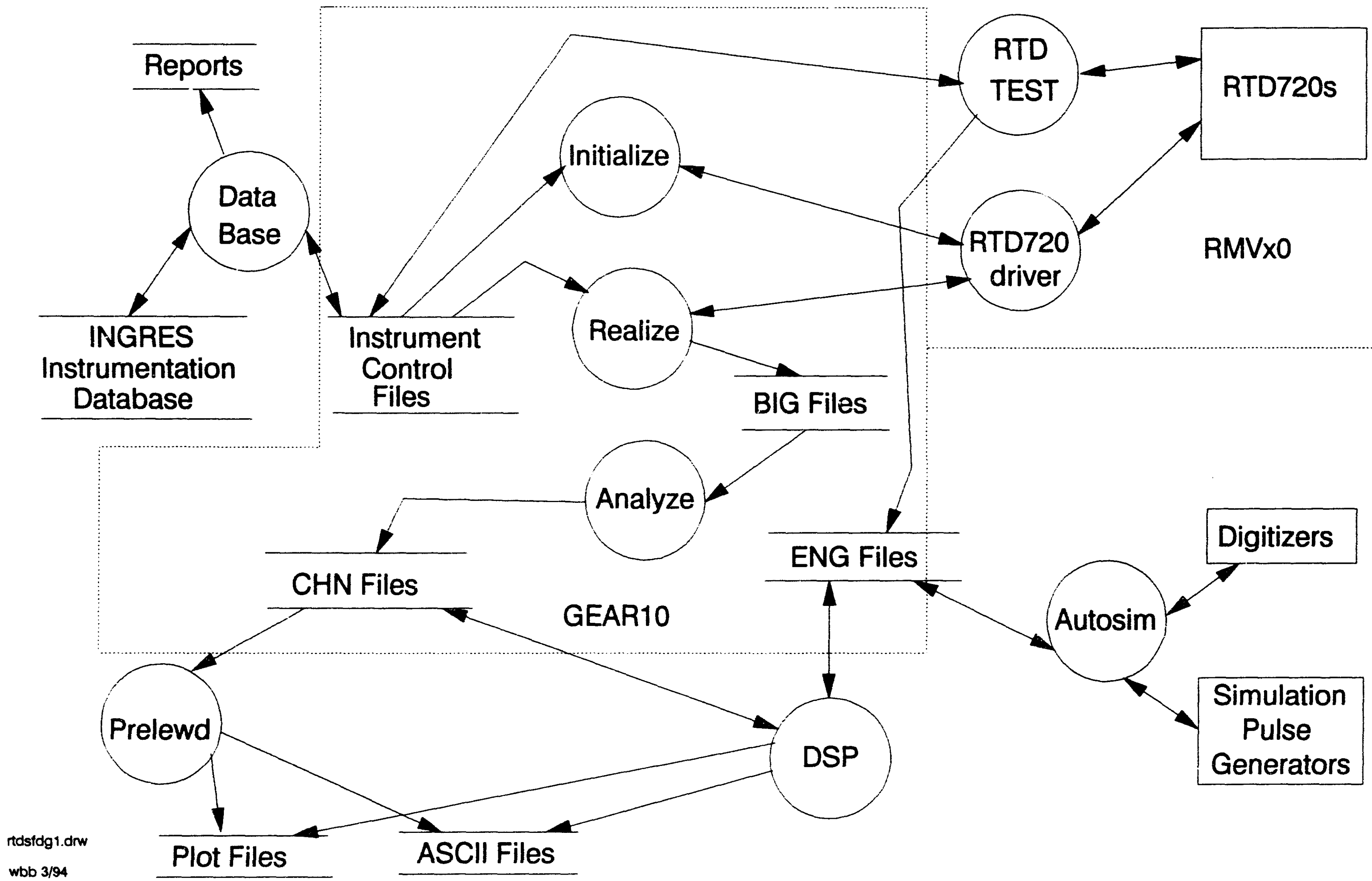


Fig. 4 RTD720 Software Data Flow Diagram



5. Control-Account Software

The CONTROL Account is a special captive VMS account used to control access to the various system programmable hardware [17]. The CONTROL account provides users with the exceptionally high VMS privileges required to run instrument control software. It maintains system and data integrity by severely limiting the actions a user can perform. The CONTROL software is written in VMS DCL language. When a user logs on with username CONTROL, the CONTROL software first verifiers the person is an authorized CONTROL account user and then further verifies the user via an internal password check. It then presents the user with a limited menu of options he/she can perform. The menu is customized depending on the type of node and thus recording system the user is running on. Thus CONTROL only offers the user access to the interactive control programs applicable to the system he/she is working on, e.g. DHTEST, ACETEST, RTDTEST, LECTEST. Two other options CONTROL typically provides are the ability to retrieve the most recent ICF from the database and to send an updated ICF back to the database.

6. Automated Dry-Run and Shot Day Software

Figs. 3 and 4 show the data flow paths for the Record Facility and the GPIB-based data recording systems respectively. The functions of many of the programs in the two systems are very similar. The change to new programs with new names was made for the GPIB system because some of the older programs, particularly PROCESS, were getting too complicated by the sequential addition of new types of data recorders. Each set of software is discussed below.

