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Light Duty Utility Arm Software Requirements Specification

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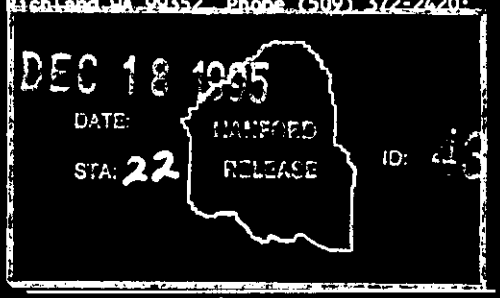
Abstract: This document defines the software requirements for the integrated control and data acquisition system of the Light Duty Utility Arm (LDUA) System. It is intended to be used to guide the design of the application software, to be a basis for assessing the application software design, and to establish what is to be tested in the finished application software product.



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COMPUTER SOFTWARE REQUIREMENTS SPECIFICATION FOR THE INTEGRATED LIGHT DUTY UTILITY ARM SYSTEM

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COMPUTER SOFTWARE REQUIREMENTS SPECIFICATION FOR THE INTEGRATED CONTROL AND DATA ACQUISITION SYSTEM LIGHT DUTY UTILITY ARM SYSTEM

1.0 INTRODUCTION

1.1 PURPOSE

This Computer Software Requirements Specification (CSRS) defines the software requirements for the integrated control and data acquisition system of the Light Duty Utility Arm (LDUA) System. It is intended to be used to guide the design of the application software, to be a basis for assessing the application software design, and to establish what is to be tested in the finished application software product.

1.2 SCOPE

This software requirements specification is a functional specification that addresses the overall performance of the LDUA control and data acquisition system after it has been integrated into the LDUA System. Detailed requirements for specific software components are not part of this software requirements specification, but are to be derived from it.

This software requirements specification has been prepared in accordance with LDUA software development plan (Reference 2). It is the deliverable required by that plan for the requirements phase of application software development. It applies only to the LDUA Baseline System as defined in reference 5.

1.3 BACKGROUND OF APPLICATION

The LDUA System is designed to deploy a family of tools, called end effectors, into underground storage tanks by means of a robotic arm on the end of a telescoping mast, and to collect and manage the data that they generate. The LDUA System uses a vertical positioning mast, referred to simply as the mast, to lower the arm into a tank through an existing 30.5 cm (12 in.) access riser. A Mobile Deployment System is used to position the mast and arm over a tank riser for deployment, and to transport them from tank to tank. The LDUA System has ancillary subsystems including the Operations Control Trailer, the Tank Riser Interface and Confinement Subsystem (TRIC), the Decontamination Subsystem, and the End Effector Exchange Subsystem. The LDUA is being designed to operate safely in the hazardous (high radiation, flammable gasses, corrosive chemicals) environment typical of the 177 underground storage tanks at the Hanford site and underground storage tanks located at other DOE sites.

Normally, the LDUA system will be remotely operated from the Operations and Control Trailer located outside the tank farm in a non-contaminated area. The Operations Control Trailer houses much of the control and data acquisition system equipment and it is connected to the equipment inside the tank farm by a 275 m (900 foot) fiber-optic umbilical cable.

1.4 DEFINITIONS

1.4.1 ACRONYMS

ANSI	American National Standards Institute
CSRS	Computer Software Requirements Specification
DOE	U.S. Department of Energy
EE	End Effector
EEES	End Effector Exchange Subsystem
FTP	File Transfer Protocol
GISC	Generic Intelligent System Controller
GUI	Graphic User Interface
LDUA	Light Duty Utility Arm
MDS	Mobile Deployment Subsystem
NFS	Network File System
TCP/IP	Transmission Control Protocol/Internet Protocol
TRIC	Tank Riser Interface and Confinement Subsystem
WHC	Westinghouse Hanford Co.

1.4.2 TERMS

Application Software Is software which performs or supports the performance of the primary service or function of the LDUA system. Application Software is the general term applied to the software covered by this software requirements specification.

Computer Software Media Is the different kinds of tapes, discs, etc. used by the computer for storing and retrieving software.

Computer Software Computer programs, procedures, and possibly associated documentation and data pertaining to the operation of a computer system. (IEEE Standard 729-1983, reference 3).

Integrated system Is a term that refers to the complete control and data acquisition system, that is, the totality when all its various parts have come together.

