OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL COVER SHEET
Complete Only Applicable Items

1. QA: QA

2. [X] Analysis — Check all that apply

Type of Analysis:
- [X] Engineering
- [ ] Performance Assessment
- [ ] Scientific

Intended Use of Analysis:
- [ ] Input to Calculation
- [ ] Input to another Analysis or Model
- [X] Input to Technical Document
- [X] Input to other Technical Products

Describe use:

Provide input to the Site Recommendation Report. Provide input to the Performance Confirmation Plan, the performance confirmation program, and the PCDAS SDD.

3. [ ] Model — Check all that apply

NTR 9-26-00

Type of Model:
- [ ] Conceptual Model
- [ ] Abstraction Model
- [ ] Mathematical Model
- [ ] System Model
- [ ] Process Model

Intended Use of Model:
- [ ] Input to Calculation
- [ ] Input to another Model or Analysis
- [ ] Input to Technical Document
- [ ] Input to other Technical Products

Describe use:

4. Title:

Performance Confirmation Data Acquisition System

5. Document Identifier (including Rev. No. and Change No., if applicable):

ANL-PCS-CS-000001 Rev. 01

6. Total Attachments:

None

7. Attachment Numbers - No. of Pages in Each:

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12. Remarks:

The following TBVs are contained in this document: TBV-407

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL REVISION RECORD
Complete Only Applicable Items

2. Analysis or Model Title:

Performance Confirmation Data Acquisition System

3. Document Identifier (including Rev. No. and Change No., if applicable):

ANL-PCS-CS-000001 Rev. 01

4. Revision/Change No.	5. Description of Revision/Change
01	Initial Issue. This analysis is a revision to and supercedes the Performance Confirmation Data Acquisition System analysis DI# BCAI00000-01717-0200-00002 Rev 00. It includes revised and updated sections on the data acquisition system and network concepts and potential designs that meets listed criteria and descriptions from the PC related SDDs, Performance Confirmation Plan, and current design enhancements.

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TABLES

ACRONYMS AND ABBREVIATIONS

AC	alternating current
ANSI	American National Standards Institute
CFR	Code of Federal Regulations
DC	direct current
DCSs	Distributed control systems
DOE	U.S. Department of Energy
ETA	Event Tree Analysis
FMEA	Failure Modes and Effects Analysis
FMECA	Failure Modes, Effects and Criticality Analysis
FTA	Fault Tree Analysis
GUI	Graphical User Interface
HRA	Human Reliability Analysis
I/O	inputs and outputs
IR	infrared
Mbps	million bits per sec
MPBX	multi-point borehole extensometer
MTBF	mean-time-between failures
MTTR	mean-time-to-repair (or restore)
OCRWM	Office of Civilian Radioactive Waste Management
OLE	Object Linking and Embedding
OMCS	Operations Monitoring and Control System
OPC	OLE for Process Control
PC	Performance Confirmation
PCDAS	Performance Confirmation Data Acquisition System
PLC	Programmable logic controller
PM	Preventive Maintenance
QAP	Quality Administrative Procedure

ACRONYMS AND ABBREVIATIONS (continued)

R&R	Remove-and-replace
RAM	Reliability, availability, and maintainability
RBD	Reliability Block Diagrams
RCM	Reliability-centered-maintenance
RTDs	Resistance temperature detectors
SSC	Systems, structures, and components
TBV	To Be Verified
TCs	Thermocouples
UCRL	University of California Research Laboratory
WP	waste package

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1. PURPOSE

The purpose of this analysis is to identify and analyze concepts for the acquisition of data in support of the Performance Confirmation (PC) program at the potential subsurface nuclear waste repository at Yucca Mountain.

This analysis is being prepared to document an investigation of design concepts, current available technology, technology trends, and technical issues associated with data acquisition during the PC period. This analysis utilizes the *Performance Confirmation Plan* (CRWMS M&O 2000b) to help define the scope for the PC data acquisition system. The focus of this analysis is primarily on the PC period for a minimum of 30 years after emplacement of the last waste package. The design of the data acquisition system shall allow for a closure deferral up to 300 years from initiation of waste emplacement. (CRWMS M&O 2000h, page 5-1).

This analysis is a revision to and supercedes analysis, *Performance Confirmation Data Acquisition System*, DI# BCAI00000-01717-0200-00002 Rev 00 (CRWMS M&O 1997), and incorporates the latest repository design changes following the M&O & DOE evaluation of a series of Enhanced Design Alternatives (EDAs), as described in the *Enhanced Design Alternatives II Report* (CRWMS M&O 1999d). Significant design changes include: thermal line loading of the emplacement drifts, closer spacing of the waste packages (WPs), wider spacing and fewer emplacement drifts, continuous ventilation of all active emplacement drifts, thinner walled WP designs which will increase external radiation levels, a 50-year repository closure option, inclusion of a drip-shield, exclusion of backfill, and new conceptual designs for the waste emplacement vehicles and equipment (Stroupe 2000).

The scope and primary objectives of this analysis are to:

- Review the criteria for design as presented in the Performance Confirmation Data Acquisition/Monitoring System Description Document, by way of the Input Transmittal, *Performance Confirmation Input Criteria* (CRWMS M&O 1999c).

- Identify and describe existing and potential new trends in data acquisition system software and hardware that would support the PC plan. The data acquisition software and hardware will support the field instruments and equipment that will be installed for the observation and perimeter drift borehole monitoring, and in-situ monitoring within the emplacement drifts. The exhaust air monitoring requirements will be supported by a data communication network interface with the ventilation monitoring system database.

- Identify the concepts and features that a data acquisition system should have in order to support the PC process and its activities.

- Based on PC monitoring needs and available technologies, further develop concepts of a potential data acquisition system network in support of the PC program and the Site Recommendation and License Application.

This analysis is being developed using the Performance Confirmation Data Acquisition System development plan (CRWMS M&O 2000i). This analysis is being performed, as issues, requirements, constraints, and objectives related to the PC program will be revised, developed, and allocated to the SDD, by way of *Performance Confirmation Input Criteria* (CRWMS M&O 1999c). When revisions to these documents are completed, it is recommended that they be reviewed for impact on this analysis. If necessary, this analysis should then be revised.

This analysis will also identify and describe key issues related to the data acquisition system during PC. This analysis can be used to guide future concept development and help assess what is feasible and achievable by application of data acquisition technology. Future design and systems engineering analysis with applicable iterations of modeling, optimizing, prioritizing, and refinement of concepts will be needed to arrive at optimal design concepts.

2. QUALITY ASSURANCE

A data acquisition system network will be used to acquire, store, and record data in support of the PC program. The different types of data acquisition equipment and the system network have been classified in accordance with QAP-2-3, *Classification of Permanent Items*, and have been found to be quality affecting per the analysis, *Classification of the MGR Performance Confirmation Data Acquisition/Monitoring System* (CRWMS M&O 1999e). They are also on the Project *Q-list* (YMP 2000a, Attachment II).

This design activity has been evaluated in accordance with QAP-2-0, *Conduct of Activities, Performance Confirmation- 99 Work Package 12012383M1, Task RPA20104* (CRWMS M&O 1999a), and has been determined to be quality affecting subject to the requirements of the *Quality Assurance Requirements and Description* (QARD) (DOE 2000).

The process for ensuring accuracy and completeness of data was performed in accordance with AP-SV.1Q, *Control of the Electronic Management of Data*. An evaluation of this work activity was performed and it was determined that no special controls are required.

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3. COMPUTER SOFTWARE AND MODEL USAGE

The Project standard suite of office software for word processing has been used in the preparation of this analysis. The figures have been drawn using Project Standard Computer Aided Design Drafting programs. These are commercial off-the-shelf software programs, approved for the Project, with no special qualifications needed.

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4. INPUTS

The primary source documents for input information utilized in this analysis are the *Performance Confirmation Input Criteria* (CRWMS M&O 1999c), the *Viability Assessment of a Repository at Yucca Mountain* (DOE 1998), and the *Performance Confirmation Plan* (CRWMS M&O 2000b).

4.1 PARAMETERS

There are no parameters available that apply to the data acquisition hardware and software to assist in defining its performance specification.

4.2 CRITERIA

This document is consistent with the guidance in the *Technical Guidance Document for License Application Preparation* (YMP 1999). The *Revised Interim Guidance Pending Issuance of the New U.S. Nuclear Regulatory Commission (NRC) Regulations (Revision 01, July 22,1999), for Yucca Mountain, Nevada* (Dyer 1999) is a document that was issued in anticipation of the interim guidance being promulgated as a Code of Federal Regulations. Applicable requirements associated with this interim licensing guidance, along with the *Monitored Geologic Repository Requirements Document* (YMP 2000b) will be defined as criteria in the *Performance Confirmation Data Acquisition/Monitoring System Description Document* and are used as criteria in this analysis by way of *Performance Confirmation Input Criteria* (CRWMS M&O 1999c).

4.2.1 The system shall provide limited local storage of electronic test data at each test location (TBV-407) (CRWMS M&O 1999c, Section 1.2.1.34) (Used in Sections 6.5.1.2 and 7.).

4.2.2 The system shall provide at least 90 percent data recovery from continuous monitors (TBV-407) (CRWMS M&O 1999c, Section 1.2.1.35) (Used in Section 6.5).

4.2.3 System data and communication wiring shall be kept physically separated from electrical power wiring (TBV-407) (CRWMS M&O 1999c, Section 1.2.1.36). (Used in Sections 6.5.1.2.3 and 7.).

4.2.4 Communications and data circuits shall be protected or shielded from electromagnetic interference to the extent specified by manufacturers of sensitive data processing, monitoring, and communications equipment used in the system (TBV-407) (CRWMS M&O 1999c, Section 1.2.1.37). (Used in Sections 6.5.1.2.3 and 7.).

4.2.5 The system shall provide instrument excitation for the system instrumentation, if needed (TBV-407) (CRWMS M&O 1999c, Section 1.2.1.38). (Used in Section 6.5.1.2).

4.2.6 The system shall provide features for manual data entry (TBV-407) (CRWMS M&O 1999c, Section 1.2.1.39). (Used in Sections 6.5.1.2 and 7.).

4.2.7 The system shall provide features for the receipt of electronic data from auxiliary or portable data acquisition equipment (TBV-407)(CRWMS M&O 1999c, Section 1.2.1.40). (Used in Sections 6.5.1.2.2, 6.5.3, and 7.).

4.2.8 The system shall provide features for assessing the accuracy of collected data (TBV-407) (CRWMS M&O 1999c, Section 1.2.1.41). (Used in Sections 6.5 and 7.).

4.2.9 The system shall interface with the Site Communications System for data communications (TBV-407) (CRWMS M&O 1999c, Section 1.2.4.4). (Used in Sections 6.5.3 and 7.).

4.2.10 The system shall transfer collected data (via the Site Communications System) to the Site Operations System for storage (TBV-407) (CRWMS M&O 1999c, Section 1.2.4.5). (Used in Sections 6.5.3 and 7.).

4.2.11 The design, selection, and integration of computer display terminals, equipment, and workspaces shall incorporate human factors engineering (HFE) practices and criteria in accordance with applicable industry standards. "American National Standard for Human Factors Engineering of Visual Display Terminal Workstations" (ANSI/HFS-100-1988), "Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs)-Part 3: Visual Display Requirements" (International Organization for Standardization, ISO 9241-3), and "Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs) – Part 8: Requirements for Displayed Colours" (ISO 9241-8), are standards recognized as U.S. Department of Energy (DOE's) preferred guidance for the design of the MGR systems, structures, and components (SSCs), but application of specific requirements to the MGR has not been determined. Future engineering analyses will determine those applicable areas (TBV-407) (CRWMS M&O 1999c, Section 1.2.5.4). (Used in Section 6.5.1). (NOTE: See Section 4.3 regarding current status of ANSI/HFS-100-1988).

4.2.12 The design, selection and integration of computer user interface software shall incorporate HFE practices and criteria in accordance with applicable industry standards. "Guidelines for Designing User Interface Software" (ESD-TR-86-278), "Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs) – Part 10: Dialogue Principles"(ISO 9241-10), "Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs) – Part 14: Menu Dialogues" (ISO 9241-14), and "Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs) – Part 15: Command Dialogues" (ISO 9241-15), are recognized as DOE's preferred guidance for the design of the MGR SSCs, but application of specific requirements to the MGR has not been determined. Future engineering analyses will determine those applicable areas (TBV-407) (CRWMS M&O 1999c, Section 1.2.5.5). (Used in Section 6.5.1).

4.2.13 The design, selection, and integration of SSCs shall incorporate HFE practices and criteria in accordance with applicable industry standards. Department of Defense Design Criteria Standard "Human Engineering" is recognized as DOE's preferred guidance for the design of the MGR SSC's, but application of specific requirements to the MGR has not been determined. Future engineering analyses will determine those applicable areas (TBV-407) (CRWMS M&O 1999c, Section 1.2.5.6). (Used in Section 6.5.1).

4.2.14 Design, selection, and integration of system equipment shall incorporate human factors engineering (HFE) practices and criteria so that the system is maintainable. HFE shall include the applicable sections of, "Human Factors Design Guidelines for Maintainability of Department of Energy Nuclear Facilities" (UCRL-15673) (TBV-407) (CRWMS M&O 1999c, Section 1.2.5.2). (Used in Section 6.5.1).

4.3 CODES AND STANDARDS

These codes and standards are part of the input criteria as presented in Section 4.2 or are from the analysis that is superceded by this analysis.

ANSI/HFS-100-1988	Human Factors Engineering of Visual Display Terminal Workstations 1988.
IEEE Std-1451.2-1997	A Smart Transducer Interface for Sensors and Actuators-Transducer to Microprocessor Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats. 1997.
ISO 9241-3:1992	Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs)-Part 3: Visual Display Requirements. 1992.
ISO 9241-8:1997	Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs)-Part 8: Requirements for Displayed Colours. 1997.
ISO 9241-10:1996	Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs)-Part 10: Dialogue Principles. 1996.
ISO 9241-14:1997	Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs)-Part 14: Menu Dialogues. 1997.
ISO 9241-15:1997	Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs)-Part 15: Command Dialogues. 1997.
NUREG-0492	Fault Tree Handbook. 1981.
UCRL-15673	Human Factors Design Guidelines for Maintainability of Department of Energy Nuclear Facilities. 1985.

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5. ASSUMPTIONS

5.1 SPECIFIC ASSUMPTIONS FOR THIS ANALYSIS

5.1.1 Thirty-five channels from each borehole will be used to size the data acquisition system. This assumed value is used as a starting point, pending additional concept development by affected organizations associated with the PC Program. Experience from ESF thermal testing indicates that over 5,000 data inputs, or readings, will be obtained from approximately 200 boreholes, which is approximately 25 signals per borehole (CRWMS M&O 1996b, pages 3-9 through 3-16). (Note: The frequency of reading each input, or scan time, would be determined during actual design). It is assumed that the PC data collection densities will be greater than this value due to the increased length of the PC boreholes. This initial value will require further examination in later analyses, however, variations in this number can be readily accommodated without severely impacting the data acquisition network configuration. (This assumption is used in Section 6.4.2)

5.1.2 There can be thirteen (13) boreholes per alcove arrangement off of the observation drifts. This value is based on providing the capability to obtain host rock data in multiple planes of the potential repository. This assumed value is used as a starting point, pending additional concept development by affected organizations associated with the PC Program. This initial value will require further examination in later analyses; however, variations in this number can be readily accommodated without severely impacting the data acquisition network configuration. The document, *Performance Confirmation Subsurface Facilities Design Analysis*, states that boreholes will be used to position monitoring instruments in their required positions near the emplacement drifts (CRWMS M&O 1998b, page 14). (This assumption is used in Section 6.4.2)

5.1.3 According to the *Site Recommendation Subsurface Layout*, there can be three observation drifts above the emplacement level to monitor repository performance. (CRWMS M&O2000e, pages 77 and 88). (This assumption is used in Section 6.4.2)

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6. ANALYSIS

6.1 INTRODUCTION

The main purpose of the analysis is to outline the design of a system and its features for collecting PC information. This analysis discusses and evaluates the current technology of hardware and software concepts that are available for the PC Data Acquisition System. It focuses on meeting PC data acquisition requirements during the period after the start of waste package emplacement and before permanent closure of the repository.