6.1 Record Facility Software

The programs described below are considered part of the automated dry run/shot day processing sequence. These programs are normally scheduled automatically by the SUPERvisor/MONitor code SUPERMON. However they may also be run manually, and this is often required for special data recovery operations. The programs PRELEWD and ATA also support GPIB-based waveform recorders.

Note that none of the software in this path causes ICF programmable settings to be downloaded to the waveform recorders or to ancillary support hardware. These settings must be transferred in a semiautomated mode using either DHTEST for SANDUS and SANDACE or ACETEST for 7912s and 6880s.

6.1.1 SUPERMON

The controlling program in processing Record Facility data is called SUPERMON. SUPERMON schedules the execution of the programs CONTROL, FETCH, DECOM, PROCESS, and PRELEWD. One set of programs is scheduled for each data stream being recorded. SUPERMON dynamically displays the status of the processing stream in various blocks of various screens on VT compatible terminals. The program provides the capability for creating, saving and recalling any number of "scenario definition files" for processing data.

6.1.2 FETCH

The program FETCH controls the programmable equipment associated with the HDDR system and reads data either from an HDDR tape or from a live data stream via the TA667 Programmable Data Distributor and the appropriate DRQ-11 controller in its associated MicroVAX II. The data is normally decommutated by the EMR 8330 PCM Decommutator. FETCH opens I/O channels to control the following HDDR system programmable hardware: TA667, EMR8330, TA653 Tape Controller, and the TA717 Function Interface. FETCH detects a t-zero interrupt from the TA717. FETCH must normally be run from the CONTROL account because CONTROL has the necessary high privileges and quotas.

In a single execution FETCH reads one ICF, processes data from one data stream and produces up to three output data BIG files and one output log file. The three possible output files are calibration (CAL), memory (MEM), and realtime (REL). FETCH receives its input instructions primarily from the ICF. These instructions may be modified by parameters entered on the command line. FETCH creates a multichannel output file called a BIG file which is described in 9.3. FETCH normally produces its BIG file on the node it's running on; it then copies the BIG file to both N12VAX and N14VAX for further processing. FETCH also produces a log file of processing information and error messages. The program supports a number of command line options.

FETCH processes SANDUS data in three phases. In the first phase data from mid-frequency TA592 modules are collected. In the second phase data from low-frequency TA591 modules are collected. In the third phase data from real-time TA591 modules are collected. The third phase requires that the HDDR tape be rewound and reread for small groups of real-time channels. Currently the size of these small groups is one.

FETCH is also used on the SANDUS local MicroVAX controllers to read data from the live stream via the TA666 Data Selector and a DRQ-11 controller.

6.1.3 DECOM

The program DECOM reads data from a Mass Memory data stream via the Dataram controller in its associated MicroVAX II. DECOM must decommutate the data it reads. It also must locate zero-time in the data. In a single execution DECOM reads one ICF, reads data from one of the Mass Memories, and creates an image of the Mass Memory contents in a "Stream" file. It then decommutates the stream data and produces both calibration and output data BIG files. DECOM also produces an output log file. DECOM receives its input instructions primarily from the ICF. These instructions may be modified by parameters entered on the command line. DECOM must normally be run from the CONTROL account because CONTROL has the necessary high privileges and quotas.

6.1.4 PROCESS

The program PROCESS performs various processing functions on the data contained in a BIG file. The operations performed are different depending on the type of waveform recorders represented in the data. In a normal single execution PROCESS reads one BIG file and produces a CHN file for each signal contained in the BIG file. BIG file and CHN file formats are described in 9.3 and 9.4.

PROCESS will handle both actual data and calibration data BIG files. For SANDUS and for the LeCroy 6880s, calibration data records are produced by internal system hardware under range-time control in the 5 minute time period before zero-time. For the 7912s calibration data is produced by running the AUTOCAL software manually. This is may be done either 48 hours or 2 hours before the dry run or the shot. PROCESS does some calculations on calibration data and stores appropriate values in the header for the actual data CHN file. For SANDUS data (both memory and real-time) PROCESS performs data compression. PROCESS produces a log file of processing information and error messages.

6.1.5 PRELEWD

The program PRELEWD is primarily used to produce batch mode plots of dry run and shot day data on the laser printers in the system. In this mode it produces a plot of all of the CHN files in a specified subdirectory. PRELEWD plots are well annotated with administrative, recorder setup, and calibration information. The program converts binary waveform recorder raw data to engineering units by applying recorder calibration information and either linear or specified nonlinear gage conversion factors. PRELEWD may also be run interactively to produce the same plots on a terminal screen. PRELEWD produces a log file of processing information and error messages. PRELEWD uses a version of the Graphical Kernel System (GKS) plotting package purchased from ATC Inc.

PRELEWD can also produce ASCII format file outputs. The format used is called SRAD which is compatible with the experimenter archiving and analysis software supported on the Department 9312 computer network.