Interactive refers to those applications where a user communicates with a computer program via a terminal, entering data and receiving responses from the computer.

On-line describes information or a function that is immediately available to the user from the computer, no preparatory work is required.

System Software - software which directly manages the physical computer resources on behalf of application software, and which supports it. For LDUA, this includes the computer operating system and its utility programs, data base management system, the language compiler.

1.5 OVERVIEW OF DOCUMENT

This software requirements specification generally follows the format of IEEE Software Engineering Standard 830 (reference 3). Some subsections have been added to this software requirements specification which are not in IEEE format, and the section numbering is therefore not in exact correspondence. There are some sections of the IEEE 830 format which do not apply to LDUA; for the sake of completeness, they have been included in this software requirements specification, but have been noted as not applicable.

Section 2.0 presents general requirements including product perspective, product functions, user characteristics, general constraints, and assumptions and dependencies.

Section 3.0 presents specific performance requirements. As a convenience, they are divided into control system requirements and data acquisition system requirements, but this does not necessarily constrain them to be provided by a particular subsystem or component.

Section 4.0 lists the documents which are referenced by this software requirements specification.

2.0 GENERAL DESCRIPTION

2.1 PRODUCT PERSPECTIVE

Figure 1 is a simplified block diagram of the LDUA control and data acquisition system that shows its major components and overall organization. The LDUA control and data acquisition system is organized according to hierarchical responsibilities (Subsystem versus Supervisory level of control), basic function (mast and arm movement versus data collection), and physical location (local versus remote).

2.2 PRODUCT FUNCTIONS

2.2.1 Control System Functions

The control system shall operate the mast and arm and those subsystems that are closely associated with the mast and arm, including the mobile deployment subsystem.