The evaluation of concepts and issues for the Performance Confirmation Data Acquisition System will include compliance with the performance confirmation program. In order to evaluate requirements and concepts for a data acquisition system for the performance confirmation program, a review and understanding of the requirements of the *Performance Confirmation Plan* (CRWMS M&O 2000b) that would appear to have an impact on the system is necessary.

The *Performance Confirmation Plan* is very briefly summarized. The reader is referred to the *Performance Confirmation Plan* for additional details. Figures 4-1, 4-2, 4-3, and 4-4 of the PC Plan present a picture of the steps in developing the plan and determining what is required for data monitoring and evaluation. These figures focus on the identification of PC factors and inputs, encompass activities needed to plan PC activities, identify the steps to implement the detailed test plans, and describe the final decision process after data have been evaluated (CRWMS M&O 2000b, pages 4-2 through 4-5). In general the *Performance Confirmation Plan* identifies the operation processes or factors, the parameters for these processes, and the testing and monitoring activities required to evaluate the waste emplacement process and the response of the repository and engineered barriers to the operation over its long term life cycle. Below, only those *Performance Confirmation Plan* requirements that have an impact on the PCDAS are presented.

In Table E-1 of the *Performance Confirmation Plan* (CRWMS M&O 2000b), performance confirmation requirements in the *Monitored Geologic Repository Requirements Document* (YMP 2000b) are listed. It specifically provides direction to use the interim guidance as found in *Revised Interim Guidance Pending Issuance of New U. S. Nuclear Regulatory Commission (NRC) Regulations (Revision 01, July 22, 1999) for Yucca Mountain Nevada.* (Dyer 1999).

In Table E-2 of the *Performance Confirmation Plan* (CRWMS M&O 2000b), PC requirements from Dyer 1999 are listed. There are four requirements from this table that impact the PCDAS scope and design. These include:

- The PC program supports performance assessment
- The PC program provides data
- The PC program provides a continuing program of surveillance
- The PC program provides for the monitoring and inspection of emplaced waste packages

The first requirement calls out that a PC program will be conducted to verify the assumptions, data, and analyses that support the performance assessment. Key geologic, hydrologic, geomechanical, and other physical parameters will be monitored throughout site characterization, construction, emplacement, and operation to detect any significant changes in the conditions assumed in the performance assessment. Observations need to be made and records made and kept. The key here are the words "monitored" and "records." The PCDAS has these functional capabilities for the PC program.

The second requirement specifies that PC activities provide data on important subsurface conditions encountered during construction as well as data on the changes in these conditions which occur during construction and waste emplacement. The key here is that the PCDAS is integral in providing PC data to the operations of the repository and that it can have a role in reporting it and possibly analyze and/or report changes in that data. Also, the PC program shall conduct analyses and monitoring of the elements (systems, subsystems, or components of the repository that are intended to function as geologic and engineered barriers after closure, and which are important to post-closure safety) of the repository barrier in order to confirm the elements are functioning as intended and anticipated. This implies potential PCDAS functional capabilities be available for a significant length of time and for safety reasons.

The third requirement calls for a continuing program of surveillance be conducted to ensure that parameters used in the performance assessment are confirmed and to ensure the NRC is informed of changes needed in the design due to a variance in the geotechnical data obtained. The PCDAS will surely have a role with meeting this requirement, possibly in reporting and communicating the variance in the data.

The fourth requirement calls out a PC program that includes monitoring and inspection of emplaced waste packages. Again, the PCDAS will be gathering data on the waste packages from the ROV or remote inspection gantry control system.

In Table E-5 of the *Performance Confirmation Plan* (CRWMS M&O 2000b) PC requirements based on the *Monitored Geologic Repository Projection Description Document* (CRWMS M&O 2000h, page 5-1) are listed. There are two requirements or parameters from this table that affect this analysis. These include:

- The repository operation and life span
- The repository ventilation system

The repository emplacement and pre-closure period of operation and life span directly affects or defines the life cycle requirement of the PC data acquisition system. This life cycle will be a period of time for emplacement lasting from a minimum of 30 years after emplacement of the last waste package. The design of the PCDAS shall allow for a closure deferral up to 300 years from initiation of waste emplacement.

The second parameter concerns the required performance of the repository ventilation system, which is that 70% of the heat generated by the waste packages within the emplacement drifts during the first 50 years of the preclosure period shall be removed by ventilation. This impacts the PCDAS need to interface with the ventilation monitoring system.

In Table E-6 of the *Performance Confirmation Plan* (CRWMS M&O 2000b), PC requirements based on Controlled Project Assumptions as provided in the *Monitored Geologic Repository Projection Description Document* (CRWMS M&O 2000h, page 5-1) are listed. There is one requirement from this table that impacts the PCDAS and this analysis. Under normal operations no human entry is planned in emplacement drifts while waste packages are present. The assessment of this requirement restricts human entry into emplacement drifts under normal operating conditions after waste emplacement, but allows the use of remotely operated vehicles (ROVs) and other remote equipment within the drifts. As PC monitoring of the rock mass requires periodic human access to the borehole collars to conduct surveys and to maintain in-situ instruments over long time periods, this restriction prohibits the monitoring of adjacent rock from within emplacement drifts. Therefore, this requires that all in-drift instruments be accessible to ROVs or be remotely operable and removable to allow for replacement and maintenance of instruments over long-time periods without direct human access. Although the ROVs are not part of this analysis, the PC data acquisition system will monitor the required parameters and collect the required PC data from the ROV control and communication system database. This requirement shows system facility interface relationships with the PCDAS.

Data control and handling is a key issue in defining, sizing, and designing the PC data acquisition system. Since all of the data monitoring and evaluation is not yet defined, it is hard to say how the PC testing activities would benefit from being integrated to the data acquisition system. No definition is given to the integration of data from offsite laboratory testing programs into a common database, let alone a common PC data acquisition system. However, in Section 5.4.3 of the *Performance Confirmation Plan*, a core-group of technical experts will maintain communications with experts and periodically report data to the public either in the form of published reports or in the maintenance of a data reporting system on the world-wide-web (CRWMS M&O 2000b, page 5-39). The PCDAS would benefit this part of the plan.

What is mentioned about the PCDAS is found in section 5.4.4 of the *Performance Confirmation Plan* (CRWMS M&O 2000b, pages 5-39, 5-40, and Figure 5-6 on page 5-38). The PCDAS is included as an operational or functional area. Once the entire scope of data monitoring, handling, control, and evaluation are defined then the integration of various databases can be considered. A decision to recommendthe control of all databases into a single database under a single PC data acquisition system and data storage life cycle enterprise plan could then be made. This would include the operational, scientific, engineering, and management control, use, costs, and communication of the raw data, data analysis, and reports.

Based on review of the *Performance Confirmation Concepts Study Report* (CRWMS M&O 1996a), the described Testing Activities of the *Performance Confirmation Plan*, the requirements above, and applicable System Description Documents, the following eight data collection strategies have been identified:

1. Various Sampling programs
2. Geologic mapping program
3. Alcove-based testing in non-emplacement areas

4. The use of borehole instruments
5. Exhaust ventilation system monitoring
6. Remote systems in the emplacement drifts
7. Contingency plans for additional alcoves, drifts or testing
8. Recovery of waste packages or testing dummy waste packages

The scope of this analysis focuses on design concepts for a data acquisition system in the following areas to support the above data collection strategies (data collection strategies given in parenthesis):

- Exhaust Ventilation Monitoring System (database interface only)(5)
- Exhaust Radiological Monitoring (database interface only)(6)
- Monitoring Emplacement Drifts by In-situ Instrumentation(2, 4, 7)
- Monitoring Emplacement Drifts by Mobile Remote Systems (data gathering communication and network aspects only. Mobile remote system is covered under a separate analysis.) (6)
- Instrumentation Installed in Boreholes from Observation and Perimeter Drifts (2, 3, 4)
- Examining data acquisition technology and discussing initial concepts for a subsurface data acquisition network (1 through 8)

6.2 EXHAUST VENTILATION MONITORING SYSTEM

The ventilation system as discussed in the *Performance Confirmation Plan* (CRWMS M&O 2000b, pages 5-2 and 5-13), is a subsurface facility supporting the PC test program. This section of the analysis describes initial design concepts for acquiring exhaust air ventilation system data into the PCDAS database to support the repository PC data monitoring needs. Ventilation data collected during the PC program will be used to update total system performance models as needed. Results of the monitoring and analysis will be used to confirm the predicted system response.

6.2.1 Ventilation Parameters to be Monitored for Performance Confirmation

Ventilation monitoring will provide data from the incoming and outgoing conditions in the emplacement drift air, including temperature, relative humidity, and the presence of airborne radionuclides. (CRWMS M&O 2000f, section 1.2.4.1). How these monitoring requirements can be met is not part of the PCDAS or this analysis. What may be important to the PC record database, is the need to know which emplacement drift may be the cause of an anomalous parameter reading.

The PC program shall obtain emplacement drift air temperature and air humidity environmental data from the subsurface ventilation system exhaust airways temperature and humidity monitoring system according to the *Subsurface Ventilation System Description Document* (CRWMS M&O 2000f, System Interfacing Criteria 1.2.4.1). The PCDAS will acquire the data of the exhaust conditions of the air exiting the emplacement drifts by interfacing with the MGR Operations and Monitoring Control System database, which in turn interfaces with the ventilation system database. Data sharing or interfacing is further discussed in Sections 6.5 and 6.5.1.1 with regards to the PC data acquisition system and its data communication network.

The same type of situation above exists for the monitoring of airborne radionuclides. The PCDAS will acquire the data of the exhaust conditions of the air exiting the emplacement drifts by interfacing with the MGR Operations and Monitoring Control System database, which in turn interfaces with the site radiological monitoring system. Again, how these monitoring requirements can readily be met is not part of the PCDAS or this analysis. What may be important to the PC record database, is the need to know which emplacement drift may be the cause of an anomalous parameter reading.

6.2.2 Sensors and Instrumentation

The Subsurface Ventilation System and the future Site Radiological Monitoring System Description Documents are responsible for defining the scope and system design for these sensors and instruments. The OMCS is responsible for ensuring that the data from these instruments is received and valid, and made available for communication to the PCDAS database. Because these sensors and instruments are the source of data monitoring for the long term lifecycle of the PCDAS, as well as their parent systems, it suggests that they be specified with the necessary robust features in order to provide accurate and uninterrupted reporting of data. For detailed information on sensors and instruments refer to the report *Ventilation Monitoring Instrumentation* (CRWMS M&O 2000c).

6.3 MONITORING EMPLACEMENT DRIFTS BY IN-SITU INSTRUMENTATION

One potential data acquisition alternative not included in the PC strategy discussed in Section 6.1 is that of installing instrumentation *within* the emplacement drifts. One of the problems with this alternative is dealing with the harsh physical conditions inside the emplacement drifts. Sensors are routinely designed to detect process conditions at extremely high pressures, high temperatures, and in very toxic gaseous environments for the refining, chemical and nuclear industries. These sensors monitor the process and transmit the control signals to control rooms using specialized and intricate electronic communication systems, power systems, and signal wiring which are all installed external to the process.

In the potential repository application, in-drift instrumentation would require that the sensor, transmitter, and associated wiring be installed in the emplacement drift. In an approximate 100-year PC operating period, the sensors and/or transmitters will undoubtedly require calibration, maintenance, and probable replacement several times. To perform these functions would require the development of intricate, expensive equipment such as robots, radiation shields, personnel protection, etc. How the harsh conditions and the inaccessibility for maintenance and calibration activities could be addressed requires additional design investigation and analysis.

Temperature sensing devices such as TCs and RTDs can sustain the ambient temperature of the emplacement drift, which is less than but up to 96°C (CRWMS M&O 2000e, page 63). Wire is commercially available for installations up to 400°C, so the signals can be wired to external transmission or data acquisition equipment. The problem is that these devices, while extremely rugged, will not last forever. Maintenance and possible replacement of the TC or RTD assembly will eventually be required. A possible alternative would be to sacrifice the temperature sensors and take the data while they are still operable. This sacrificial approach then introduces other factors such as when the sensors eventually fail, how far back in time is the data still valid?

Removal of the devices, associated wiring and any other installation hardware is another consideration. This alternative, while feasible, does introduce other concerns and design considerations that require further investigation. Results of the current ESF thermal tests can be used to assess the viability of this alternative.

6.4 OBSERVATION AND PERIMETER DRIFT MONITORING BOREHOLE INSTRUMENTATION

There is a wide variety of instrumentation available for the required monitoring applications. The observation and perimeter drift borehole instrumentation is discussed in its own analysis, *Performance Confirmation In-Situ Instrumentation* (CRWMS M&O 2000g). The observation drifts and the boreholes from them will be equipped with many different sensors and instruments for the measurement of rock mass, rock stress, stress change, hydraulic properties, strength, and deformation.