6.1.6 ATA

ATA stands for Automated Trend Analysis. This collection of programs along with the Ingres database creates, maintains, and generates reports from a database of pulse parameter measurements [18]. Normally the pulse parameter measurements are made on waveforms containing dry run signal simulation pulses. The program was designed to have three major functions. First ATA can print customized reports of the measured pulse parameters for a dry run. Although not fully implemented yet ATA was intended to be able to compare the parameters for each signal on each dry to a standard for that signal and produce a report of deviations. The intent was that this would make it much easier for recording subsystem operators to locate problem channels. Finally ATA can automatically track trends if parameters are changing. Such trends might be an indication of a problem in the making. In practice our recording systems do not reach a stable state until about 3 weeks before an event, if then. We have not had the time to load the "standard" waveform parameters into the database. However experimenters and system operators have found the pulse parameter reports useful and wish to continue using the program.

In its automated execution mode ATA will process all of the CHN files in a specified subdirectory. It first converts the data to engineering units as described for PRELEWD in Section 6.1.5. It then computes ~ 37 pulse parameters using algorithms developed for DSP. The parameters are stored in an Ingres database. A wide variety of custom reports are available. ATA will also measure and store pulse parameters from ENG files. In order to use ATA, one must be a valid Ingres database user.

6.2 GPIB-based Recording System Software

This software is described completely in [7] as implemented for the RTD720 recorders on HUNTERS TROPHY. The sections below describe the implementation that supports both the RTD720s and the LeCroy 7242Bs. There have been two significantly different versions of this software. In the automated collection mode that was used on HUNTERS TROPHY the various programs were run from the master node GEAR10 using the program SCHEDULER. The setup program INITIALIZE and the readout program REALIZE were split between the GEAR10 node and the local control RMVxx nodes. After HUNTERS TROPHY we regressed to a temporary standalone mode where both SCHEDULER and GEAR10 have been eliminated. The various programs are now run from the CONTROL account directly on the VLC control computers. These computers are now referred to as VGDxx nodes instead of RMVxx nodes. The standalone software supports having RTD720s and 7242Bs mixed on the same GPIB. We are currently designing a completely new version of this software that will also support aboveground test facilities. The new version will return to using the master/slave control computer/software architecture.

6.2.1 SCHEDULER

SCHEDULER is a program written in VMS DCL language that provides for automatically setting up and reading data from a number of RTD720 waveform recorders connected directly to local control nodes [7]. Fig. 4 shows a data flow diagram of this operation. The various programs involved in these operations are described later. This code normally runs on the GEAR10 type VAX node.

SCHEDULER is run from the GEAR10 CONTROL account.

6.2.2 INITIALIZE

The program INITIALIZE reads a specified ICF and downloads all of the programmable settings therein to the appropriate waveform recorders. Previously INITIALIZE ran on a GEAR10 type VAX node. It used VMS task-to- task communications and DECnet to pass information to a co-program called GPIB_HANDLER running on an RMVxx type VAX node. Programmable settings information were passed from INITIALIZE to GPIB_HANDLER. Status and error messages were passed the other direction. INITIALIZE creates an output log file of processing information and error messages. The current standalone version runs completely on a VGDxx VAX node and does not use task-to-task communications. There is one copy of INITIALIZE running for each GPIB bus being used.

6.2.3 REALIZE

The program REALIZE reads data from all of the waveform recorders defined in a specified ICF. Previously REALIZE ran on a GEAR10 type VAX node. It used VMS task-to-task communications and DECnet to pass information to a co-program called GPIB_HANDLER running on an RMVxx type VAX node. Instrument definition information was passed from REALIZE to GPIB_HANDLER. Waveform data and status and error messages were passed the other direction. REALIZE stores all of the waveform data acquired from the instruments on the bus in a single BIG file. REALIZE also creates an output log file of processing information and error messages. The current standalone version runs completely on a VGDxx VAX node and does not use task-to-task communications. There is one copy of REALIZE running for each GPIB bus being used.

Before reading data, REALIZE polls all of the digitizers on the bus to determine if they have triggered and completed collecting data. This process is complicated by the fact that both the RTD720 and 7242B can record multiple records into segmented memory following multiple arm and trigger sequences. The polling works well when all triggers are received. REALIZE provides for operator intervention in the case where not all triggers are received.

6.2.4 GPIB_HANDLER

The program GPIB_HANDLER sends settings, checks trigger status, and reads data from all of the waveform recorders on a specified GPIB. The program runs on an RMVxx type VAX node. Previously it worked in conjunction with either INITIALIZE or REALIZE running on a GEAR10 type VAX node. The programs used VMS task-to-task communications and DECnet to pass data and status information back and forth. GPIB_HANDLER may be run either on a MicroVAX II where it supports the DEC IEQ11 type dual GPIB interface or on a VAXstation 4000/VLC where it supports DEC IEZ11 SCSI type GPIB interfaces. In the master/slave implementation, GPIB_HANDLER also creates an output log file of processing information and error messages on the RMV node.

In the standalone GPIB software system the functions of GPIB_ HANDLER have been incorporated into INITIALIZE and REALIZE. Also in this version the log file information is contained in either the INITIALIZE or REALIZE log file.

6.2.5 ANALYZE

The program ANALYZE processes data from BIG files to produce CHN files. There is a CHN file produced for every signal defined in the Instrumentation Database and thus in the ICF. Due to time-domain multiplexing and multirecord recording, there may be many CHN files produced for each waveform recorder channel. In addition ANALYZE produces a CHN file containing the entire record for a given recorder channel. ANALYZE runs on either a GEAR10 or VGDxx type VAX node. There is no automatic external calibration capability associated with GPIB-based recorders. Thus, unlike PROCESS, ANALYZE does not have to handle external calibration data in creating CHN files. ANALYZE produces a log file of processing information and error messages. There were no significant changes required for ANALYZE in going to the standalone mode.