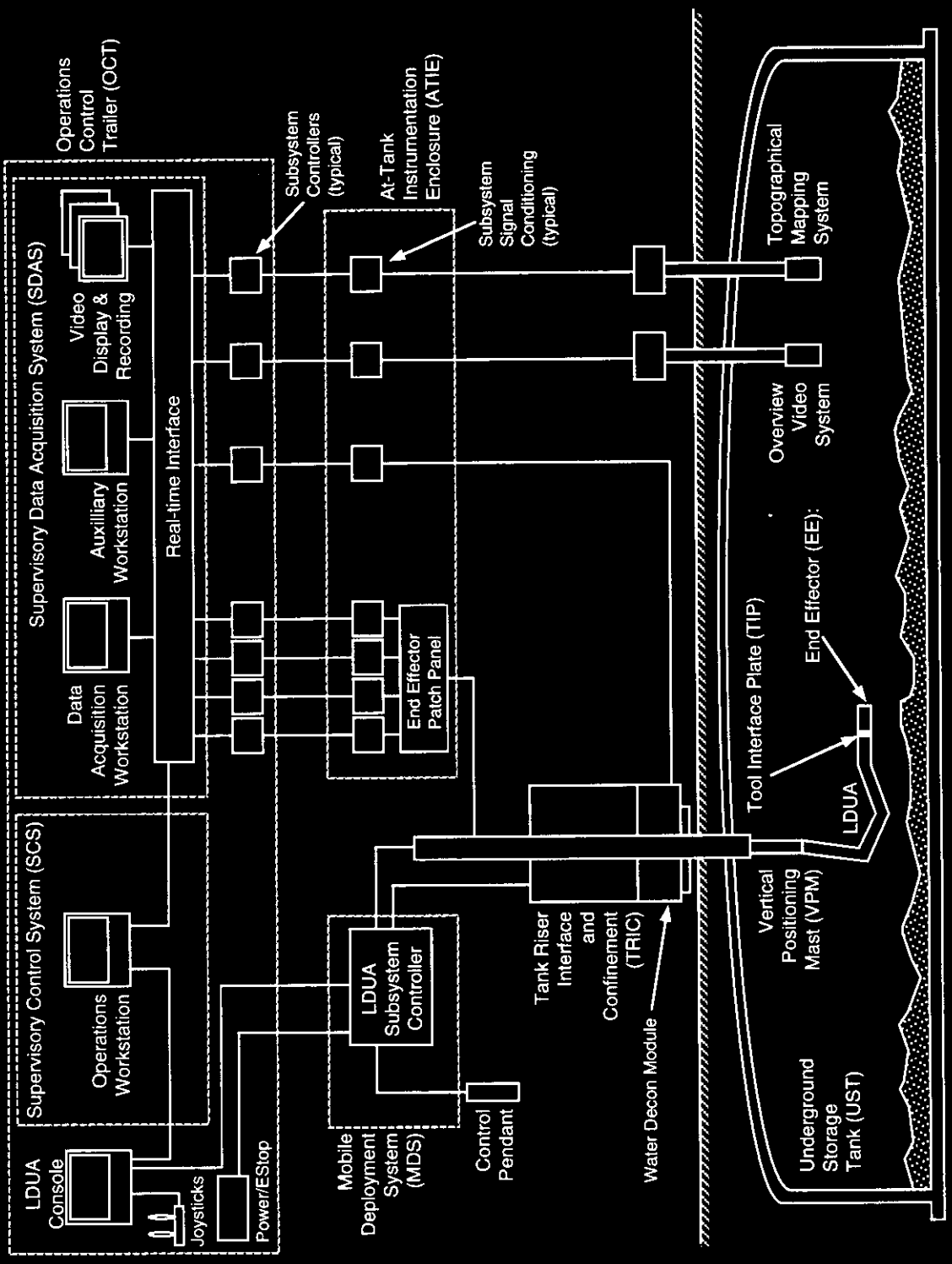

Figure 1, LDUA Control And Data Acquisiton System Block Diagram

2.2.2 Data Acquisition System Functions

The data acquisition system shall operate the end effectors and those subsystems that are not closely associated with the mast and arm, including the Tank Riser Interface and Confinement (TRIC) Subsystem environmental components, the decontamination subsystem, and the ventilation subsystem. It shall also acquire, process, display, and store data from these subsystems.

The data acquisition system shall also provide a means of displaying and recording video information from the end effectors and observational video cameras.

2.3 USER CHARACTERISTICS

The LDUA application software shall be designed for use by tank farm operator. These operators will typically not be engineers or scientists, but will be skilled workers who have received significant training on the LDUA. It may also be assumed that such subject matter experts will be available to the operators for situations that are not addressed by their training. Operators will only be expected to interact with the user interface provided by the LDUA control and data acquisition system - they will not be expected to understand how to directly use the operating systems of the computers on which it executes.

People who wish to retrieve information directly from the LDUA system will receive appropriate training in how to access and query the system. This group of people may include scientists, engineers, technicians, operators, or others.

2.4 GENERAL CONSTRAINTS

There are no general constraints that apply.

2.5 ASSUMPTIONS AND DEPENDENCIES

2.5.1 General Operating Scenario

The LDUA system is designed to be run by two operators using computer workstations shown in figure 1 that are located in the Operations Control Trailer. The **arm operator** is responsible for operating the deployment subsystems (mast, arm, etc.), and the **end effector operator** is responsible for operating the end effectors and collecting data.

2.5.2 Operator Interfaces

The Operations Workstation provides 3-D animated graphic display for visualizing the operation of the mast and arm. The operator may preview motion of the arm and check it for collisions. If the motion is acceptable

and collision-free, the operator shall be given the option of having the executing the motion as it was simulated.

The LDUA Console works in conjunction with the Operations Workstation. It provides display and access to the detailed status and operating parameters of the mast and arm controller. Hand controllers (such as joysticks) are connected to the LDUA Console for teleoperation of the mast and arm.

The Data Acquisition Workstation provides the user interface for operating end effectors, collecting data, and for monitoring and controlling the TRIC environment subsystems. It provides a single point from which data can be acquired, processed, and stored. All aspects of video switching and display and recording are also controlled by the Data Acquisition Workstation, including the video cameras, the routing of signals, the VCRs, and the overlay of titles and other selected information onto the video.

The Auxiliary Workstation provides the ability to obtain information from the system without disturbing the operators at the primary workstations.

2.5.3 Point of Control

The system shall implement the Point of Control (POC) strategy described in the LDUA functions and requirements (reference 1) and shall provide a Display of POC status.

2.5.4 Control of Videotape

It is assumed that some of the video tapes made during an LDUA campaign will be considered valuable data that should be controlled. The LDUA control and data acquisition system has been designed accordingly (see section 3.2.1). In order for these design features to be meaningful, a video tape identification and labelling procedure must be established by the organization responsible for operating the LDUA System and controlled storage for master copies of the video tape must also be provided.