6.4.1 Parameters to be Monitored

Reference sources for the development of the following list of 7 categories of parameters include Table D-1, "Key Performance Confirmation Parameters for Design" of the *Concept Study Report* (CRWMS M&O 1996a) and section 1.2 of the *Performance Confirmation Input Criteria* (CRWMS M&O 1999c). There are 21 specific parameters that will be monitored within the following categories:

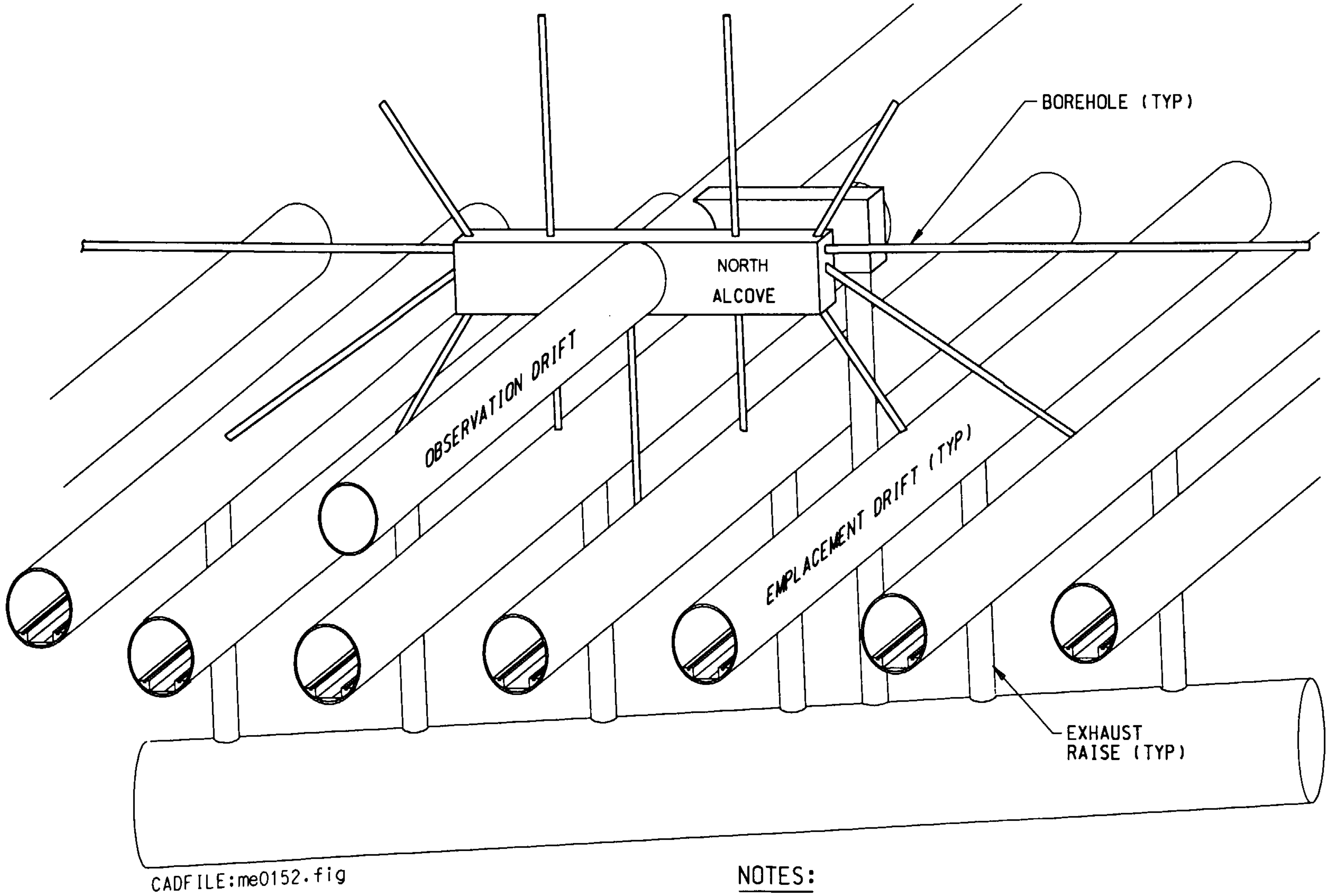
- Seismic
- Rock mass hydraulic
- Rock mass pneumatic
- Rock mass mechanical
- Rock mass thermal
- Groundwater pressures
- Groundwater temperatures

Sources have been used for guidance, with the objective being to produce a list of measurable parameters, but not to list all derivative parameters or properties that can be obtained from the measurable parameters. For example, the measurement of thermal conductivity may be important to know for PC purposes, however, this property is determined from temperature measurements (by RTD, thermocouple) at various locations. In this case, therefore, temperature is the basic parameter to be measured, not thermal conductivity.

6.4.2 Borehole Monitoring Data Transmission

This section discusses how the measured parameters can be recorded, how the data signal wiring may be routed, and how the data may be acquired by the PC Data Acquisition System (PCDAS).

Figure 1 shows a possible scenario for observation drift borehole monitoring. From the figure, it can be seen that numerous boreholes could be drilled from alcoves which extend both north and south off of the observation drifts, which, in this alternative, are constructed parallel to the emplacement drifts. The alcoves remove the instrumentation from the main haulage way of the observation drift, which should reduce the disruption of testing activities and other operations.



NOTES:

THIS FIGURE IS FOR ILLUSTRATION ONLY OF THE RELATIONSHIP OF THE OBSERVATION DRIFT ALCOVE, EMPLACEMENT DRIFT, AND EXHAUST RAISE.

Figure 1. Observation Drift W/ Alcoves

The first observation drift can be excavated during the pre-emplacement development period so that it can be ready to begin data acquisition with the emplacement of the first waste packages. Subsequent observation drifts can be constructed during normal development operations.

This concept resembles the current plans for the ESF thermal test, where the heated drift is not accessible, but is monitored via borehole instruments. Selected boreholes could penetrate the emplacement drift wall, if deemed appropriate, allowing instrumentation to be inserted directly into the emplacement drift, and then withdrawn. Instrumentation can be installed in the boreholes from the observation drifts, and if repair or re-calibration is needed, they can be removed and reinserted from the observation drift. In the case of instruments that must be grouted in place, additional holes can be drilled in the event of an instrument failure.

Thermal, mechanical, hydrological, and chemical instruments can all be installed in one borehole to provide the required information. The number of sensors to be installed in a borehole determines the resulting borehole diameter. The diameter is a result of the physical aspects of the equipment to be mounted in the borehole, such as wire size and number of devices. Boreholes containing larger sensory equipment, such as MPBX transmission devices, will accommodate fewer channels than boreholes which contain small devices such as temperature and humidity sensors. This analysis will size the data acquisition system by using the quantity of thirty-five channels originating from each borehole (Section 5.1.1).

The review and update of the data acquisition concepts continues to be based on the potential repository drift designs, the number of drifts, and the layout concepts shown in (CRWMS M&O 2000e). Although the drift configurations are in a state of proposed revision, the impact on the data acquisition system should be considered at a later date, and therefore are not considered at this time. The final quantities and types of transmission equipment to be installed in each borehole can then be developed as the PC design progresses.

Refer to Figure 1 and 2. If there are thirty-five channels (Section 5.1.1) originating from each borehole, the North alcove will have a total of 210 input channels to the data acquisition system and the South alcove will have a total of 245 input channels (Section 5.1.2). This results in a total of 455 input channels per alcove arrangement off of the observation drift. It is anticipated that there will be ten alcove arrangements off of each observation drift as shown in Figure 3. The number of data inputs, or readings, for each observation drift is therefore 4,550 (10 x 455). By adding approximately 20 % for spares and design contingencies, the number of channels for each observation drift is increased to 5500. (Note: The frequency of reading each input, or scan time, will be determined later in the design cycle). Refer to Section 5.1.3 and Table 1 for a relationship of percent of repository coverage versus the quantity of observation drifts and resulting quantity of input signals. The quantity of observation drifts is not yet determined but a number shown in the table is provided to give a rough order-of-magnitude of the quantity of signals that may ultimately be required.

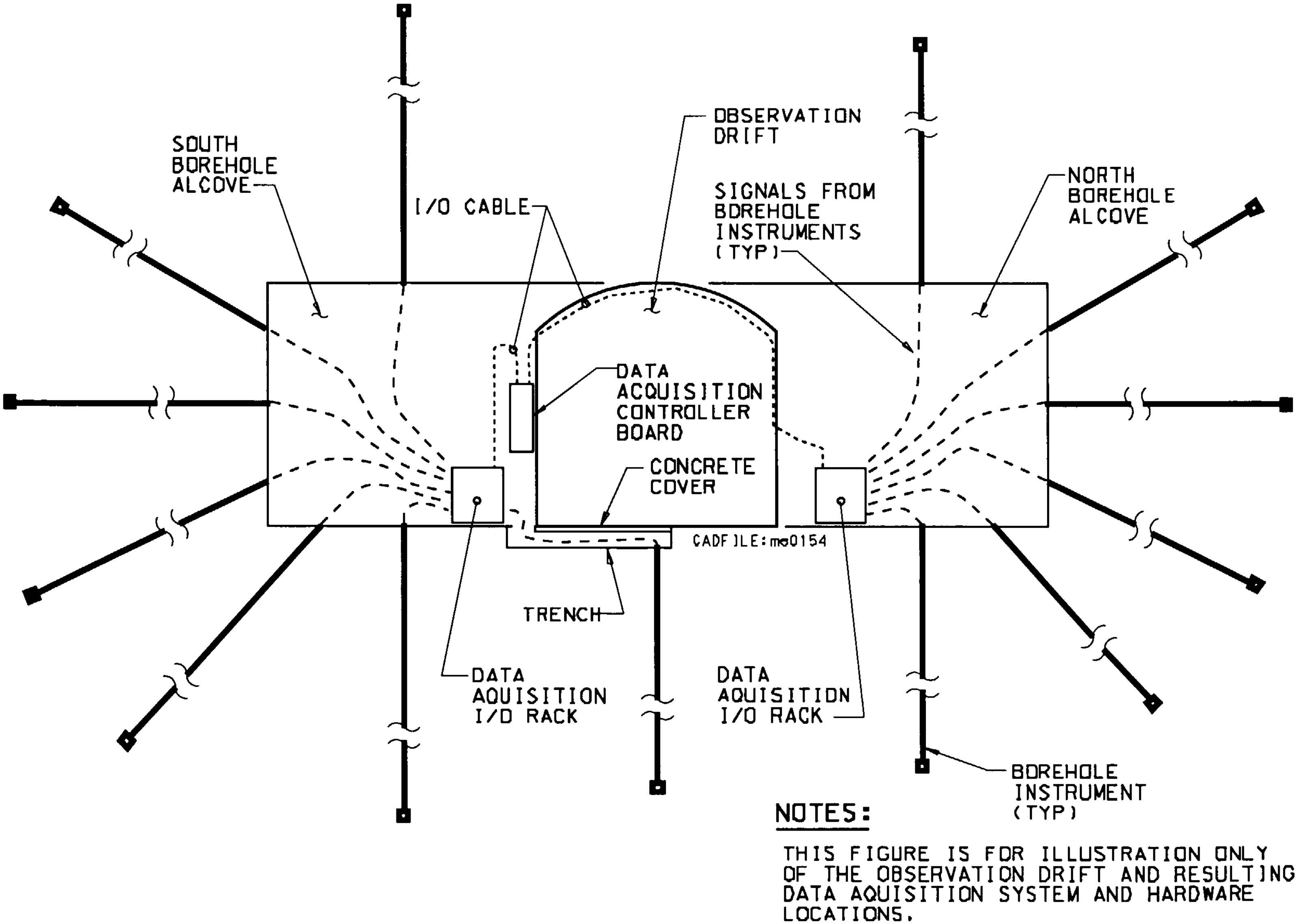
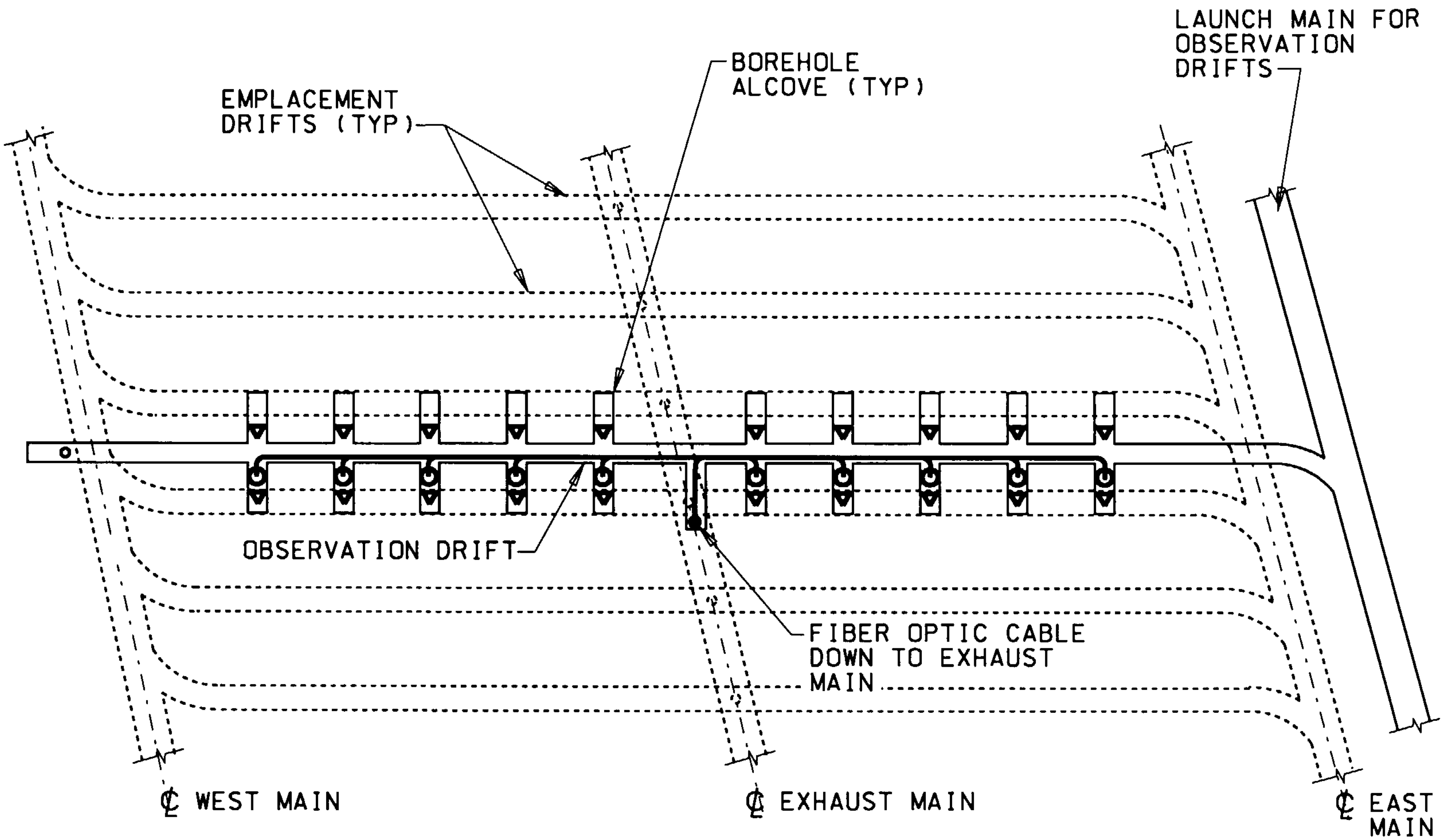


Figure 2. Observation Drift Monitoring Data Acquisition



PLAN - OBSERVATION DRIFT LAYOUT

CADFILE:me0155.fig

LEGEND:

O CONTROLLER BOARD ENCLOSURE

▼ I/O RACK ENCLOSURE

NOTE:

THIS FIGURE IS FOR ILLUSTRATION ONLY OF THE ALCOVE ARRANGEMENT OFF OF EACH OBSERVATON DRIFT

Figure 3. Observation Drift Monitoring System Layout

Table 1. Observation Drift I/O Signals

% of Total Number of Emplacement Drifts Monitored	Number of Observation Drifts	Number of Input Signals
4 %	1	5,500
12%	3	16,500
20 %	5	27,500
53 %	13	71,500
100 %	25	137,500

If there are three observation drifts, (Section 5.1.3) then the total number of inputs to the data acquisition system from observation drift borehole monitoring can be 16,500. If the quantity of observation drifts increases, then the quantity of data acquisition input signals would increase accordingly. According to the analysis, *Site Recommendation Subsurface Layout*, there are 3 observation drifts for the Truncated Case (CRWMS M&O 2000e, Table 14 and Figure 9). Whatever the final outcome of I/O points, efforts should be made to make it a reasonable number, so a reasonable and workable data acquisition system configuration can be achieved.

The wiring for each signal from the boreholes will exit the borehole in either the North or South alcove off of the observation drift. It is in these alcoves that the acquisition hardware should also reside. The data acquisition hardware, which will reside relatively close to the borehole signal transmission devices, will consist of a controller board, I/O card racks, I/O cards, and cables which connect the I/O card racks to the controller board. The following discussion will present one observation drift borehole monitoring data acquisition network to show the viability of such a system. Additional effort will be required to arrive at the most optimal installation from a cost, installation, and maintainability standpoint.

There will be 210 channels required in the North alcove and 245 channels required in the South alcove. In the North alcove, 210 channels can be accommodated by fourteen to sixteen channel input cards. Adding three cards for spares and design contingencies brings the total number of cards for the North alcove to seventeen. This quantity of cards can be housed in two I/O card rack assemblies, which can typically house 4, 8, 12, or 16 cards.