6.2.6 PRELEWD and ATA

PRELEWD makes batch mode plots of the data from GPIB-based recorders as described in 6.1.5. ATA measures pulse parameters from data from GPIB- based recorders as described in 6.1.6.

7. Interactive Data Reduction Software, DSP

The Digital Signal Processing (DSP) workstation provides a wide range of signal processing functions. These functions include interactive plotting, zooming, waveform measurements, transformations, smoothing, filtering, data comparisons, and linear system characterization. Its primary purpose is to analyze data files associated with radiation-effects testing at the NTS, but it may also be used with other sources of signal data. DSP is designed for a VAX/VMS computing system. It uses the commercial GKS software for graphics. It may be executed in menu/prompt mode or automated by macro files.

8. Interactive Instrument Control Software

This section describes the various software programs written to provide interactive control of waveform recorders and other programmable instruments in the data acquisition system.

8.1 DHTEST

The program DHTEST provides for interactive control, setup and testing of SANDUS and SANDACE recording systems. DHTEST uses the information in an ICF to download proper settings to the recording system. DHTEST also uses intermediate files called Master and Working files to temporarily store settings information. Unlike the similar programs ACETEST and RTDTEST, DHTEST does not have the capability of changing setting information in an ICF and sending the ICF back to the database for updating. Thus all SANDUS setting information must be entered directly into the Ingres database using the database application software. Also, unlike the other programs, DHTEST has no ability to acquire and plot data. SANDUS operators must use FETCH, PROCESS and DSP or PRELEWD to do this. DHTEST normally runs on the MicroVAX II computer located in a given SANDUS. However the program can be run from any node on the network and communicate with the SANDUS TA485 controller via DECnet and a downhole terminal server port. This allows communication with SANDUS in case of an emergency on shot day.

8.2 ACETEST

The program ACETEST provides for interactive control, setup and testing of Tektronix 7912 and LeCroy 6880 recording systems. ACETEST uses the information in an ICF to download proper settings to the recording system. ACETEST has the capability of changing setting information in an ICF and sending the ICF back to the database for updating. The program can acquire and plot data locally. It can also produce BIG files for further processing by PROCESS, PRELEWD, and DSP. ACETEST normally runs on the local subsystem controller MicroVAX II. However the program can be run from any node on the network and communicate with the ACE controller either directly via ethernet or via a terminal server port. This allows communication with recording systems in case of an emergency on shot day.

The ACETEST INIT command must be used to download the programmable settings from the database and ICF to the recorders. ACETEST makes heavy use of the DRC in setting up and checking out 7912 systems and similarly makes heavy use of the TA709 for 6880 systems.

8.3 AUTOCAL

The AUTOCAL program provides the capability of performing external automatic calibration of the Tektronix 7912 system. The program's main sequence of operations is first to send appropriate settings to one of the calibration signal generators: a DC voltage source, a sinewave generator, and a programmable pulse generator. It then routes the calibration signal to one of the 7912s via a system of coax switches. It programs the 7912 to record the calibration signal. Finally the program reads the calibration data, checks it for validity and stores the output in a special form of a BIG file called a CALBIG file. AUTOCAL gets all of its setup information from an ICF. The program controls the 7912s via the ACE and DRC. It controls the calibration signal generators and the coax signal switches using the ACE as the GPIB controller.

AUTOCAL may be run either on a local subsystem controller microVAX or on one of the HDDR microVAXes. When running on a local controller, it uses a DEC IEQ11 GPIB interface to collect 7912 data. When run on an HDDR controller, it collects data from the high speed digital bit stream from the DRC.

AUTOCAL also contains provisions for automatically adjusting the 7912 focus setting using the internal grid and for automatically adjusting the trace intensity. These values are updated in the ICF for later updating in the Ingres Instrumentation Database.

8.4 AUTOSIM

The AUTOSIM program provides several capabilities associated with controlling signal simulation pulse generators underground and acquiring data from waveform recorders used to characterize the outputs from the pulse generators [19]. AUTOSIM is a menu-base program using the VMS forms management utility FMS. The program can read simulation generator setup parameters from an ICF and download the settings to the hardware. It can also turn power on and off to the various simulation stations underground. It can place a system in repetitive trigger mode or generate single triggered outputs. The software can also set up and trigger the analog fiber optic downhole calibration system. AUTOSIM can read data from Tektronix 11801, SCD5000 and TDSxxx (xxx=620, 640, 820) waveform recorders and from Hewlett Packard network analyzers. It stores digitized waveforms in disk files in ENG format. The ability to read data from downhole waveform recorders is critical both for computing k-factors and for generating software cable frequency response compensation functions.

AUTOSIM communicates with various equipment it controls via RS232-to-GPIB conversion boxes. These boxes are in turn connected to terminal server ports. For NTS events these systems are primarily located underground. However they may be connected anywhere on the network that a terminal server port is available. AUTOSIM can run on virtually any node on the network.