3.0 SPECIFIC REQUIREMENTS

3.1 CONTROL SYSTEM REQUIREMENTS

3.1.1 Mast and Arm Control

The control system shall provide for operating the mast and arm to the desired position or along the desired path everywhere within the operating envelope of the mast and arm. These operations shall include:

a. teleoperation (human-in-the-loop) of mast and arm from hand controllers in joint mode or cartesian mode.

b. the ability to follow an automatic sequence of one or more goal positions in joint or cartesian mode.

c. selection of cartesian mode to be with respect to the world coordinate frame or tool coordinate frame.

The details of the basic mast and arm control are controlled by the LDUA specification (reference 4).

3.1.2 Mobile Deployment Subsystem Control

The control system shall provide for operating the Mobile Deployment Subsystem to accomplish engagement with the TRIC and alignment to the 30 cm riser for entry into the tank. These operations shall include:

a. upending the mast containment housing and

b. controlling the translation and inclination of it by the operator to achieve centering and alignment on the deployment riser.

3.1.3 Motion Preview/Collision Detection

The control system shall allow all motion of the mast and arm to be previewed against the world model (see section 3.1.4) of the in-tank operating environment, and checked for collision.

a. The operator shall be allowed to approve the previewed motion for execution. If there has been a collision, the operator shall be so informed. An override capability shall allow the operator to execute previewed motion even if a collision has been detected.

b. The preview shall be effective for all of the types of motion control described in section 3.1.1.

c. The preview shall halt at the point when the collision is detected, and shall indicate on the display where the collision has occurred (for example, by means of a color change or flashing area).

d. The operator shall be allowed to choose any perspective from which to view the display.

3.1.4 World Model

The control system shall provide a three dimensional (3D) model of the tank environment in which the mast and arm operate. This model shall provide:

a. tank interior surfaces, including the walls, dome, and floor

b. tank internal structures, including risers, saltwells, and so forth.

c. a tank frame coordinate system with an origin that is in the same relative position for each tank

d. an accurate animated model of the LDUA mast and arm that can show the position and motion of the actual arm, or be used for previewing simulated motions

e. contour of the waste surface which shall be derived from the information provided by the mapping subsystems (see section 3.2.3.1).

f. a minimum approach distance shall be established for each model. Near misses at a distance less than the minimum approach distance shall be considered collisions. The minimum approach distance shall be based on the estimated accuracy of the model and the model shall be constructed so that the minimum approach distance does not exceed 30 cm.

3.2 DATA ACQUISITION SYSTEM REQUIREMENTS

3.2.1 Data File Log

The data acquisition system shall store the information that it obtains from subsystems as files (except for video data which shall be stored on video tapes). When a data file is made part of the official record of an LDUA campaign, an entry shall be made in the data file log which shall identify the name and location of file, the date and time, the type of information it contains, and the person responsible (custodian).

A similar entry shall also be made in the data file log when a video tape that is to made part of the official record of an LDUA campaign is removed from the system, that is, when it will no longer be used for recording (see section 2.5.4).

3.2.2 Video Display and Recording

The data acquisition system shall provide a means of displaying and recording video information from the end effectors and observational video cameras. This feature shall allow the operator to:

a. switch signals from any video source to any compatible video monitor or video recorder

b. control the video recorders

c. overlay selected information, such as mast and arm position, onto the video

3.2.3 Subsystem and End Effector Operation

The data acquisition system shall operate the end effectors and subsystems not assigned to the control system, and shall acquire data from them. It shall provide the operator with the ability to do all the operations described in the this section from the Data Acquisition Workstation (see section 2.5.2).