The I/O rack cannot communicate with higher level process equipment and, therefore, requires connection to a controller board. The controller board enclosure can be mounted in the South alcove and the controller board could be mounted in the same enclosure that contains the South alcove I/O card rack. Because the controller board will interface with other controller boards and the main PC computer system, it can also be mounted near the observation drift, which can contain the communication backbone. 245 channels, for the south alcove I/O, can be accommodated by 16 - sixteen channel input cards. Adding four cards for spares and design contingencies brings the total number of cards for the south alcove to twenty. This number of cards can be housed in two I/O card rack assemblies.

For the above example, one controller board will be located in each alcove arrangement of the observation drift. The distance between each alcove arrangement, and therefore, each controller board, will be roughly 100 meters. To facilitate communication between each controller board and PC computer(s) on the surface, a fiber optic trunk line or backbone should be installed down the length of the observation drift. This fiber optic cable could be routed down the length of the observation drift, down the observation drift exhaust raise to the exhaust main where it can tie into the fiber optic cable running down the exhaust main. The signals would then be available for surface monitoring, trending, alarming and storage.

The above discussion presents a viable method for the observation drift borehole monitoring data acquisition network for PC. A fiber optic trunk line can be run down the observation drift and can be connected to controller boards which in turn can be connected to I/O racks which in turn can be connected to I/O cards which in turn can be wired to the instruments mounted in the boreholes as shown in Figure 4. The fiber optic trunk line would be routed to the exhaust main where it can tie into the exhaust main fiber optic line. Sufficient spare input capability exists to accommodate the design as it progresses. Thermistors can be installed in each data acquisition enclosure to monitor the temperature and alarm if it approaches the upper operating limit for the hardware or poses a hazard to operating and maintenance personnel..

6.5 PERFORMANCE CONFIRMATION SUBSURFACE DATA ACQUISITION SYSTEM NETWORK (PCDAS)

This section presents an overview of the type of digital based monitors and controls that will be used for the PC data acquisition network. The basis for the PC data acquisition network is the analysis, *Subsurface Repository Integrated Control System Design*, functional block diagram Figure 6, physical architecture diagrams Figures 19, 20, and 22, data communication diagrams Figures 25 and 26, and control room layout Figure 27 (CRWMS M&O 2000d). An estimate of the total system Input/Output (I/O) requirements will also be discussed.

Some initial concepts for the PC Data Acquisition System will also be discussed and issues and concerns regarding the characteristics and criteria required for the system will be presented. In addition, this section will address the criteria requirements in Section 4.2, as well as available hardware and software technologies that will support these criteria and achieve a reliable and robust system.

It is important to state the benefits and the uses of a data acquisition system. Data acquisition system technology increases the network throughput of measured data and improves the data record accuracy. It allows for easy sharing of data with various similar or dissimilar equipment or systems, and the data gathering, logging, communication, and handling functions do not interfere with real time control processes or other data systems communicating over the same network media. Data acquisition applications can involve high or low data speed and high or low data resolution, depending on the application needs. Data acquisition technology can include a remote telecommunications link to support data collection and monitoring in remote areas of a facility where hardwired connections are not possible. A data acquisition system is normally supported by a supervisory console at a central monitoring area or reading location.

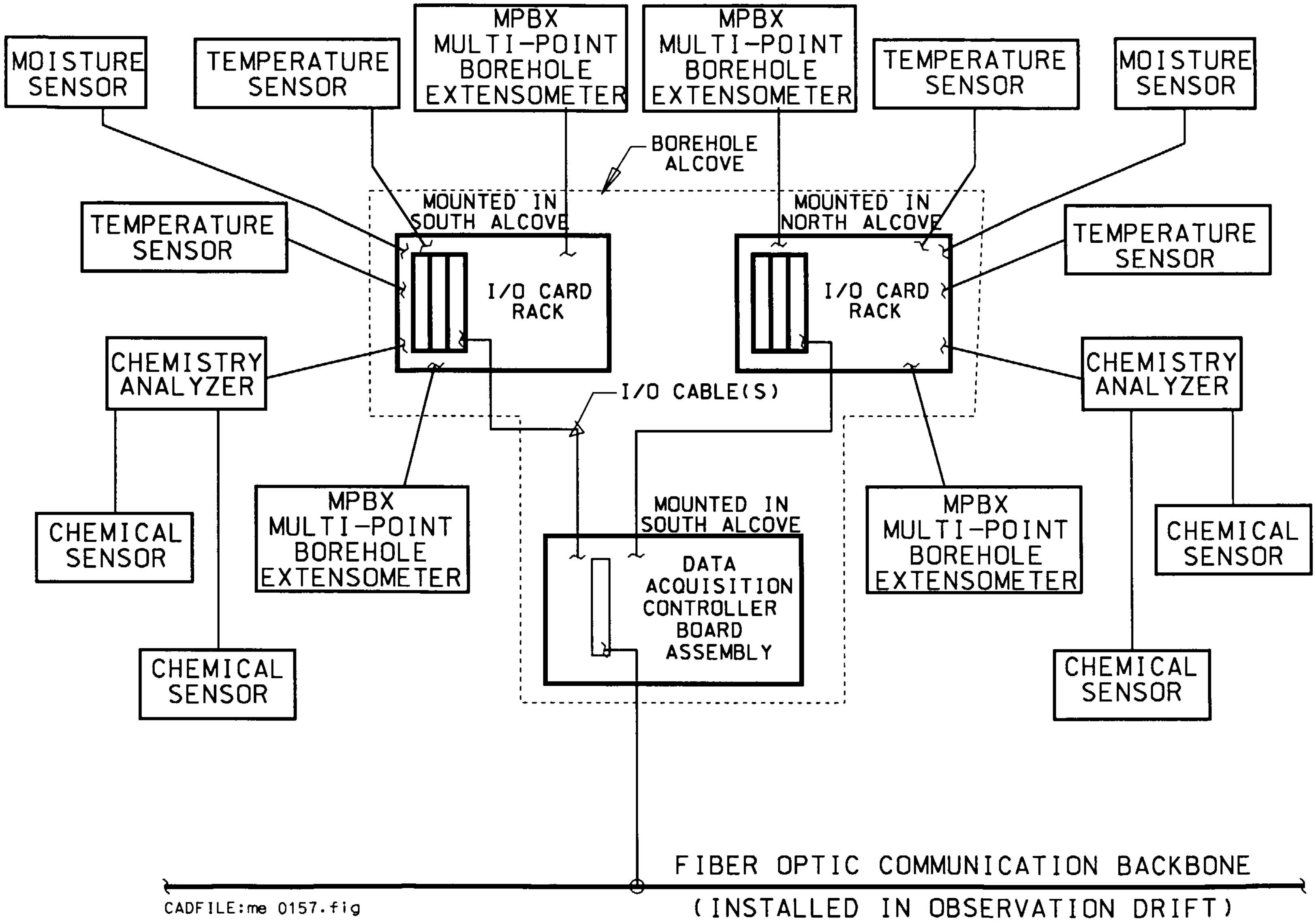


Figure 4. Schematic Block Diagram Observation Drift Monitoring

This system notifies personnel of data or situations requiring an immediate or quick response. A data acquisition system also reduces maintenance, power, and labor costs (DeFusco 1999, page 105). All these data acquisition features or technologies provide the capabilities to support the current operating concepts of the YMP repository and related SDD criteria for data acquisition. They are essential parts to both the PCDAS and the overall MGR Operations Monitoring and Control System.

Discussions of hardware and software are sometimes intermixed or combined in this analysis because of the integration and dependence of the two, both at the application and system network levels. Data acquisition hardware and software technology supports the PC program data acquisition design criteria with these features:

- Configuration and combination of different databases from different data highways into one database
- Data sampling rate
- Data throughput
- Data resolution
- Selection of the best data input configuration and graphics development software
- Human machine interfaces, or HMIs.

These features, as well as others, will impact major detail design specification limits of the PCDAS hardware and software components. See Section 6.5.1. The PCDAS database includes data gathered from its own monitoring equipment, and data obtained from system communication interfaces with other monitoring system databases within the repository. These include:

- Borehole observation drifts

- Remote observation and inspection of emplacement drifts (including visual, radiological and thermal inspection, and remotely operated systems),

- Waste package monitoring, in-situ waste package monitoring (subsurface excavations and surrounding rocks),

- Recovery of waste packages for testing, and subsurface test facilities and support (permanent observation drifts, emplacement drift ventilation, seismic monitoring alcoves, in-situ seal testing alcove, backfill testing alcove drifts, other PC alcove testing in non-emplacement areas between the waste packages and the saturated zone).

One of the main reasons for having a PC program is to establish the Postclosure Safety Case for the potential repository. It is a plan of long-term testing and monitoring and addresses inherent limitations and uncertainties associated with the short term testing and characterization that have and is currently going on. It will confirm the assessment of principal factors affecting postclosure performance. All data collected will provide needed information for determining that the natural and engineered systems and components are functioning as intended and anticipated or for helping determine where the program requires changing itself (DOE 1998, page 2-10 and 2-11). The PCDAS plays a large role as the means for the subsurface repository PC verification.

The PC program shall provide data important to parameters and conceptual models used in the performance assessment (Dyer 1999, Subpart F, Section 131). According to Dyer 1999, the PCDAS will also need to comply with all specific requirements coming from proposed rule 10 CFR 63, Federal Register 64 FR 8640. In the proposed rule, Subpart F, 63.131(d)(3), it says the PC program monitors and analyzes changes from the baseline conditions that could affect the performance of a geologic repository. The PCDAS needs to conform to the requirements of the *Performance Confirmation Plan.* The PC program shall gather sufficient data to help in the license application to close the repository (CRWMS M&O 1999d, Executive Summary, pp. vii and viii). This lends credibility and importance that a reliable and robust data acquisition system has an impact in providing data for use by the ventilation system, affecting its determination of the duration and amount of emplacement drift ventilation required. In turn, this impacts the electrical power operating costs of the pre-closure period. An efficient or a high rate of data recovery from the various PC monitoring instrumentation systems is required. A typical commercially available digital based data acquisition system can meet at least a 90% data recovery from continuous monitors (See Section 4.2.2).

The *Performance Confirmation Plan* (CRWMS M&O2000b, pages 5-39 and 5-40) states that the PC test program shall consist of a multi-component PC emplacement drift monitoring system, to monitor the geologic, hydrologic, and geochemical conditions adjacent to the emplacement drifts, and to monitor conditions surrounding the repository block. Support systems to accomplish this include PC Observation Drifts and alcoves, remote inspection vehicles, data received and shared from the subsurface ventilation system, in-drift instruments, sample coupons, and other operational systems. Observation drifts shall provide access for the thermal monitoring of areas altered by heat. Should the PC test program require such an integrated network, the PCDAS database interface and incorporation of the databases of the remotely operated system shall include visual, thermal, and radiological monitoring. The visual inspection monitoring shall obtain records of waste package surfaces, drift inverts and walls, ground support systems, and drift collapse and rock falls in the drifts following waste package emplacement. The thermal inspection monitoring shall measure waste package surface temperatures, temperatures of the emplacement drift wall, and drift air temperatures following waste emplacement. The radiological inspection monitoring shall measure radiation levels in the emplacement drifts to detect potential waste package failure and radionuclide release (CRWMS M&O 1999d, Appendix B, pp. B-2 and B-3). The current scope of the Subsurface Repository Integrated Control System (CRWMS M&O 2000d) supports this design criteria of multiple independent systems integrated over a common data acquisition and communication network that incorporate PCDAS field sensors and instrumentation, and monitoring and control system hardware and software.

By way of Dyer 1999, proposed rule 10 CFR 63 Subpart F, 63.131(d)(3) discussed above, opens the scope and increases the opportunities and functional criteria for the PCDAS to be more than just a monitoring system. The PCDAS may or can be required to assist in providing the efficient and robust means for the analysis of the measured changes it monitors. Though specific functional requirements currently do not exist for the PCDAS to provide data analysis for measured changes in the data it monitors, the PCDAS may be the logical place to provide such data analysis. Specific or custom application software for measuring and reporting the rate of change of a measured data point, and the interpretation of the change with respect to a specific baseline condition or process parameter value could be provided. If this functional criteria and when other eventually defined criteria is determined, then these needs and potential impacts on the PCDAS would likely require revision to this analysis.

The *Performance Confirmation Plan* (CRWMS M&O 2000b, pages 6-1 through 6-4) states that the PC program shall be used to update total system performance models as needed. Results of monitoring and analysis shall be used to confirm the predicted system response. The PCDAS can be given the functional responsibility to compare gathered data to the predicted response of a parameter or measured variable and report variances or differences from the accepted values. Application software modules can also be incorporated in the PCDAS to update total system performance models as needed. The *Performance Confirmation Plan* (CRWMS M&O 2000b, pages 6-6 through 6-8) also states that PC data collected shall also be used to update regulatory reports and licensing documents, technical database reports, data comparison reports, and data/model comparison reports. The PCDAS will have database management, system management, and communication system application software and programming to make the data available to the appropriate supervisory console and system within the OMCS (CRWMS M&O 2000d).

Some of the specific variables and conditions of the potential repository that will be monitored by the PCDAS include (DOE 1998, page 4-109, and CRWMS M&O 2000b):

- Air temperature and relative humidity
- Type and amount of radioactive gases
- Condition of the waste packages and the emplacement drifts
- Placement and recovery of test coupons of sample materials in the emplacement drifts
- Groundwater flow into the emplacement drifts and evidence of standing water accumulating in the drifts
- Air permeability, in situ stress, and deformation and displacement of the rocks around the emplacement drifts
- Soil and rock temperatures
- Moisture content, vapor content and humidity, fluid temperature, and air pressure in the altered zone

There will need to be specific and dedicated equipment and instrumentation to support the PC data gathering processes and the connection to the data acquisition system network. There will be requirements for industrial grade instrument sensors and transmitters, scientific grade instruments and analyzers, intelligent field sensors and instruments, and a variety of common and sophisticated mechanical systems. Some of the data acquisition equipment will need to be as robust as some of the sensors and field instruments, discussed later in this analysis.

The PCDAS equipment and system network design will need to support a minimum 30 year monitoring period after emplacement of the last waste package. The design of the PCDAS shall allow for a closure deferral up to 300 years from initiation of waste emplacement. The monitoring period is a test of the advisability to allow the near-field rock to be heated above the boiling point of water. If inadvisable, then increased ventilation will be required and the monitoring period would be longer than 30 years. (CRWMS M&O 2000h, page 5-2).

The PCDAS will need to be designed with the understanding of technology trends, its equipment and software specified and selected with the future in mind, and the ability to support itself by accepting manufacturer's hardware and software upgrades as well as replacements.

6.5.1 Data Acquisition Hardware

Discussions on hardware will address the driving technology changes in data acquisition systems regarding personal computers, serial bus and device level networks, Ethernet, the Internet, and wireless communications. As previously stated, in some cases software issues are included together with the hardware discussed. The PCDAS hardware can be broken down into two levels. The levels consist of higher functional level network components that interface to the MGR Operations Monitoring and Control System, and the data acquisition application package or system components. This section will discuss the issues and factors that affect the hardware with respect to these two areas. Discussions also include the fact that there are cause and effect relationships between the network and application hardware components. For both hardware levels the preferred approach would be to use digital based, commercially available, or proprietary, rather than custom components.

There are many functional criteria, systems interrelationships, parameters, and operating requirements that affect the PCDAS hardware requirements and their eventual specification and selection. These include:

- safety-related system classification
- data communications connectivity
- network bandwidth and throughput
- network segmentation
- redundancy
- data acquisition rate or frequency
- supervisory functions
- administrative functions
- modularity
- maintenance
- troubleshooting
- ease of replacement
- reliability
- physical requirements and constraints
- installation requirements and constraints
- human machine interface (HMI) factor.