8.5 RTDTEST and LECTEST

The programs RTDTEST and LECTEST provide for interactive control, setup, testing, data acquisition, and plotting from Tektronix RTD720 and LeCroy 7242B waveform recorders respectively. RTDTEST provides the capability of modifying the instrument settings fields in the ICF and causing the Ingres Instrumentation Database to be updated. Both RTDTEST and LECTEST are menu-based programs. RTDTEST currently uses the VMS forms management utility FMS. They are typically run from the

CONTROL software on the local VGDxx type VAX nodes. Both programs can generate ENG type output data files for further processing. Note that unlike the SANDUS and 7912 systems, the use of an interactive control program is not necessary to download proper settings to the recorders before a dry run or the shot. These two programs are used for troubleshooting and for acquiring data for special tests.

9. Data Files and Directories

This section provides a brief description of the various data file contents and file and directory naming conventions used in the NTS data acquisition system software.

9.1 Instrumentation Database

The Instrumentation Database consists of relational database tables created and maintained using the Ingres software package. Access to these files is normally via database application programs written in Fortran. The Instrumentation Database is maintained both in Albuquerque on the node ABQDBM and at NTS on node N12DBM.

9.2 Instrument Control Files

The information in the Instrumentation Database is copied to Instrument Control Files (ICF) for dissemination to the rest of the data acquisition system. In the past proper dissemination of ICFs was a major problem. The system was modified in 1991 for the DISTANT ZENITH event, and nearly all of the old problems have been eliminated [20]. Information can be placed in an ICF by one of the following methods:

1. Copying it from the Instrumentation Database
2. Inserted by an operator using ACETEST, RTDTEST, etc.
3. Inserted by AUTOCAL.

ICFs that have been modified using methods 2 and 3 are no longer disseminated throughout the network. Instead they are sent to a special mailbox directory on N12DBM. The database application checks this mailbox periodically; and when it finds a new ICF, it updates the Ingres database. The database application then creates a new ICF. The CONTROL account sees that the new ICF is disseminated to the rest of the system. The impact of this new method is that 7912 recording system operators cannot make changes to the instrument settings later than about 1 hour before a dry run and expect the data to be processed properly.

ICFs are stored in the directory DD:[TABLES] on the various nodes on which they are used. There is one ICF per Record Facility output data stream; and there is one ICF per GPIB-based system bus. Only the ICFs required by a given node are stored on that node.

The CONTROL Account is responsible moving ICFs to and from the various nodes in the system. On Record Facility nodes, Mass Memory and HDDR, CONTROL is activated automatically by SUPERMON. On local instrument controller nodes such as ACEs, SANDUS, and GEAR10 CONTROL is run by an operator.

9.3 BIG Files

BIG files contain a single header followed by all the data read from all the recorders associated w th a given ICF, i.e. all the data from a data stream or from a GPIB. The contents of the header are essentially the contents of the ICF. The waveform data are stored as 16-bit binary values with 12 bits for data and a 4 bit opcode. The opcode is used to designate error conditions and for data compression.

BIG files are produced by the programs FETCH, DECOM, ACETEST, AUTOCAL, and REALIZE. They are processed and converted to CHN files by PROCESS and ANALYZE. BIG files are stored in subdirectories of the logical disk DD:. FETCH and DECOM produce the BIG files on the local node and then transfer them to both N12VAX and N14VAX.

BIG files do not use standard VMS RMS file formats or control information. They appear to the operating system as a stream of bytes without structure. The BIG ROUTINES described in 10.3 must be used to access BIG files.

9.4 CHN Files

CHN files contain a comprehensive header followed by all of the data for a signal. The header contains information both from the ICF and from any calibrations that were done. Data values are stored in binary format in 16 bit words: 4 bit opcode and 12 bits of data. The opcode system supports both hardware and software data compression. CHN files are considered the primary production data in the data acquisition computer system.

In the case of time domain multiplexing on 7912s, RTD720s, and LeCroy 7242Bs, a CHN file is generated for each multiplexed signal as well as one for the entire data record.

CHN files are produced from BIG files by PROCESS on both N12VAX and N14VAX. CHN files are produced by ANALYZE on GEAR10 and VGDxx nodes. CHN files are used primarily by PRELEWD DSP, and ATA.

9.5 ENG Files

ENG files contain data for a signal in floating point format suitable for further numerical manipulation. These files contain a small header consisting of number of points, intersample spacing, first sample time, and plot titles. ENG files are primarily used as DSP working files. Other programs such as AUTOSIM, LECTEST and RTDTEST can create ENG files; and ATA can process them. In converting CHN files to ENG files, DSP applies all calibration steps defined in the CHN file header.

ENG files are normally stored in an individual user's local working disk storage space.

9.6 Data File Directories

Production data and ICFs are stored in special partitions of the logical disk "DD" on computer system nodes. ICFs are always stored in DD:[TABLES]. Current data files are stored in a directory named either for the Record Facility data stream or for the GPIB bus number. For example HDDR data from SANDUS 505 would be stored in DD:[HDDR.SAN505] and data from RMV11 would be stored in DD:[SOURCE.RMV11]. Data from dry runs before the current date are typically only stored on N14VAX. These data files are stored in directories named as described above but preceded by the dry run date, e.g. DD:[920910.HDDR.SAN505]. N14VAX has room for about 1 week's worth of dry runs. Older dry run data files are stored on the optical disk jukebox associated with N14VAX.