3.2.3.1 Topographical Mapping Subsystem

The data acquisition system shall provide the operator with the ability to obtain a surface map of the entire surface of the waste, or of selected portions of the waste surface and tank interior. In particular, it shall all the operator to:

a. command a mapping scan to be taken

b. control and adjust the parameters of the scan

c. store scan in file and make appropriate entry in log

3.2.3.2 Shoulder Camera

The data acquisition system shall provide the operator with the ability to control the LDUA shoulder camera. In particular it shall allow the operator to:

a. control the camera parameters (zoom, iris, lighting, etc.)

b. control the camera orientation (pan, tilt, height)

c. route and recording of the video signal from the camera by means of the video display and recording subsystem (see section 3.2.2)

3.2.3.3 Optical Alignment Scope

The data acquisition system shall provide the operator the ability to operate the Optical Alignment Scope so that (in conjunction with operation of the Mobile Deployment Subsystem for the LDUA Console) alignment of the Vertical Positioning Mast to the riser can be achieved and confirmed. In particular, it shall allow the operator to:

a. control of the boresight camera parameters (zoom, iris, lighting, etc.)

b. route the video signal from the camera by means of the video display and recording subsystem (see section 3.2.2)

c. control of the alignment verification laser(s)

d. operation and monitoring of the clearance sensors (proximity detectors).

3.2.3.4 Overview Video Camera System

The data acquisition system shall provide the operator the ability to use the Overview Video Camera System to observe in-tank operations. In particular, it shall allow the operator to:

a. control the camera parameters (zoom, iris, lighting, etc.)

b. control the camera orientation (pan, tilt, height)

c. route and recording of the video signal from the camera by means of the video display and recording subsystem (see section 3.2.2)

3.2.3.5 Overview Stereoscopic Video Camera System

The data acquisition system shall provide the operator the ability to use the Overview Stereoscopic Video Camera System to observe in-tank operations. In particular, it shall allow the operator to:

a. control the camera parameters (zoom, iris, lighting, stereo separation, etc.)

b. control the camera orientation (pan, tilt, height)

c. route and record the video signal from the camera by means of the video display and recording subsystem (see section 3.2.2)

3.2.3.6 High Resolution Stereoscopic Video Camera System

The data acquisition system shall provide the operator the ability to use the High Resolution Stereoscopic Video Camera System to visually inspect the surface of the waste or in-tank structures. In particular, it shall allow the operator to:

a. control the camera parameters (zoom, iris, lighting, stereo separation, etc.)

b. overlay the current position of the arm onto the video

c. route and record the video signal from the camera by means of the video display and recording subsystem (see section 3.2.2)

3.2.3.7 Still/Stereoscopic Photographic System

The data acquisition system shall provide the operator the ability to use the Still/Stereoscopic Photographic System to make photographs of selected views of the tank interior, using the video viewfinder to compose the photograph. In particular, it shall allow the operator to:

a. control the video viewfinder camera parameters (iris, lighting, etc.)

b. control the photo cameras' shutters.

c. route and record the video signal from the camera by means of the video display and recording subsystem (see section 3.2.2)

d. overlay the current position of the arm onto the video

e. record the date, time, frame number, and current position of the end effector for each frame as entries in the data file log (see section 3.2.1).

3.2.3.8 Operations Overview Video Subsystem

The data acquisition system shall provide the operator the ability to use the Operations Overview Video Subsystem to observe the above-ground operations of the LDUA System inside the tank farm. In particular, it shall allow the operator to:

a. control the camera parameters (zoom, iris, lighting, etc.)

b. control the camera orientation (pan, tilt, height)

c. route and recording of the video signal from the camera by means of the video display and recording subsystem (see section 3.2.2)

3.2.3.9 Tank Riser Interface and Confinement (TRIC)

There is no TRIC equipment presently in the LDUA Baseline System that requires operation from the data acquisition or control system.

3.2.3.10 Water Decontamination Subsystem

The data acquisition system shall provide the operator with the capability to control and monitor the water decontamination subsystem. In particular, it shall:

a. Control the water supply system pump (on/off)

b. Monitor the water supply pump status (running/off)

c. Control the decon spray (on/off)

d. Display the output from the radiation monitors

e. Decon status log
   - Record and display log of Radiation Monitor readings
   - Record and display log of decon spray on/off
   - Save log to file and recall for display

3.2.4 Auxiliary Workstation

The data acquisition system shall provide a means of displaying key information without disturbing the primary operators. This feature shall operate from the Auxiliary Workstation allow the operator to:

a. switch signals from any compatible video source to the video monitors and video recorder in the visitor area of the Operations Control Trailer

b. view the data file log (see section 3.2.1)

3.3 EXTERNAL INTERFACE REQUIREMENTS

3.3.1 Operating Screens

Operating screens for the workstations (see section 2.5.2) shall be based on a graphic user interface (GUI) package. These screens shall provide:

a. a windowing environment

b. menus, push buttons, sliders, and other such virtual controls

c. operator commands by means of a pointing device, such as a mouse or trackball

3.3.2 User Input Files

There are presently no known user input files.