These criteria, parameters, and the functional criteria from the *Performance Confirmation Input Criteria* (CRWMS M&O 1999c), will need to be specified with their limits defined in the design specifications for all the PCDAS hardware and software components.

Correct specification of the hardware will be important. Physical and installation requirements and constraints on the PCDAS hardware such as temperature and radiation exposure will impact selection of the proper hardware. Because of the long lifetime requirements of the PCDAS, factors such as modularity, replacement, troubleshooting, reliability, and maintenance will be very important issues, considering the system and its components will require changing, perhaps several times during the life of the preclosure period. Decisions to build in the appropriate degree of redundancy into the PCDAS hardware will require specific additional analysis of the system requirement for a robust, failsafe, and dependable operation.

6.5.1.1 Network Hardware Components

The network components include items such as the communication medium (wire, wireless, etc.), server computers, routers, data concentrator, hub wiring, and cabinets. A representation of this hardware scheme for the PCDAS can be found in the *Subsurface Repository Integrated Control System* analysis, (CRWMS M&O 2000d, Physical Architecture Diagram-Sheets 1 and 2, Figures 19 and 20, respectively).

Other network components consist of a leaky feeder network including a radio frequency modem(s), a router and data concentrator connecting at a node to the FDDI non-safety-critical systems LAN. The leaky feeder highway is the data communication highway that also supports the PC mobile remotely operated inspection gantry. Current concepts also have the leaky feeder highway supporting other subsurface operating systems controls and communications. See Figure 22 of CRWMS M&O 2000d. The FDDI LAN is the communication backbone to the PCDAS. It also supports several other subsurface operating systems. It supports the interface with the Site Communication System and allows the transfer of data to the Site Operations System, meeting design Criteria 4.2.9 and 4.2.10. See Figure 1 of CRWMS M&O 2000d. The LAN recommended in the *Subsurface Repository Integrated Control System* analysis is an Ethernet highway with TCP/IP protocol. This protocol guarantees delivery of all data ensuring that a collision between two packets of data will not occur, called the token-passing method. Once on the communication LAN, the PCDAS data will be well supported and protected from any network induced errors.

One significant point to consider is the quantity and rate of PC data collection and its impact to the design of the overall MGR Operations Monitoring and Control System control and communication network. The quantity and rate of data collection required by the PCDAS will impact the overall design of the networks that support the PCDAS. These include the waste emplacement leaky feeder network, the design of the MGR operations PC supervisory monitoring and control computer platform and console, and the design of the MGR Operations Monitoring and Control System FDDI LAN. This is because these networks are shared with other subsurface operating systems and controls. The specification and selection of the types of commercial available or proprietary application hardware and software for the PCDAS also directly impact the design of the MGR Operations Monitoring and Control System FDDI LAN. See Section 6.5.1.2 on Application Hardware Components.

With this established network functional architecture and with continued future development of the *Performance Confirmation Plan* (CRWMS M&O 2000b) and the *Performance Confirmation Input Criteria* (CRWMS M&O 1999c), a more detailed concept of hardware and software component requirements for the PCDAS can be developed.

6.5.1.2 Application Hardware Components

The PCDAS application or functional hardware will include components consisting of several commercially available or proprietary distributed control system (DCS) controllers. A distributed control system (DCS) is used as one of the most common types of data acquisition systems. These systems are proprietary and commercially available. They consist of computer based hardware platforms, operating systems, and network technology usually built to open industrial standards, thus allowing for interfacing capabilities with multiple and different manufacturer's DCS systems. Although the typical DCS, with open system network design capability, is primarily used for multi-tasking and real-time monitoring and control of industrial processes, it is commonly used simultaneously as a data acquisition system. Included with the DCS will be I/O multiplexers and wiring cabinets, proprietary communication device drivers such as fieldbus I/O, programmable logic controllers (PLCs) with I/O boards and wiring cabinets, personal computer stations with slot and slotless I/O, and HMI work stations.

Each of these different hardware systems of data acquisition and monitoring will probably have a proprietary data highway. The individual data acquisition controllers will communicate over a common network topology to the MGR Operations Monitoring and Control System PC supervisory control console located in a control room within the Central Control Center (CCC). This will be done using appropriate Ethernet local area network (LAN) hubs throughout the repository, then on to a fiber distributed data interface (FDDI) based router and concentrator. See Section 6.5.2, PCDAS Network Topology Overview. Each of these systems will provide features for manual data entry per design Criteria 4.2.6, and will provide limited local storage of electronic test data at each test location per Criteria 4.2.1. All links from the PCDAS controllers to the FDDI LAN are doubly redundant (OCRWM O&M 2000d, Section 6.4.2 and 6.4.3).

6.5.1.2.1 Wireless Communication Data Acquisition Hardware

The PCDAS interfaces to the subsurface RF leaky feeder wireless data highway network. The PCDAS receives the data for the remote communication of operating and control data for the inspection gantry, and for PC data communication from the inspection gantry. This interface is the MGR Operations Monitoring and Control System.

Wireless communications would support other PC equipment systems or areas of monitoring where wiring installations may be difficult to install, not feasible, or cost effective. The predominant form of wireless communication will probably be by radio. One rugged industrial environment where licensed wireless narrowband radio modem communication has been proven over the years is the offshore oil platform. Many unmanned platforms are monitored with data being collected at a single manned platform. These systems consist of a human machine interface at a host computer that communicates with the remote platform PLCs via a point-to-point radio network (Smith and Kimball 1999, page 51). The mining industry also uses proven wireless radio control and data communication systems all over the world. The reader can review documents CRWMS M&O 1998a; CRWMS M&O 2000a, Section 6.5; and DOE 1998, pages 4-108, 110, and 112, for further discussions about the anticipated use of wireless radio modem based monitoring and control systems in the YMP repository.

The use of spread spectrum or cellular phone could also be a possibility. Fluke is a company that has decided to span the remote and distributed world of data acquisition with a spread spectrum data logger or portable device. It has the capability to transmit data up to ¼ mile without losing the connection (Laduzinsky 1999, page 47). This product and others similar could be quite useful for difficult, small, and remote PC data acquisition needs within certain test drifts and alcoves. See Section 6.5.1.2.2 on Portable Data Acquisition Hardware for additional discussion.

A complete representation of the network hardware and communication scheme for the PCDAS can be found in CRWMS M&O 2000d, *Subsurface Repository Integrated Control System Design* analysis, Physical Architecture Diagram-Sheets 1 and 2, Figures 19 and 20, respectively, and the Data Communications Network, Figure 25.

6.5.1.2.2 Portable Data Acquisition Hardware

The PCDAS will need to include hardware features for the receipt of electronic data from auxiliary or portable data acquisition equipment according to design Criterion 4.2.7. Remotely installed portable data acquisition equipment and systems are very efficient today because of advances in microprocessor designs and data display and surface-mount technologies. They have robust electronic and physical designs and are available in portable AC line or DC battery power options. This is all possible without sacrificing any data acquisition features for the sake of portability, such as weight, and maintaining compatibility with a variety of physical environments and conditions of temperature and humidity throughout the repository (Fuller 1999, pp. 39 to 44).

Available portable data acquisition equipment includes stand-alone dataloggers, hybrid recorders, PC laptops, handheld display units, and small "*post it*" loggers. The stand-alone datalogger features on-board data storage, can execute preprogrammed scanning routines, and can be operated without the aid of a computer. The addition of a cellular phone communication link to a datalogger, or wireless mode, for remote site dialing to get data to a central data acquisition system can be achieved (Resweber 1999). The datalogger can be easily programmed either from the push-button front-panel interface or from a computer using a configuration program. In a non-stand-alone mode, several types of portable data acquisition equipment are able to pass data in real-time to a host computer using a variety of communication connection standards. Some of these standards include the universal serial bus, the computer bus, parallel port, PC slot, and Ethernet protocol. They can sample data usually up to 250 readings per second (Fuller 1999, pp. 39 to 44). This would seem to meet the needs of the monitoring that the PC program would require.

The chart recorder is another "old stand-by" device that would prove useful in specific remote areas of the repository that would require manual data gathering not covered by the PC data acquisition communication network. These units can be set up to display real time data as well as review historical data on screen, without the use of a computer. For the smallest of portable data acquisition equipment, a handheld display recorder or hybrid datalogger is available that can store up to 8 channels and offer real-time color trend display. This may be useful for a specific and quick need of data input or for a remote or new data point requiring monitoring by the PC program. (Fuller 1999, pp. 39 to 44).

When selecting the proper portable equipment the signal conditioning capabilities are important in order to avoid additional costs. If many inputs were required it would be best to have the portable data acquisition device capable of programming and assigning specific signal conditioning functions to individual input channels. Other concerns when specifying a portable data acquisition device is the need for substantial on-board memory to store large data files, and the ease of configuration and data retrieval. The most common is to upload data in the form of comma separated variable formatted files. Selection should also include the ability to program for all task functions from its front panel, as well as through configuration software. A system with personal computer memory cards is often used to store scanning routines for different tasks that are easily recalled by a user. The cards also store monitored data. Set-up configuration files stored on-board is a convenient and timesaving method of changing parameters. Parameters include sample speed, trigger type (signals to start and stop data recording), signal conditioning assignments, alarms, and data files. The setup files are downloaded to the portable data acquisition unit, or in most PC laptop systems, remain in the laptop and pass information between itself and the data acquisition unit. The field input connections to the input channel on the data acquisition device should be carefully planned for. Removable plug in type connections are the most effective. These can be left at each installation, ready to reconnect for the next hand collection of field data (Fuller 1999, pp. 39 to 44).

A problem with all portable devices is their high common mode noise and shifting ground reference levels because of the input channels single-ended input configuration type. The selection of channel capacity for differential inputs would have the common mode rejection ratios (CMRR) that will suppress electrical noise. Channel to channel isolation should also be considered to protect against channel-to-channel voltage differences and maintain measurement accuracy (Fuller 1999, pp. 39 to 44). Accuracy of the collected data from the repository is important.

6.5.1.2.3 The Device Network and Intelligent Transmitters and Sensors

The device network is an expanding technology today that competes well in certain cases against traditional field instrument I/O multiplexing and extensive field wiring. A device network is essentially a set of smart or intelligent transducers connected by a common data communication cable that has a proprietary control and communication network bus hardware and software architecture associated with it. The transducers are manufactured with specific firmware or computer chips that allow for the interface and communication to the proprietary bus, or allow for an "open" bus architecture to different buses.

To achieve the highest level of data accuracy, consideration of the use of smart or intelligent field sensors and instruments (collectively called transducers), together with digital data communication device network bus standard is recommended for use where feasible in the PCDAS. These transducers can provide self-identification, self-testing and adaptive calibration, ease of setup, and improved rejection of spurious inputs. Smart transducers help by converting data into information and reducing communications bandwidth requirements (Johnson 1999, page 17). These characteristics would surely and greatly benefit the extremely large databases of some of the primary monitoring systems for the data acquisition system.

A device network would work well with the geotechnical and environmental monitoring sensors. It would provide significant savings in wiring and installation labor, eliminating individual and traditional I/O wire pairs per signal device. At the device level on the functional block diagrams of the *Subsurface Repository Integrated Control System Design* (CRWMS M&O 2000d) a single device network data highway would exist that could include many highway nodes connecting each instrument and monitoring/control device to one data highway communication fiber or coaxial cable. Several instrument and device network standards or different bus structures exist that are likely to be useful for the PCDAS. Some of these include Fieldbus, LonWorks, ControlNet, DeviceNet, and Profibus for digital instruments and Seriplex and SensorBus for sensors.

IEEE Std-1451.2-1997, *A Smart Transducer Interface for Sensors and Actuators-Transducer to Microprocessor Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats*, is one of a series of standards for connecting any smart transducers to any networks. The standard covers network-capable smart transducers from the interface to the transducer to a high-level object model of behavior, attributes, and data communications. This standard makes it possible for manufacturers to produce network-capable and network-independent plug-and-play transducers for use in networked controllers and distributed data acquisition systems (Johnson 1999, page 17). With the application of this standard and the use of smart transducers, it enhances the ability to provide the technical assurance that the PCDAS can be upgraded or expanded as needed during the life of the PC monitoring period for the repository.

The greatest asset of IEEE-1451.2 is it lets the user select those instruments best suited to performance requirements and not because they connect to a particular network technology. This can only benefit the various PC requirements of the four primary data acquisition PC monitoring systems (ventilation system monitoring, in-situ monitoring of emplacement drifts, mobile remote monitoring of emplacement drifts, observation and perimeter drift monitoring) allowing for open systems, interoperability, interchangeability, and connectivity of varying manufacturer's sensors. IEEE-1451.2 also provides a standard for sensors to be directly connected to Ethernet (Gruner 1999, page 53), supporting the proposed and recommended PCDAS physical architecture and communication protocol as discussed in the analysis, *Subsurface Repository Integrated Control System Design* (CRWMS M&O 2000d, Sections 6.4.2 and 6.4.3).

The use of the device network supports design Criteria 4.2.3 and 4.2.4. Requirements for data circuit protection or shielding from electromagnetic interference, and separation from electrical power lines would not be an issue of concern because of the digital field signal versus the traditional analog one. Another advantage of the intelligent transducers is their internal diagnostic capabilities for monitoring the health of the transducer and thus assessing the accuracy and correctness of the collected data received from it. This should satisfy design Criterion 4.2.8 for features of assessing the accuracy of collected data within each of the individual PC system's sensors, controllers, and monitoring computer platforms.

If the in-situ geotechnical sensors require instrument excitation, then the controller and I/O devices, or the DCS selected shall be capable of supplying the required voltage and frequency potential. There are specific data monitoring controllers that can do this. Two manufacturers of this type of hardware are Geomation, Inc. and Slope Indicator Co. Their data acquisition systems can also be fully integrated to larger data networks by various wire and wireless communication interfaces. This meets the requirement in design Criterion 4.2.5 for system instrumentation excitation.

As an interesting note, some predictions and opinions in the control instrumentation business today are that 50% of new control and instrumentation installations will be based on a device level network by the year 2002 (Gerold 1997, page 55).

6.5.1.2.4 The Personal Computer

Today's rapid technological development and future trend of the industrial grade personal computer will continue to drive its use and acceptance in data acquisition system practices. The personal computer will be the most likely primary device for monitoring data in the PC program. This is due to a large part of the fast and continuous development and advances in system integration, configuration and ease of use, and software driver application programming interfaces for use by the personal computer. It is at the personal computer level where different system hardware components require a specific software need, a cause and affect dependent relationship, and where an open system architecture of dissimilar or proprietary hardware can communicate seamlessly on an integrated data acquisition network. A host of technological advancements in today's control system designs have made issues as performance limitations, unreliability, and lack of interface standards at the personal computer level obsolete. Distributed I/O modules and devices, device level networking, intelligent sensors, the advancements of the Internet and Ethernet based TCP/IP communication protocol, and wireless communication capabilities, all have made the personal computer physical operating and monitoring platform the tool of choice for most applications of data acquisition.

Today, the personal computer is predictable and robust, offering benefits of supporting open architectures, networking, connectivity, performance, and familiarity. Benefits of using the personal computer, as a minimum, are (Klein 1999, page 15-16):

- *Integration of all data into a single tag database.* This allows for the combination of logic control, programming, operator interface and data collection functions into a single platform. With the PCDAS this will be a very large database.

- *Superior data connectivity* between applications on the same or different platforms through interfaces such as object linking and embedding (OLE) for process control, component object model (COM), distributed COM, and dynamic data exchange. Different proprietary device drivers or data highways will be able to be easily integrated. Data exchange is benefited by deeper interaction and added flexibility.