9.7 Log Files

All of the major software programs in the NTS system produce log files that contain both error and informative messages about each major subtask. Log files are an excellent source of information when troubleshooting difficult problems. Experienced log file interpreters can often isolate problems to specific pieces of hardware or software submodules. Since entries in a log file may be somewhat cryptic, they should be examined by someone who is very familiar with the particular program.

Log files are stored as sequential ASCII text files in the same directory as the output data files for a given program.

Error messages in log files are flagged by special codes. The utility program SLOG described in 10.4 extracts error messages from log files and combines them into a single report.

10. Utility Programs and Procedures

10.1 CHNREAD

CHNREAD is a useful program that allows its user to dump every record in selected data blocks from a CHN file. The dump is both to an ASCII disk file and to the terminal screen. It will also allow the owner to modify selected fields in a CHN file header. It will work with all CHN file types (CHN, CAL, and T48).

CHNREAD is interactive, requesting first the directory, then the CHN filename, followed by a "yes" or "no" response for each of the records present. The program then provides the user a menu with choices to search the file randomly, search for a specific pattern, or add, delete, or modify specific words or fields in the header.

10.2 BIGREAD

BIGREAD is a utility program which allows the user to view the contents of a BIG file. It will create an ASCII file containing the BIG file header description record, user selected channel headers, and if desired, their data. It is primarily used to verify the integrity of channel header records. It depends upon routines which will dump the contents of the various records that are in the BIG file. BIGREAD is interactive, writing selected information to the terminal screen and to a LOG disk file.

10.3 BIG ROUTINES

The BIG ROUTINES are a set of subroutines which together to open, close, read, and write to a BIG file. They are used extensively in all programs creating or reading BIG files. A BIG file appears to the operating system as a stream of bytes. The structure is apparent only to the BIG ROUTINES. The BIG ROUTINES are OPEN_BIG, CLOSE_BIG, READ_BIG, WRITE_BIG, WRITE_BIG_2, READ_BIG_HDR, and WRITE_BIG_HDR. WRITE_BIG_2 writes data to a big file using two buffers.

10.4 SLOG

The program SLOG examines a supplied set of LOG files generated by the main data processing programs in the system. SLOG extracts those lines from the LOG files which have a certain form and reports those lines in a useful format. Many of the LOG files are quite long making locating the significant parts tedious. SLOG examines the information coded in columns 101 thru 112 which contain the program name, the current channel and subchannel, the execution node, source and collection point, and the severity of the message. SLOG uses the severity level as a filter to pick lines from the LOG files. It then sorts the lines by program source, collection point and channel. On some NTS events the extent of the error messages in SLOG output files have been used as a major metric for monitoring the readiness of the entire data recording system.

10.5 NIGHTMARE/ARCHIVE

NIGHTMARE and ARCHIVE are VMS DCL programs that copy all the dry run data and associated files to special directories with names that reflect the date. Normally the files are maintained on the node N14VAX. This node also has an optical juke box, and older dry runs are copied to optical disks. NIGHTMARE was used up through HUNTERS TROPHY. It is scheduled to automatically run at midnight on days when an event dry run has been taken. ARCHIVE was written to support the standalone GPIB systems. It must invoked manually from the VGDxx CONTROL account.

11. Embedded Controller Firmware

This section contains a brief description of the firmware used in the NTS Data Acquisition System. Firmware refers to software used to program an embedded microprocessor which in turn controls a piece of custom digital data handling hardware. The firmware resides in EPROMS in the appropriate device.

The development platforms, language, and embedded CPU type for the various devices used in the UGT data acquisition system are given below.

Device	Host	Development Language	Embedded CPU Type
TA485,486	PDP-11	Assembly	LSI-11
TA666,667	VAX	Assembly	68000
TA668	Motorola/UNIX	C, Assembly	68030
ACE	VAX	C	68000
TA709	Motorola/UNIX	C	68030
TA705	VAX	Assembly	68000

Executables are typically downloaded to EPROMS via a serial port connected to a Data I/O EPROM burner.

Please consult the appropriate device manual for details on the firmware for each device.

12. References

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[6] "Tektronix 7912 System Description" (To be written)

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[17] W. G. Perkins, "Description of CONTROL-Account Software for DIAMOND FORTUNE", April 21, 1992.

[18] J. W. Lee, "Signal Parameter Algorithms for Trend Analysis of Digital Data Acquisition Systems", SAND90-2550, July 1991.

[19] E. D. Baker, "Autosim User Guide", SAND93-1571, January 1994.

[20] W. G. Perkins, "Instrumentation Table Movement - DIAMOND FORTUNE and HUNTERS TROPHY", April 3, 1992.

Appendix A. SENTINEL Documentation

Attached is a memo describing the type and location of documentation for much of the software described in this report. Rather than being stored in the directory UK:[PKAESTNER.SENTINEL...] as described in the memo, this documentation is currently stored in LD:[DOC.SENTINEL...] on the ABQVAX node.