3.3.3 Hardware Interfaces

There are no special hardware interface requirements.

3.3.4 Software Interfaces

Other than the operating systems chosen for the control and data acquisition system (see section 3.5.2), there is no requirement to interface with any specific software package.

3.3.5 Communications Interfaces

There is no requirement for the application software to communicate with the external world except via the user interfaces and the system hardware.

3.4 PERFORMANCE REQUIREMENTS

3.4.1 Response Time

It shall be a goal of LDUA application software to respond to any user input within 1.0 second with either the result of what the input requested, or some sort of acknowledgement that the system has accepted the input and is processing it. If completion of user's request requires more than 5 seconds, visible indication of progress shall be provided (if possible). This requirement is a design guideline rather than a hard requirement.

3.4.2 Number of Users Supported

The LDUA control and data acquisition system shall support 3 simultaneous users, one at the operations work station, one at the data acquisition workstation, and one at the auxiliary workstation (see section 2.5.2).

3.4.3 On-line Storage

The LDUA data acquisition software shall operate properly with minimum of 1,000 megabytes of on-line storage. It shall have the capability to support greater amounts of on-line storage to provide for future expansion.

3.5 DESIGN CONSTRAINTS

3.5.1 Programming Languages.

The preferred languages for the application software shall be American National Standards Institute (ANSI) Standard C or C++, supported by Unix[1] bourne shell scripts (including such standard Unix utilities such as *awk*, *grep*, *sed*, and so forth). Other languages shall be acceptable where the above are impractical or uneconomical.

3.5.2 Operating System Interface

Unix or Unix variants shall be preferred for the LDUA control and data acquisition system. Where possible, if two functionally identical system calls exist, Unix System V versions of system calls shall be preferred.

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[1]"Unix" is a registered trademark of Unix Systems Laboratories, Inc.

3.5.3 Network

Transmission Control Protocol/Internet Protocol (TCP/IP) shall be used for network communications between LDUA application software components. Berkeley sockets shall be used for inter-process communications and Network File System (NFS) shall be used for file sharing. Other TCP/IP protocols such as File Transfer Protocol (FTP) may be used where appropriate.

3.6 ATTRIBUTES

3.6.1 Security

The LDUA application software shall utilize the access control provisions (user accounts and passwords) of the operating systems to assure use of the system only by authorized users. All commands that cause a change of state in the LDUA control and data acquisition system, or that cause actuator movement, shall be accessible only through a password protected interface.

3.6.2 Maintainability

There are no specific requirements for the application software that apply to maintainability - the maintainability of LDUA application software will be assured as function of its overall development process, which is controlled by the LDUA software development plan (Reference 2). This plan will assure adequate documentation, design verification, and product validation.

3.7 OTHER REQUIREMENTS

3.7.1 Operations

3.7.1.1 Normal Mode Operations.

The normal operating mode for LDUA shall be with all equipment powered up and the application software running.

3.7.1.2 Startup Mode Operations.

Startup operations shall consist of powering up the equipment, booting the operating systems, initializing support packages as necessary, and executing and initializing the application software. Process equipment (especially actuators) will be powered up or enabled after the application software has been successfully initiated.

3.7.1.3 Shutdown Mode Operations.

The LDUA application and operating system software will be put through a shutdown sequence before computer power can be turned off. Much of this shutdown sequence is built into the Unix operating system. Process equipment

(especially actuators) will be powered down or disabled prior to shutdown of the application software.

3.7.1.4 Backup Mode Operations.

Periodically, the data acquisition system logging and data files shall be backed up to off-line storage. Process equipment will not be in use during backup - it will probably be put in standby.

3.7.1.5 Recovery Mode Operations.

Recovery from a data acquisition system failure that corrupts files shall consist of restoring files from the off-line storage media containing the backups of those files. Recovery from a failure that corrupts files containing the system software or application software shall consist of restoring the files from their distribution media.

3.7.2 Site Adaptation

The LDUA application software is purpose-built for LDUA and is designed to be used only for that system. Therefore, no site adaptation is required.

4.0 REFERENCES

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DISTRIBUTION SHEET

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