- *Flowchart programming* or an intuitive graphical description of the PC process or monitoring systems. Graphics builders will be used to create custom objects specific to a particular data point or an important consequence or a critical event occurrence. This feature is normally a big benefit to configuration of control system functions, but will benefit the PCDAS configuration and HMI.

- *Operator-level diagnostics* automatically detect faults in an intelligent field sensor, controller, or transmitting device, as well as operator error messages, and operator repair and recovery screens. These diagnostic tools are available in flowchart programming.

The flowchart programming and operator-level diagnostics features will very likely save significant hours and operating costs associated with intelligent field sensors and instruments programming, troubleshooting, configuration, and repairs throughout the long life of the PC program.

If there is a downside to the personal computer for use as the central monitoring point for the PCDAS, it would be that the openness of the system to more choice of hardware and software solutions makes the user responsible for those choices. The user must have the talent and knowledge to integrate and maintain a multiple-supplier system. Making sure of compatibility of components, keeping up with the pace of change of personal computer technology become paramount to the user or the user's contracted system integrator. The user will have to manage the risk. The cost of personnel training and system maintenance can become potentially significant and necessary for the PCDAS's effective life and longevity (Control Engineering 1997). It would be expected that the PCDAS would require a yearly operating and maintenance budget that includes a large portion of it dedicated to training and education on hardware and software data acquisition technology.

6.5.1.2.5 Distributed Field I/O Systems

New distributed I/O hardware modules, such as field I/O devices and controllers with local intelligence, is also helping answer the need for modular, smart, open solutions. The advances in networking and microprocessors make open-system approaches all the more viable. This makes for the ease and comfort of use of varying data gathering field devices and sensors with the different platform and software drivers of distributed control systems (DCSs), programmable controllers (PLCs), and personal computer based systems. This will support the PCDAS in a tremendous sense if the I/O quantities and robust requirements of the PCDAS make it easier to use different data acquisition proprietary systems for different parts of the system network with different types of data gathering requirements. Some examples of these field I/O devices are those that can operate with different fieldbus protocols or serial links, and in some cases, up to six bus protocols (Polischuk 1999, pages 25 and 27).

An advantage of distributed field I/O modules is the ability to locate them in close proximity to the field sensors and extend a single fiber optic or coaxial cable to each block I/O from the main controller. This reduces field wiring costs. The communication network fiber or cable will support an open network, with Profibus-DP, Ethernet, DeviceNet, and Foundation Fieldbus representing some of the common device level networks and protocols interfacing the I/O modules to the controllers. According to a study, this I/O product used with DCSs, PLCs, and personal computer based systems, will have a market growth from $1.9 billion in 1998 to $2.8 billion in 2003. The four control networks or buses above will represent 55% of the total market (Polischuk 1999, page 26).

There are predictions that the trend for the development and use of Ethernet I/O products and systems will be increasing significantly in the current decade (Polischuk 1999, page 27). Other devices being offered are ones that offer a universal input module that will link thermocouples, millivolts, volts, and current inputs directly on an Ethernet network. This may prove to be a benefit to the PCDAS especially if Ethernet is the protocol of the repository communication network as recommended in the analysis, *Subsurface Repository Integrated Control System* (CRWMS M&O 2000d, sections 6.4.2 and 6.4.3).

6.5.1.2.6 Data Acquisition Technology, Support of Ethernet, and the Internet

The use of data acquisition systems has grown tremendously in the industrial process world. Many manufacturers and vendors are investing tremendous resources in developing and networking hardware and software data acquisition units and components. Developments in semiconductor electronics, software, networking, and the Internet have brought new features to data acquisition systems, and many of the features have been adopted to make data acquisition systems easier to use. These developments have been achieved because of the growth of Ethernet based communication LANs that exist in industrial factories and plants around the world. With a Windows operating system, support of Ethernet and TCP/IP protocol through application software as OPC (for support of PLC data acquisition devices) and graphical programming (picking, placing, and connecting graphic element icons on the personal computer screen), there appears to be a strong enduring environment for data acquisition system development and advancement (Laduzinsky 1999, pages 42 and 43). Web technology brings elements together to communicate information. The everyday Netscape Navigator or Internet Explorer with Ethernet and TCP/IP is all that is needed to access any PCDAS data from anywhere that data access is required. Internet access is an available core technology that should be part of the PCDAS software. This technology supports the PC Plan reporting of data and communicating over the Internet to the public (CRWMS M&O 2000b, Section 2.1.7, page 2-8).

This strong development environment will benefit the future design of the PCDAS. The technology and products developed should be substantial and will meet the design criteria requirements and support the configuration of a very large and robust PCDAS in the future. The data acquisition software being developed is predominantly for use on the personal computer, making it the operating interface hardware platform of choice. It is the software that gives value to the data acquisition system. As backplane bus and network bandwidth increases, basic personal computer based data acquisition systems can handle more sophisticated and larger projects. Efforts for third party software to read and understand data collected by a data acquisition system through the development and use of a protocol called the Open Data Acquisition Standard (ODAS) is also part of the new trends in DA technology (Laduzinsky 1999, page 48). This should be further reviewed as time progresses to the actual YMP design phase.

Since the 1970's, access to sensor readings remotely via the Internet has been possible. Today, internet-based sensing, or remote instrument monitoring, is a mature, commercially available technology, though its application has been limited in many areas (Putnam 1999, page 60). The Web also opens up vast possibilities in remote instrument maintenance, service, repair, and tuning. Diagnostic tools for troubleshooting smart instruments can be used over the Internet. Internet access will be a benefit to the PCDAS. With the correct data acquisition to Internet interface products, data from the PCDAS will be able to be communicated, in read only, or remote viewing only protected form, while on-line and without disruption to the PCDAS itself.

This would provide a benefit to off-site YMP regulating authorities and managing personnel as well as the requirement to communicate to any of the off-site scientific laboratories involved with data assessment and interpretation from the PCDAS systems.

Even required software revisions and upgrades to the PCDAS can be made through the Internet. Connection to the Internet or the DOE Intranet, for example, is made by a dedicated computer 10 BaseT Ethernet port or external modems. Some personal computers made today can store data in HTML files, Java web programs, or directly with Internet database servers. State of the art methods of Internet-based sensing and control use Web browsers to deliver direct sensor data viewing. The most efficient way of doing this today is to separate the serving of sensor data from the serving of the web page. There are two different data streams. The sensor microprocessors send only the sensor data across the Internet. The Web page is served separately from a high level or dedicated web server or from the local hard disk, (Putnam 1999, pages 61 and 63), in this case, at the YMP site. Other Web software will broadcast the PCDAS data to user's personal computers.

6.5.2 PCDAS Network Topology Overview

A network can be defined as a collection of communicating devices that are interconnected and autonomous. A network provides for resource sharing capabilities with the devices on the network, with such devices as printers, modems, files, disks, and applications. A network has a common computer that controls and directs the communication between devices on the network. All of the following conditions are essential for a functional network (Bates, R.J. and Gregory, D.W. 1998, pages 446 through 465):

- A communicating device is any system that transmits or receives data. A communicating device can be a mainframe, personal computer, modem, controller board, or telephone.
- The interconnection of devices asserts that this equipment can exchange data. The interconnection may be over some physical medium, such as optical fiber, or through the air via radio waves or lasers.
- The devices on the network are autonomous, or "crash independent". That is, failure of a single device does not cause other devices to become inoperable and bring down the entire network.
- The devices on the network have unique network addresses.
- High communication speeds and very low error rates.
- Geographic boundaries.

Some of the equipment and software required for the PC data acquisition system will be incorporated in the MGR Operations Monitoring and Control System network in a manner incorporating the above features. The controller boards will all be interconnected via fiber optic cable. Requirements and limits for a particular controller's proprietary data highway physical configuration will define the overall topology for the PCDAS. If different, or a mix of manufacturer's equipment is used in the PCDAS, then the integration of it to a common network will likely create the need for special multiplexing and communication hardware together with the necessary software for configuration and communication. The number of PCDAS controllers and the overall maximum allowable length of a proprietary highway are constraints that will also impact the PCDAS network design. The particular topology of the network requires further investigation and design effort. Brief discussions of the various types of topologies follow.

In a star topology (Bates, R.J. and Gregory, D.W. 1998, page 467), all devices on the network are interconnected through a central node by its own wire(s). All communication is from one device, or one node to another; the central node acts only as a switch to provide a pathway between pairs of devices attached to it. The central device ensures that the communication traffic for a given node reaches it. A good example of a star network is a telephone switchboard, since access from one station on the network can occur only through the central device. The central node does pose high single point of failure concerns. This topology does not appear to be well suited for the repository application.

In a bus topology, a cable is usually laid out as one long branch onto which smaller branches are used to interconnect each station to the main data highway. All locations on the communications medium are directly electronically accessible to all other points. Any signal on the bus becomes immediately available to all other nodes on the bus without requiring any form of retransmission (Bates, R.J. and Gregory, D.W. 1998, page 466). Bus networks can be compared to the way appliances in the home are connected to the AC power line. Buses are probably one of the oldest network topologies. Buses are usually limited in the communicating medium that they can use, but do not typically suffer from single point failure problems.

In a ring topology, the communicating devices are connected by a set of point-to-point links that are organized in a closed fashion. Rings are commonly employed in networks. If one link of the ring is cut or disconnected, the entire network remains on-line. This is because the communications can reverse directions in the circular ring. The communications software can even locate the point where the disconnection or break has occurred.

Some networks are a mixture of topologies. Because of the inherent reliability and reduced single failure potential of a mixture, it is recommended that the repository network be constructed in that manner. As mentioned before, the PCDAS network will be a node or several nodes on the MGR Operations Monitoring and Control System network. The number of nodes and the length of the PCDAS network off each node will impact the MGR Operations Monitoring and Control System network design. See Figures 20, 22, 25, and 26 in the *Subsurface Repository Integrated Control System Design* analysis (CRWMS M&O 2000d).

The MGR Operations Monitoring and Control System network supports the data communications for the PCDAS. The MGR Operations Monitoring and Control System network is a FDDI LAN topology installed around the perimeter of the repository such as down the north main, then down the East main, over to the West main and eventually back out the north ramp to the surface facilities. Off of this ring can be other smaller redundant rings such as down the exhaust main and the south ramp. Off of the exhaust main, branches could be run up to the observation drifts and the associated data acquisition equipment located therein. The entire aspect for the proper network topology to be installed in the repository requires additional design effort and investigation. Refer to Figure 5 for a depiction of the interconnection of the PC data acquisition devices.

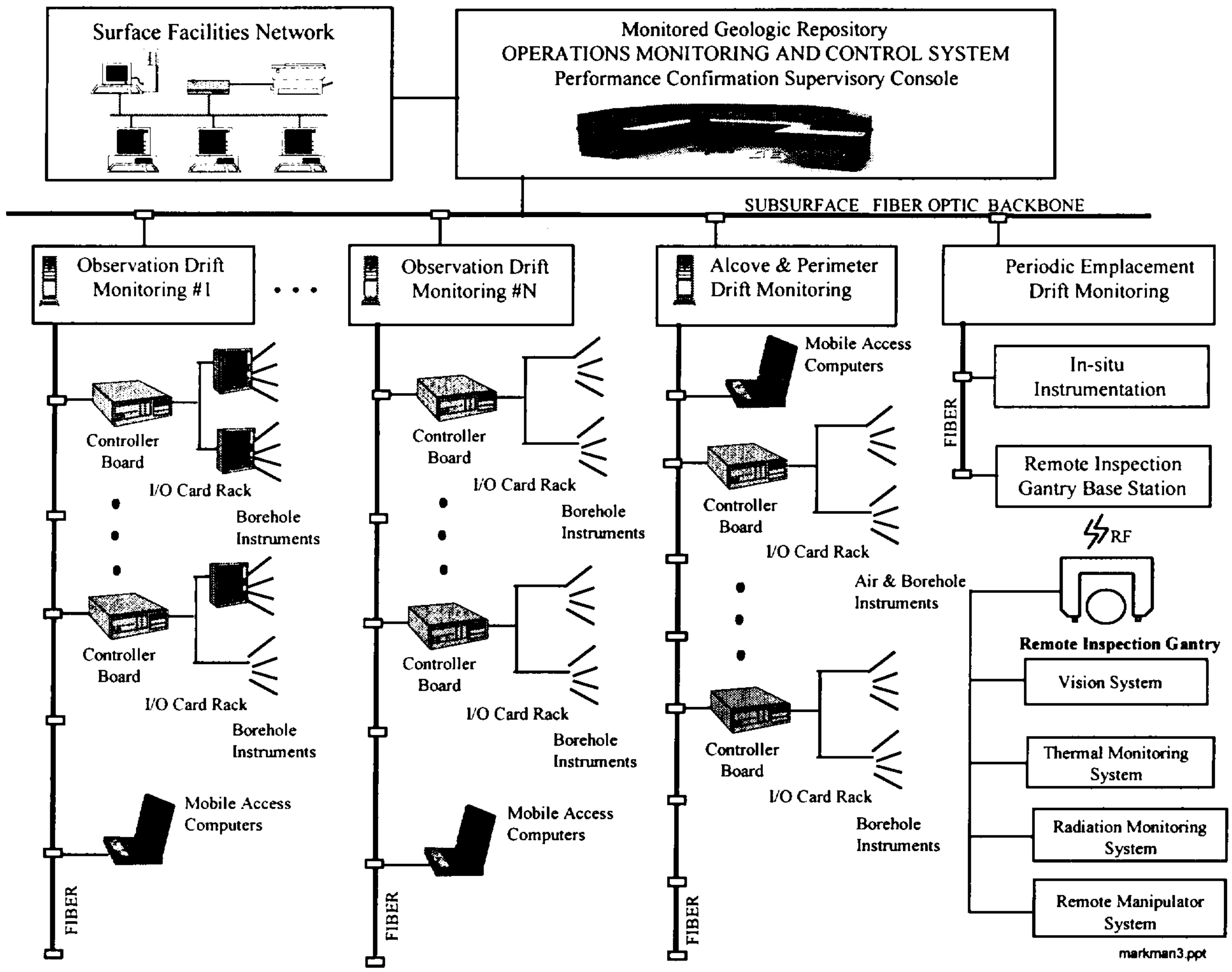


Figure 5. Subsurface Data Acquisition Network For Performance Confirmation

6.5.3 Operator Interfaces and Control Stations

All of the devices for transmission of PC data will be networked together and will allow personnel on the surface to view and manage this information. Operator interface and handling of the information will be as required in design Criteria 4.2.11, 4.2.12, 4.2.13, and 4.2.14. In addition, NUREG-0700, *Human-System Interface Design Review Guideline*; ANSI/HFS-100-1988, *American National Standard for Human Factors Engineering of Visual Display Terminal Workstations*; and Parts 3, 8, 10, 14, and 15 of ISO 9241 shall apply as called out in these specific design criteria. As discussed in Section 6.5.1 and as defined in the *Subsurface Repository Integrated Control System Design* analysis (CRWMS M&O 2000d, Figure 27), the PCDAS will be included as part of a centralized control room with a dedicated PC supervisory console. This supervisory console can be equipped with engineering workstations, control consoles and graphics terminals that can provide the operators with direct real-time data from the FDDI LAN. Also included are human-machine interface (HMI) workstations, computers, telephone handsets, video monitors and recorders, and data printers. (CRWMS M&O 2000d, Section 6.5, and DOE 1998, page 4-112).

Sufficient storage capacity should exist for time-stamping the PC data as it is received. This data can then be periodically plotted out to provide information from which accurate interpretations regarding the repository environment can be made. The network can be installed with sufficient access points or nodes to allow an authorized individual to temporarily hook up a lap top or notebook computer underground and have access to the transmitted data. See section 4.2.7. Some portable data acquisition hardware has this capability.