Date: March 9, 1994

To: F M. Raymond, 9322-1, MS 1391

Peter C Kaestner

From: Peter C. Kaestner, 9321, MS 1168

Subj: SENTINEL Documentation

A request for SENTINEL documentation has gone out several times to the responsible people, and most have responded in a timely manner. In order to complete this task, I have assembled the available documentation, and present it in the two forms:

1) A magnetic tape containing VAX/VMS BACKUP file of the documentation directory and four subdirectories:

ABQVAX::UK:[PKAESTNER.SENTINEL...]

2) Hardcopy (paper) printed from the better source file.

The documentation directory contains:

A) A WordPerfect file. Not all documentation is available in this format (.WP file extensions).

B) An ASCII file suitable for printing. If there is a WordPerfect file, an ASCII file is created from it. All documentation is available in this format (.DOC, .MEM, .MEC, or .LIS file extensions). I feel that ASCII files will be readable for a longer time than WordPerfect files.

Each file is stored in one of the four subdirectories:

TRADITIONAL (or non-GPIB);
GPIB;
OTHER; and
LIBRARIES_ETC.

The TRADITIONAL subdirectory contains information about programs particular to the SANDUS, ACE, HDDR and MASS MEMORY hardware. It includes SUPERMON, FETCH, DECOM, PROCESS, Conversion Routines, DHTEST, and ACETEST. I have seen documentation for SUPERMON, but it has not been passed on.

Much of the remaining documentation comes from the SANDIA REPORT **Data Collection System, Volumes 1 and 2 and Appendices**; SAND93-

2064, UC-706, printed September 1993. This document was written in WordPerfect. I have included chapters from both Volume 1 and Volume 2, where appropriate, for completeness. Some minor changes may have been made in the individual files by the author(s). I will refer to this document as the RTD report.

The GPIB subdirectory contains information about programs that work with recorders using the GPIB. This includes the captive account CONTROL, REALIZE (and its alter ego INITIALIZE), ANALYZE, RTDTEST, and LECTEST.

The OTHER subdirectory contains files about programs not dependent on particular hardware or which are peripheral to the main line programs described above. PRELEWD, AUTOSIM, and DSP are examples of this type of program. It also includes user/maintenance manuals for the ICF and BIG file handling subprograms described very tersely in the file **UTILITY**.

The LIBRARIES ETC subdirectory contains files which do not fit into other subdirectories. This includes the UTILITY library, but does not include the screen management routines which were written by Jon Anspach (EG&G) for use with SUPERMON. It also includes file descriptions for both BIG and CHN files.

In the following text, all filenames are in **BOLD UPPERCASE**. If the filename does NOT have an extension it exists as both a WordPerfect file (extension "**.WP**") and an ASCII file (extension "**.DOC**"). If the filename does have an extension, it exists only in that form. All WordPerfect files have an ASCII equivalent, the reverse is not true.

ABQVAX::UK:[PKAESTNER.SENTINEL.TRADITIONAL]

FETCH is covered with both a User's Manual and a Maintenance Manual. The two files are **FETCH_USERS** and **FETCH_MAINT** respectively. The user's manual is an upgrade of Jon Anspach's documentation.

DECOM is very much the same story. The two files are DECOM_USERS and **DECOM_MAINT**.

PROCESS describes PROCESS, and was written by R. Isidoro (Ret.), and M. Bauder (2663, MS 0986).

The file named **CONVERSION_ROUTINES** is an upgrade of Jon Anspach's documentation of two routines he wrote to convert back and forth between SANDUS status bits and database entries. These are used by PROCESS.

ABQVAX::UK:[PKAESTNER.SENTINEL.GPIB]

The captive account, CONTROL, is discussed in two files, both written by R. Isidoro (Ret.). The file **NESCONTROL** discusses the various options faced by a user, and **DIAGS** discusses two of these options (Diagnostics and the Scheduler) in more detail.

REALIZE and INITIALIZE are discussed in two files which come from the RTD report. REALIZE and INITIALIZE have a great deal of commonality, and are both covered in **REALIZE_USERS** and **REALIZE_MAINT**.

ANALYZE is discussed in the file **ANALYZE**. This file is similar to the two chapters in the RTD report about ANALYZE. It was written by R. Isidoro (Ret.), and M. Bauder (2663, MS 0986).

The program RTDTEST is discussed in two files, chapters from the RTD report, **RTDTEST_OPERATORS**, and **RTDTEST_MAINT**. They were both written by R. Caudell (9321, MS 1168).

The program LECROY_TEST is discussed in the file **LECROY_TEST**, written by T. Downey (9321, MS 1168). It is NOT in the RTD report.

ABQVAX::UK:[PKAESTNER.SENTINEL.OTHER]

PRELEWD is discussed in two files from the RTD report, **PRELEWD_USERS**, and **PRELEWD_MAINT**. While primarily aimed at the RTD report audience, they include some details about non-GPIB use.

The file **AUTOSIM** is a copy of the SANDIA Report AUTOSIM User Guide, SAND93-1571, UC-705, Printed Jan 1994. It was written by E. Baker (9321, MS 1168). It is NOT in the RTD report.