6.5.4 Data Acquisition Software

The purpose of this section is to discuss the various products and features of data acquisition software that are commercially available. Specific points in this section include software being the key to defining data acquisition performance, the layers of software that allow for the function, configuration, and use of a data acquisition system, connectivity of bus structures, and industry standards and operating systems.

The PCDAS network and application software will be a significant part of the entire PC program. This software will be included as an essential part of the software planning and development program recommended in the analysis, *Subsurface Repository Integrated Control System Design* (CRWMS M&O 2000d, Sections 6.8.1, 6.8.2, and 6.8.3). It is also reasonable that there would be some SRICS functional software criteria requirements regarding the PCDAS. The PCDAS software may also have an interface with the MGR Operations Monitoring and Control System and its communication software driver.

The PCDAS is currently considered a non-safety critical system. Should any portion of the PC system have its classification changed to safety-related, then the software planning and development would take on added dimensions in terms of its strategic features and robust requirements. From Figure 28 in CRWMS M&O 2000d, the PCDAS software will include packages of all types and levels, with emphasis on the application level. The PCDAS will also have its system level components and application support level components. These will vary in strategic features and requirements based on the eventual baseline issue of the functional design criteria and requirements as defined in CRWMS M&O 1999c, *Performance Confirmation Input Criteria.*

Data acquisition system performance with today's technology is being defined more and more by software. A software system allows for a system's hardware connection and essential ability of a hardware component to operate, communicate, and interface with a computer network, or a proprietary controller and network. With the advancement of the personal computer, operator graphical user interfaces, and user operating systems with open industry standard interface capabilities, the ability to build and tailor the system that fits the specific user needs is very achievable (Chesney 1999, page 8). The open system software products available today and their continued advancement will significantly enhance the opportunity for the PC program to meet its requirements. Current surveys indicate a trend in data acquisition software for more custom application needs. This trend is also projected to grow (Hoske 1999, page 131). With today's open systems making possible "best fits" to a user's need, it would seem that this trend is only normal and expected. Also, with this need for probable third-party software, the software is becoming the most expensive component of the data acquisition system installation. Some predictions and opinions in the control instrumentation business today are that 75% of the cost of an automation project will be devoted to software and services by the year 2002 (Gerold 1997, page 55). The software driver is the most important component in the data acquisition software architecture. It allows the system to take advantage of all the particular I/O hardware features (Chesney 1999, page 8). It also provides a common software interface or connector at each component so components can communicate. With open system characteristics, it is possible to use a wide variety of commercially available signal conditioners, I/O devices, computers, and application software allowing all of them to be effectively integrated and to communicate with each other. The collection of the monitored signals can become a vast database of PC data from different field sensors, transmitters, I/O boards and devices, using different software device drivers. This will be important to the scanning and merging of data derived from in-situ or geotechnical sensors and transmitters with signals and data from industrial transmitters and primary sensing devices such as humidity and temperature transmitters.

Data Acquisition software can be divided into three layers:

- measurement and automation services
- development tools
- end-user applications

The measurement and automation services layer is the foundation and consists of the device drivers mentioned above, and utilities such as configuration and calibration tools. These tools will allow for the PC monitored data to be viewed and recorded all in understandable engineering units. Individual channels on an I/O device can be independently configured, named, and other attributes defined. The manual setting of switches and jumpers on I/O devices is no longer required. The configuration utility also provides the graphical user interface (GUI) (Chesney 1999, page 8 and 9).

A calibration tool provides functions that, for example, allow a smart transducer to be calibrated over the network via software. This eliminates hands-on involvement at the field sensor location. Smart transducers and their communication protocols would need to be compatible with the calibration tool (Chesney 1999, page 9).

This calibration software tool will have a valuable impact to the PC program where some sensor locations are in hard to get to places, where manual access is difficult or near impossible, and where signal wire can't be pulled. This software tool will provide valuable support to the in-drift emplacement monitoring by the PC inspection gantry, or remotely operated vehicle. It also supports the human access requirements for the *Performance Confirmation Plan*, perhaps eliminating or reducing some of the risks involved with human access for an otherwise manual maintenance calibration procedure. This is especially true because there will be hundreds of transmitters and sensors in the PC data acquisition system, and under normal conditions, no human entry is planned in the emplacement drifts while waste packages are present, except under off-normal conditions (CRWMS M&O 2000b, Table E-6, page E-20).

The development tools layer is software packages used by the system configurator or engineering technical staff to create end-user applications. These tools provide the type of development environment, which may include graphical, text-based, component-based, or human machine interface (HMI) based (Chesney 1999, page 9). Because of some of the diversity of PC and monitoring systems, different development and programming environments may be selected. Since all data from the various PC systems needs to be merged or shared, various codes may need to be shared. In this case, tools that break down code into components or that can use code from another development tool will need to be used. Care will need to be exercised so the data acquisition hardware is compatible with the development tools selected.

The end-user application layer is the application software you create. Here is where the user takes the software development tool selected to create the user interface, to acquire data from I/O devices, perform analysis or control, and write the data to a file or graph. Another way would be to select a turnkey end-user application that requires no programming. These applications perform predetermined analysis and control routines. A development tool that includes an application wizard may be used. Wizards use prompts and create an end-user application template to get the programmer started (Chesney 1999, page 9).

Data acquisition software of the future will build on these characteristics discussed above. New operating systems and PC buses will continue to offer higher performance or more user-friendly interfaces. To take full advantage of a new bus, a new operating system is usually necessary. Platform independent device drivers will probably be the best bet for the long run. Look for software that can work seamlessly from one field device to a different field device, or support multiple types or manufacturer's devices. Automated application development wizards will become more intelligent and comprehensive. Parameters for an application will be entered into the operating system and the software will configure the hardware and write the application.

The connectivity of different bus structures has sparked the demand for software to support open systems, or systems allowing for different networks to be integrated without affecting communication. The quantity and frequency of data collection, and the distance considerations between the many controllers or nodes on the highway of the PCDAS, will determine viable data highway options. It will impact the selection of any custom and commercially available application controllers, device drivers, operator interface platform and driver, and software development tools.

The open industry-standard interface Object-oriented technology, object linking and embedding (OLE), and OLE for Process Control (OPC), has provided the user full interoperability with different sensor device networks, PLCs, and other register I/O factory floor devices without regard to the specific application software of the sensor or controller. This software driver application programming interface brings disparate I/O devices, manufacturing automation equipment, and business systems together. OLE provides plug-and-play connectivity between software and hardware from different suppliers (Chesney 1999, page 10). OLE provides a richer interaction, more flexible data exchange than just text only between disparate systems. OLE also has functionality built into it to create, access, and use the data. It provides for linking and embedding, where linking multiple source applications to a single resultant application creates compound documents. Or, the object can be embedded so that the source applications do not have to be on the drive of the control system computer. Embedding requires a lot more memory than linking, however. This is very important for a robust data acquisition system such as the PCDAS. It is a great and easy way to share data between applications or different proprietary databases that may be used for the different primary systems of data monitoring for PC (Boerkei 1999, page 43). Use of OLE for the PCDAS would help allow for seamless connectivity and an open system.

OPC is currently acting as the industry catalyst for a shift to personal computers for automation and data acquisition solutions. The transition to personal computer based data acquisition devices will happen on a large scale as more data acquisition software vendors begin to provide OPC severs for personal computer based devices. Seamless connections to HMI and supervisory control and data acquisition (SCADA) control software packages are and will continue to be a growing benefit and reality due to the OPC server. Standardization and interoperability will become more important allowing the integration of more hardware and software from multiple vendors. Software standardization will be widely accepted (Chesney 1999, pages 10 and 11). OPC has also been a catalyst to the development of comprehensive operator interfaces.

Another standard, Open Data Acquisition Standard (ODAS) is primarily for personal computer plug in I/O boards. It defines the software interface for personal computer data acquisition cards, or the communications mechanism between application software and the device drivers for DA hardware. With the multiplexed converters right on the personal computer's bus, data is sent directly to the personal computer's memory. With a universal OPC-to-ODAS interface layer allowing OPC-compliant applications to communicate with ODAS devices, more ODAS devices will eventually be able to communicate with OPC applications (Ludy 1998, pages 69 and 71).

Still another relatively new method in the data acquisition system industry is to do away with personal computer slots, a slotless personal computer, eliminating the plug-in board and replacing them with new serial buses like Universal Serial Bus (USB). This was built around the idea that the personal computer would remain a sealed-case personal computer-which meant the user would never open the case to add I/O enhancements. This is called Simply Interactive PC Framework (SIPC) (Cleaveland 1998, page 41). The USB has taken hold in some industry data acquisition applications but because of its short highway allowable length, it does not appear to be usable for the PCDAS. This technology and its continued advances should be reviewed in the future because the use of a slotless personal computer may have significant advantages with maintenance and software configuration issues.

6.5.5 Estimated Size and Complexity

From the information stated previously, there can be approximately 650 points from the exhaust air or ventilation monitoring system database, interfaced and acquired by the PCDAS, approximately 200 points from the mobile remotely controlled inspection system, and approximately 16,500 points (Truncated Case) from the observation drift monitoring system. Allowing a design contingency of 3,500 points for additional perimeter, empty emplacement drift borehole and test alcove monitoring brings the total number of inputs to 20,850. It is worth noting that the sample rate for these points, except for the ventilation monitoring system database, may range from once a day, to once an hour, to once every fifteen minutes, to continuous monitoring. In other words all 20,850 points will not be continuously updated; if they were it could cause high volumes of network traffic.

The fiber optic backbone, which may be installed in the repository, could operate up to and in excess of ten million bits/sec (Mbps). The software must be configured to handle this high data rate. Assume that the network can handle the conservative data rate of 100 Mbps. Analog values are usually converted to digital signals in 12 or 16 bit resolution. If the data rate of the network (100 Mbps) is divided by 120 bits, which could be representative of one analog value with start delimiter, addressing, and end delimiters, the network can support transmitting over 800,000 analog values every second. PC monitoring has roughly 20,850 points and repository operations will have numerous points, but the total will undoubtedly be less than 800,000. It is therefore highly doubtful that the network will become saturated and data could become lost or not updated in a timely manner. Faster network speeds will only increase the number of points available for transmission.

6.6 SYSTEM RELIABILITY, AVAILABILITY, AND MAINTAINABILITY (RAM)

As the design concepts for the PCDAS evolve and mature it will be important to thoroughly evaluate the system's reliability, availability, and maintainability. A formal, in-depth, "RAM analysis" of the PC data acquisition system is by itself an extensive analytical undertaking and is outside the scope of this document. However, because of the importance of this topic to the overall success of the design and implementation, this section will begin to identify and outline RAM issues related to the PCDAS.

A RAM analysis of data acquisition systems for PC will assess the probability of success for various design concepts as the design evolves. Expressions for reliability or availability, where appropriate, will estimate the probability of the system being operable for intended service periods and environments. Usually, analysis works in "failure space" to assess the probability of failure or unavailability of each subsystem of the inspection system in the inspection environment (e.g., taking into account the levels of radiation, temperature, humidity, and dust) during defined mission duration. For example, one mission time is the cycle time for the entry - to -exit of the inspection gantry in each emplacement drift. Another mission time might be the time between planned refurbishment of one inspection module (e.g., video camera).

6.6.1 Reliability/Availability Analysis

Quantitative system reliability and availability analyses are performed to estimate the probability of mission success and to enable quantitative trade-off evaluations of alternative designs and operations as well as alternatives for test and maintenance. This subsection illustrates some of the fundamental relationships that affect system reliability and availability.

The most often used basis for system reliability modeling is the exponential model for time to failure. In the exponential model, the reliability of a component is expressed as (Vesely, et al. 1981. NUREG-0492, p. X-20):

$$R(t) = \exp(-\lambda t) \qquad \text{(Eq. 1)}$$

Where: $R(t)$ is the probability that the component is functioning properly from time 0 through time t,
t is the mission time, and
λ is the failure rate (number of failures per unit time) of the component.

The exponential model can be applied also to the subsystem and system levels with appropriate definitions of failure rate for the assembly.

Analysis is often more convenient by using the unreliability, or failure probability, given as (Vesely, et al. 1981. NUREG-0492, p. X-20):

$$F(t) = 1 - \exp(-\lambda t) \quad \text{(Eq. 2)}$$

Where: $F(t)$ is the probability that the component does not function properly (or fails to survive) at least until time t, and other terms are the same as above.

For non-repairable components, the unavailability is equal to the unreliability. An important characteristic of the exponential distribution is that the Mean-Time-Between Failures (MTBF) are the inverse of the failure rate (Orvis, et al., 1981, p. 7-4). For example:

$$\lambda = 1/MTBF \quad \text{(Eq. 3)}$$

MTBF is an often-used parameter that may be included in equipment design, advertising, or purchase documentation. Using expression (3) in equation (2), the expression for unavailability for non-repairable failures is defined as (Vesely, et al. 1981. NUREG-0492, p. XI-11):

$$Q_N(t) = F(t) = 1 - \exp(-\lambda t) \quad \text{(Eq. 4a)}$$

Or by substituting equation 3 into 4 it is derived that:

$$Q_N(t) = 1 - \exp(-t/MTBF) \quad \text{(Eq. 4b)}$$

and the unavailability $Q_N(t)$ is seen to increase with time t. When $t >> 1/\lambda$ (i.e., MTBF), equation (4b) is approximated as (Vesely, et al. 1981. NUREG-0492, p. XI-11):

$$Q_N(t) \approx \lambda t \approx t/MTBF. \quad \text{(Eq. 5)}$$

If subjected to periodic tests at T_T, the average unavailability of the non-repairable component is (Vesely, et al. 1981. NUREG-0492, p. XI-13):

$$Q_N(T_T) \approx (1/2)\, T_T/MTBF. \quad \text{(Eq. 6)}$$

The MTTR, which stands for the Mean-Time-to-Repair (or Restore), is an often-used parameter to express the maintainability for a component or system. The MTTR is inserted for t in equation (6), along with MTBF, to predict the unavailability of a repairable component:

$$Q_R = 1 - \exp(-MTTR/MTBF). \quad \text{(Eq. 7)}$$

Usually, MTTR << MTBF, so expression (7) is approximated as (Vesely, et al. 1981. NUREG-0492, p. XI-12):

$$Q_R \approx MTTR/MTBF$$

which is a common expression that succinctly illustrates that achieving high availability, i.e., achieving low unavailability, requires increasing MTBF and reducing MTTR.

The above expressions for unavailability are applicable to the time regime prior to when components reach wear-out; i.e., components are assumed to fail randomly in time per the exponential distribution. Such random failures are due to inherent, randomly occurring manufacturing flaws; or randomly occurring over-stress condition like voltage spikes). One aspect of a RAM program (or a reliability-centered-maintenance (RCM) program) is to assure that the conditions for random failure are maintained by operational controls, periodic inspection and/or refurbishment. Prediction for time of wear-out and refurbishment are part of the Predictive Maintenance process.

In this exponential model, MTBF is usually assumed to be constant in time but may be a function of environmental factors, where the baseline, or generic MTBF, is multiplied by one or more factors to account for the environment (e.g., effects not included in the basic value such as factors to represent radiation intensity, humidity, and/or temperature); see for example *Guidelines for Chemical Process Quantitative Risk Analysis* (American Institute of Chemical Engineers 1989, p. 341). The effect of accounting for the environment factors is to alter the inherent properties of a component so that it is less resistant to random variation in applied stresses, (e.g., to a slight over-voltage), or to trigger an incipient flaw.

In more detailed analyses, the MTBF can be modeled as dependent on both the environmental intensity and the exposure time in the hostile environment. For example, in some cases, it may be possible to take credit for annealing effects where environmental effects, (e.g., radiation damage), are reversed when the system is removed from the hostile environment.

In addition, components can be induced to fail by external influences such as collisions with other subsurface vehicles, irregularities in the electrical power system voltage or current, human actions, etc. A comprehensive analysis of the probability of occurrence of such causal factors is not part of the RAM program for the inspection system, *per se*, but is an appropriate activity for a general RAM program for the repository.

Designing for adequate reliability will involve provisions for redundancy in subsystems and/or hardening to withstand the environment where deemed necessary, depending on the criticality of a given operational or measurement function without interruption during the mission time. In addition, the possibility of failures induced by human error will be addressed for their effect on reliability and availability. Human factors engineering of the operational control system, preparation of clear procedures, and operator training will help to reduce the likelihood of such errors.

6.6.2 Maintainability Analysis and Design

In general, the design must include provisions for preventive and corrective maintenance. Depending on cost and logistical constraints, the sensor subsystems might be designed for a remove-and-replace (R&R) maintenance philosophy. The design would accommodate ease of access and connectors and fasteners to facilitate R&R. Components so removed would be re-furbished for re-use or discarded.

In general, the maintainability provisions for the data acquisition subsystems will assume preventive maintenance in accord with the reliability analysis. That is, periodic testing and refurbishment, using the principles of reliability-centered-maintenance (RCM) will be applied to assure a suitably low probability of failure during the life of the PC program. These issues will be the subjects for future analysis.

6.6.3 Recommendations for a Future RAM Program

A future RAM analysis program for the PC data acquisition system should support the selection among design alternatives and support optimization of design for cost versus success of the mission for the required maintainable service life of 50 years. See Section 6.5. The analysis should address issues such as:

- Random failure, inherent to particular sensors, mechanisms, etc.
- Environmental effects on failure rates
- Human exposure issues on maintenance activities; need for auxiliary shielding and/or cooling
- Applications of Preventive Maintenance (PM) and Reliability-Centered Maintenance (RCM) concepts
- Human Reliability Analysis (HRA) during operations and maintenance, installation, configuring for specific mission
- Maintenance Philosophy for various subsystems
- Repairability/Accessibility of various failure modes of each subsystem
- Logistic and Spare-parts support program

Orvis, et al., 1981, developed guidelines for establishing a RAM program for a prior concept for mined geologic disposal of high-level nuclear wastes. The guidebook provides instructions for applying both qualitative and quantitative methodology for RAM analysis and design support. Although the guidelines were developed at a time when salt-dome sites were being considered, the techniques for defining, prioritizing, and analyzing RAM elements remain relevant. Techniques for simulation modeling are not included in the guidelines as they had been exploited only in limited applications at the time.

As noted in Orvis, et al., 1981, "Application of many of the techniques ... can be quite time consuming and costly" and it asks, "Should a comprehensive RAM analysis be applied to every component, equipment item or system?" The answer is "no", but efforts should be prioritized using a "decision tree" to suggest a level of RAM activity appropriate to a given unit: i.e., None; Minimum Effort; Moderate Effort; or Maximum Effort. The key elements in the decision process are "high confidence" in the performance based on prior knowledge or experience, "little effect or no effect on performance", "access for maintenance during operation", and degree of "uncertainty" about effect on performance or accessibility.

Depending on the level of RAM effort defined for a given unit, the program may apply one or more of the following:

- RAM Checklists (including Reliability Checklist; Maintainability Checklist)
- Failure Mode and Effects Analysis (FMEA) [or a variant such as Failure Modes, Effects and Criticality Analysis (FMECA)]
- Reliability Block Diagrams (RBD)
- Maintainability Evaluation (e.g., estimates of access times, repair times, radiation exposure of workers, etc.)
- Fault Tree Analysis (FTA); for detailed reliability analysis of subsystems and systems)
- Event Tree Analysis (ETA); to define RAM related scenarios

Except for the checklists, which are qualitative, the other techniques can be applied both qualitatively and quantitatively. The qualitative application of FMEA, RBD, FTA, and ETA provide a structured technique to examine how and why a mission may fail or why a failure may be critical. The quantitative application of these techniques can help in optimization of cost vs. performance.

To support a quantitative analysis, including simulation, the RAM program must also include a database development. Failure rate data for repository-specific components and equipment has to be developed. Where no experience data exists for the specific environment or duty, data synthesis and estimates must be developed. Environmental effects of radiation and temperature on failure rates must be included.

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7. SUMMARY AND CONCLUSIONS

This document may be affected by technical product input information that requires confirmation. Any changes to the document or its conclusions that may occur as a result of completing the confirmation activities will be reflected in subsequent revisions. The status of the input information quality may be confirmed by review of the Document Input Reference System Database (DIRS). Within this document there is one TBV (TBV-407) associated with several of the input criteria in Section 4. The resolution of this TBV does impact the conclusions or output of this document because when the PCDAS SDD is baselined it may change the requirements for the PCDAS. The TBV applies to the baseline of *the Performance Confirmation Data Acquisition/Monitoring System Description Document*, as specified in the Input Transmittal, *Performance Confirmation Input Criteria* (CRWMS M&O 1999c). This analysis supports the general concept of providing existing and developing technology trends and information in data acquisition system hardware and software designs for the PC program. Because the primary input criteria is not baselined, and the lack of a complete scope definition for the PCDAS, conclusions are not drawn from this analysis. The criteria, where appropriate, is addressed only in the fact that features are available with data acquisition systems that will be able to achieve the need or requirement in the criteria.

The assumptions in the analysis, Section 5.1, are used to help qualify and describe the overall size of the PCDAS and the types and quantity of data it may monitor. The impact of these assumptions on the results helps to compare and show existing data acquisition technology can meet PCDAS requirements.

The following paragraphs provide a brief summary of the material covered and design criteria used within this document, and highlight the key results and suggested recommendations where appropriate.

Section 6.5 presents discussion on various requirements for the PCDAS gathered from the project documentation supporting the PCDAS, such as the *Performance Confirmation Input Criteria*, *Performance Confirmation Plan*, *Monitored Geologic Repository Project Description Document*, and proposed rule 10 CFR 63 by way of Dyer 1999. One of the general things that becomes apparent is the fact that the PCDAS will need to be a reliable system with robust features. One of these features would be the ability of the system to maintain an efficient or high rate of data recovery. With the discussions of data acquisition technology and available features throughout the analysis, it is reasonable to suggest that Criterion 4.2.2 can be met.

This analysis presents a discussion on data acquisition hardware components and technologies. Sections 6.5.1.1 and 6.5.1.2 present discussions on PLC and DCS based networks and systems. Network components such as the leaky feeder network, the PCDAS data communication highway, and the overall FDDI LAN make up the communication backbone to the PCDAS. The physical architecture for the PCDAS is shown in Figures 1, 19, 20, and 22 of the *Subsurface Repository Integrated Control System Design* analysis (CRWMS M&O 2000d). This discussion addresses and shows support for design Criteria 4.2.9 and 4.2.10. Proprietary distributed control system controllers, programmable logic controllers, and data highways will communicate over a common network topology, connecting to the MGR Operations Monitoring and Control System supervisory console located in a control room within the Central Control Center. Each of these systems will have features supporting manual data entry Criterion 4.2.6 and limited local data storage Criterion 4.2.1.

The PCDAS hardware used will impact the overall hardware and software selection and configuration of the MGR Operations Monitoring and Control System control room and the MGR control and data communication network. It will also affect the selection of the MGR Operations Monitoring and Control System's main computer hardware and software platform, and the FDDI LAN. It is recommended that the schedule for the design of the PCDAS and the MGR Operations Monitoring and Control System should be as concurrent as needed, and include the necessary design tasks within the overall control system design schedule.

Section 6.5.1.2.1 presents a discussion on wireless communications and data acquisition hardware. Wireless communications such as radio will support PC equipment systems or areas of monitoring where wiring installations may be difficult or not feasible to install. The PCDAS interfaces to the waste emplacement gantry, for control and data transfer with the MGR Operations Monitoring and Control System. Portable data acquisition products are also available that are supported by spread spectrum and cellular phone wireless communications highways. These may prove to be useful in difficult, small and remote drifts and alcove data acquisition needs.

Section 6.5.1.2.2 presents a significant discussion on portable data acquisition monitoring system hardware. With current over abundance of commercially available products the PCDAS will be able to be supported by the receipt of data from portable devices, meeting Criterion 4.2.7. It is recommended that a thorough investigation of portable devices be conducted so their selections can be made as needed.

Section 6.5.1.2.3 presents discussions on device networks and intelligent transmitters and sensors. This type of communication network with intelligent transmitters and sensors eliminates hardwired I/O systems, or systems with one pair of wires for each sensing input. Criteria 4.2.3 and 4.2.4 are supported with this technology, nearly eliminating all the necessary shielding for electromagnetic interference protection and electrical power line transient voltages from hardwired installations. The device highway and intelligent transmitters also provide diagnostic capabilities for monitoring the health of the transducers, thus assessing the accuracy and correctness of the collected data received. Criterion 4.2.8 is met with this technology. Criterion 4.2.5 is met when commercially available I/O devices, controllers, and selected DCSs with capabilities for supplying the excitation voltages and frequencies to certain in-situ geotechnical sensors are used.

Section 6.5.1.2.4 outlines a discussion on the personal computer and its choice as the preferred HMI interface for today's data acquisition monitoring systems. The technological development of the personal computer is due in large part to the fast and continuous development and advances in system integration, configuration and ease of use, and software driver application programming interfaces for use by the personal computer. The personal computer supports open system environments of hardware and software, where the old issues of performance limitations, unreliability, and lack of interface standards have been eliminated. The typical personal computer features of flowchart programming and operator-level diagnostics, will very likely save significant hours and operating costs associated with intelligent field sensors and instrument programming, troubleshooting, configuration, and repairs throughout the long life cycle of the PC program. The downside to the personal computer is the openness it brings for more choices of hardware and software solutions, the more responsibilities on the user for those choices, and the need for having the talent and knowledgeable workforce to integrate and maintain a multiplier-supplier system. This risk, as in any system chosen, would have to be managed by the user and would require a yearly operating and maintenance budget.

Section 6.5.1.2.5 presents a discussion on distributed field I/O systems. These systems include field devices with local intelligence. The distributed I/O hardware modules are helping answer the need for modular, smart, and open solutions. This makes it possible to use varying data gathering field devices, sensors, and instruments with the different computer platforms and software drivers of distributed control systems (DCSs), programmable controllers (PLCs), and personal computer based systems.

This capability to intermix I/O devices with various data acquisition equipment can support the PCDAS. This is especially true should determined I/O quantities, different types of data gathering requirements, and other robust requirements make it easier and efficient to use different data acquisition proprietary systems for various parts of the system network. Some examples of these field I/O modules are those that can operate with different fieldbus protocols or serial links, and in some cases, up to six bus protocols. Other advantages include the ability to locate the modules close to the field sensors and extend a single fiber optic or coaxial cable to each block I/O from the main controller, reducing field wiring costs.

Section 6.5.1.2.6 outlines a discussion on the Ethernet highway, TCP/IP protocol, and the Internet. Developments in semiconductor electronics, software, networking, and the Internet have brought new features to data acquisition systems, and many of the features have been adopted to make data acquisition systems easier to use. These developments have been achieved because of the growth of Ethernet based communication LANs that exist in industrial factories and plants around the world, and the development of Windows operating system's support of Ethernet and TCP/IP protocol through application software such as object linking and embedding for process control (OPC) (for support of PLC data acquisition devices) and graphical programming (picking, placing, and connecting graphic element icons on the personal computer screen).

With Web technology and the personal computer, the Netscape Navigator or Internet Explorer with Ethernet and TCP/IP is all that is necessary to remotely access any PCDAS data that may be required or needed. The Internet access capability is an available core technology that supports the *Performance Confirmation Plan* in several ways. It supports the reporting of data and communicating over the Internet to the public (CRWMS M&O 2000b, Section 2.1.7, page 2-8). It also supports the apparent need to communicate with various outside PC science laboratories and offices performing tests and data analysis. The Internet also opens up vast possibilities in remote instrument maintenance, service, repair, and tuning. Diagnostic tools for troubleshooting smart instruments can be used over the Internet. With the correct data acquisition to Internet interface products, data from the PCDAS will be able to be communicated, in read only, while on-line and without disruption to the PCDAS itself. Even required software revisions and upgrades to the PCDAS host computer platform and application programs could be downloaded and made through the Internet.

Section 6.5.3 presents a discussion on operator interfaces and control stations. All of the devices for transmission of PC data will be networked together and will allow personnel on the surface to view and manage this information. Operator interface and handling of the information will be as required in design Criteria 4.2.11, 4.2.12, 4.2.13, and 4.2.14. The PCDAS will be included as part of a centralized control room with a dedicated PC supervisory console. This supervisory console can be equipped with engineering workstations and personal computer CRTs and graphics terminals that can provide operators with direct and fast access to data from the FDDI LAN. Also included are human-machine interface (HMI) workstation computers, telephone handsets, video monitors and recorders, and data printers.

Section 6.5.4 outlines a discussion on data acquisition software. There is typically an operator need or demand for knowledge and information within an operating facility that must meet some safety, safety-related, or robust requirements, such as those in the YMP repository. There are also factors driving advances in data acquisition technology. This need, and these advances include microprocessor technology and current trends for faster communication, increased user's needs and demands for connectivity between different hardware platforms, networks, and multiplexers, and the demand for open systems. Commercially available software has been developed for support of network, proprietary, and HMI platforms, graphic and user operating system interfaces, application and development tools and programs, data acquisition standard bus protocols and hardware interfaces, and remote I/O and controller hardware. These software developments support fast, accurate, and robust data gathering capabilities from many different computer based hardware platforms. This software allows data to be integrated into a single common database, such as the PCDAS, originating from several different independent and multiplexed systems and databases. This software is most frequently developed to operate within a personal computer and its compatible user operating system. It is the software that will give the real value to the PCDAS and it will be the largest cost item.

The operating system platform on the personal computer commonly uses an open software standard such as object-oriented programming. This permits the development of a software object that mimics a physical entity. Each object has associated attributes. These can include an entity as a temperature sensor/transmitter with attributes for a tag number, engineering units, I/O channel number, operator faceplate on the graphic display terminal, etc. This object-oriented development helps manage software development risk. Risks however do not go away. Deployment of any custom software applications in an open system such as the PCDAS, brings on added user responsibility for managing and controlling the software development and documentation.

The PCDAS software and software strategies used will impact the overall software selection and configuration of the MGR Operations Monitoring and Control System's FDDI LAN and communication control driver(s). It will also affect the selection of the MGR Operations Monitoring and Control System's main computer platform. The schedule for the design of the PCDAS and the MGR Operations Monitoring and Control System should be as concurrent as necessary, and include the necessary design tasks within the overall control system design schedule. The Subsurface Integrated Control System Software Planning and Development

Program (CRWMS M&O 2000d, Section 6.8.1) must include the necessary PCDAS software requirements and strategies.

Section 6.8 presents a discussion on system reliability, availability, and maintainability. Information was presented relating to the issues of equipment reliability, availability, and maintainability. Recommendations for a future RAM analysis and program are recommended.

This revised analysis, as well as the original analysis, include discussions on the ventilation exhaust monitoring system, the location of data acquisition sensory equipment within the emplacement drifts, observation drifts and the use of borehole in-situ geotechnical monitoring instrumentation, and communication network topologies. Because these concepts presented have not progressed, the recommendations and conclusions remain the same for these PC issues and their impacts to the PC data acquisition system and network.

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8.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES

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9. ATTACHMENTS

Not applicable.