DSP is described in the seven ASCII files, **USERGUIDE.MEM**, **USERGUIDE.MEC**, **PROGGUIDE.MEM**, **PROGGUIDE.MEC**, **MACROGUIDE.MEM**, **MACROGUIDE.MEC**, and **MENUS.LIS**. These files are from the DEC word processing program RUNOFF, and do not easily convert to WordPerfect. The *.MEM files are the main text files, the *.MEC files are their table of contents files, and MENUS.LIS is a diagram of the many DSP menus. Each .MEM file contains instructions on the additional files that must be printed. These were written by J. Lee (9321, MS 1168).

There is a short discussion of data logging in the file **DATALOG.DOC**. This was not done on SENTINEL, but is included here for completeness. It was written by R. Tomlinson (Ret.).

Subprograms for creating, writing, modifying, and reading ICFs are described in the two files **ICF_FILE_MAINT**, and **ICF_UTILITY_ROUTINES**. They are also mentioned in **UTILITY**, which has a little information about subprograms in the UTILITY library. These files are from the RTD report.

Subprograms for creating, and using BIG files are described in the file **BIG_FILE_ROUTINES**. This file is from the RTD report. These subprograms are also mentioned in **UTILITY**.

Programs which allow a user to view the contents of an ICF, a BIG file, or a CHN file are described in **FILE_READ_MAINT**. This file is from the RTD report. The programs, ICFREAD, BIGREAD, and CHNREAD, will work on all files regardless of their hardware orientation.

DHCOMM contains a discussion of the down hole communications by L. Livingston (9321, MS 1168).

ABQVAX::UK:[PKAESTNER.SENTINEL.LIBRARIES_ETC]

The file **UTILITY** is a compendium of the headers from the non-SMG routines in the UTILITY library. The routines were mostly written by Jon Anspach (EG&G), and most have been modified since written. All modules which have a name of the form *TBL* (the "*" is used to imply an unknown number of characters, a wildcard), are described in more detail in the two files **ICF_UTILITY_ROUTINES**, and **ICF_FILE_MAINT**. All modules which have a name of the form *BIG* are described in more detail in the two files **BIG_FILE_ROUTINES**, and **FILE_READ_MAINT**.

BIG files are described in BIG_FILE, which despite being from the RTD report, does describe non-GPIB BIG files. It was written by R. Isidoro (Ret.), and me.

CHN files are described in the file **CHN_FILE_FORMAT** which includes a description of non_GPIB CHN files.

Copies to (w/o enclosures):

MS 1168	9321	W. B. Boyer
MS 1168	9321	R. D. Aden
MS 1169	9322	C. W. Cook
MS 1170	9305	M. J. Navratil
MS 1170	9324	P. L. Nelson
MS 1391	9322	W. J. Kluesner

Distribution:

2	Defense Nuclear Agency Attn. Kiran Shah FCTIU 4420 Mitchell St. North Las Vegas, NV 89031	
1	MS9018/8523-1	Central Technical Files
5	MS0899/7141	Technical Library
1	MS0619/7151	Technical Publications
10	MS0100/7613-2	Document Processing for DOE/OSTI
1	MS1169/9304	G. L. Ogle
1	MS1391/9305	P. L. Nelson
15	MS1168/9321	W. B. Boyer
1	MS1168/9321	R. D. Aden
1	MS1168/9321	E. D. Baker
1	MS1168/9321	D. J. Belding
1	MS1168/9321	T. L. Downey
1	MS1168/9321	R. L. Kinchen
1	MS1168/9321	J. W. Lee
1	MS1168/9321	L. Livingston
1	MS1168/9321	P. F. McKay
1	MS1168/9321	R. A. Mills
1	MS1168/9321	J. L. Romine
1	MS1168/9321	L. Bishop (Diversus)
1	MS1168/9321	D. Geuss (Bell Atlantic)
1	MS1168/9321	R. Salas (EGG)
1	MS1168/9321	M. Ward (EGG)
1	MS1169/9322	C. W. Cook
1	MS1169/9322	R. E. French
1	MS1391/9322	R. Davis
1	MS1168/9322	G. J. Hansen
1	MS1168/9322	E. S. Herrera
1	MS1391/9322	J. W. McKeever
1	MS1168/9322	R. G. Oliveira
3	MS1391/9331	F. M. Raymond
1	MS1391/9331	M. E. Burke
1	MS1391/9331	J. A. Chael
1	MS1391/9331	W. J. Kluesner
1	MS1391/9331	D. S. Nelson
1	MS1391/9331	R. L. Wilson
1	MS1391/9331	E. W. Marsh (EGG)
1	MS1391/9331	B. J. Wohlbrandt (EGG)
1	MS1160/9312	K. M. Glibert
1	MS1160/9312	B. C. Bedeaux
1	MS1160/9312	D. C. Brown
1	MS1160/9312	P. L. Wehrman
1	MS1160/9312	F. Biggs
1	MS1391/9331	K. Thomas (EGG)
1	MS1159/9311	T. K. Bergstresser
1	MS1159/9311	A. J. Chabai
1	MS1159/9311	W. H. Barrett
1	MS1159/9311	C. W. Smith
1	MS1159/9311	S. D. Stearns
1	MS1159/9311	J. I. Greenwoll
1	MS1159/9311	H. D. Garbin
1	MS1160/9312	G. J. Lockwood

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8/18/94

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