FEB 01 1996 (21) ENGINEERING DATA TRANSMITTAL

Page 1 of 1

1. EDT 140946

2. To: (Receiving Organization)	3. From: (Originating Organization)	4. Related EDT No.:
Remote System and Sensor Applications	Remote System and Sensor Applications (8A800)	N/A
5. Proj./Prog./Dept./Div.:	6. Cog. Engr.:	7. Purchase Order No.:
LDUA Project	J. E. Ellis	N/A
8. Originator Remarks: WHC-SD-TD-CSRS-002, "Computer Software Requirements Specification for the World Model - Light Duty Utility Arm System," is issued for Revision 0 review.		9. Equip./Component No.: N/A
		10. System/Bldg./Facility: N/A
11. Receiver Remarks:		12. Major Assm. Dwg. No.: N/A
		13. Permit/Permit Application No.: N/A
		14. Required Response Date: 1/30/96

15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Desig-nator	(G) Reason for Trans-mittal	(H) Origi-nator Dispo-sition	(I) Receiv-er Dispo-sition
1	WHC-SD-TD-CSRS-002		0	Computer Software Requirements Specification for the World Model - Light Duty Utility Arm System		1		

16. KEY

Approval Designator (F)	Reason for Transmittal (G)	Disposition (H) & (I)
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)	1. Approval 4. Review 2. Release 5. Post-Review 3. Information 6. Dist. (Receipt Acknow. Required)	1. Approved 4. Reviewed no/comment 2. Approved w/comment 5. Reviewed w/comment 3. Disapproved w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)

(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.
1		Cog. Eng. J. E. Ellis		1/26/96	N1-21	M. W. Thornton			L7-05	3	
1	1	Cog. Mgr. D. S. Dutt		1/29/96	N1-21	L. F. Hill			S4-58	3	
1		System Lead B. A. Carteret		1/29/96	N1-21	M. R. Koch			R1-49	3	
1		Design Auth. G. R. Kiebel		1/29/96	N1-21	R. B. Conrad			K5-09	3	
						J. C. Tucker			K5-22	3	

18. J. E. Ellis — Signature of EDT Originator — Date 1/26/96

19. D. S. Dutt — Authorized Representative for Receiving Organization — Date 1-29-96

20. D. S. Dutt — Cognizant Manager — Date 1-29-96

21. DOE APPROVAL (if required) Ctrl. No.
- [ ] Approved
- [ ] Approved w/comments
- [ ] Disapproved w/comments

BD-7400-172-2 (04/94) GEF097

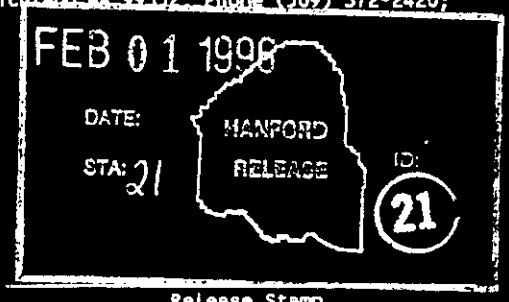
Computer Software Requirements Specification for the World Model Light Duty Utility Arm System

J. E. Ellis
Westinghouse Hanford Company, Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-87RL10930

EDT/ECN: 140946 UC: 2060
Org Code: 8A800 Charge Code: H1E02
B&R Code: EW4010000 Total Pages: 13

Key Words: Computer Software Requirements Specification, World Model, Light Duty Utility Arm (LDUA)

Abstract: This Computer Software Requirements Specification defines the software requirements for the world model 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.



Karen L. Noland 2/1/96
Release Approval Date

Release Stamp

Approved for Public Release

Contents

Contents

COMPUTER SOFTWARE REQUIREMENTS SPECIFICATION FOR THE WORLD MODEL LIGHT DUTY UTILITY ARM SYSTEM

1.0 INTRODUCTION

1.1 PURPOSE

This Computer Software Requirements Specification defines the software requirements for the world model 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 performance of all LDUA world models. Each deployment of the LDUA will require a world model which meets the requirements of this specification.

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 the world model software development.

1.3 DEFINITIONS

1.3.1 Acronyms

ANSI	American National Standards Institute
DOE	U.S. Department of Energy
GISC	Generic Intelligent System Controller
GUI	Graphic User Interface
LDUA	Light Duty Utility Arm
MDS	Mobile Deployment Subsystem
TCP/IP	Transmission Control Protocol/Internet Protocol
WHC	Westinghouse Hanford Company

1.3.2 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 is computer programs, procedures, and possibly associated documentation and data pertaining to the operation of a computer system.

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 is 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.

1.4 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.

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

2.0 GENERAL DESCRIPTION

2.1 PRODUCT PERSPECTIVE

The LDUA World Model software is a component of the Supervisory Control System, which in turn is a subsystem of the LDUA System. 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 many ancillary subsystems including the Supervisory Control System, the Supervisory Data Acquisition System, the Operations Control Trailer, the Tank Riser Interface and Confinment Subsystem, the Decontamination Subsystem, the End Effector Exchange Subsystem, and several end effector subsystems. 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 (OCT) located outside the Tank Farm in a non-contaminated area. The OCT 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.

Much of the fundamental architecture of the LDUA control and data acquisition system is based on emerging technology, known as Generic Intelligent System Control, or GISC. GISC is an approach to the construction of control systems for complex robotic systems whereby sophisticated overall system performance is obtained by coordinating the operation of a collection of subsystems, each with complementary capabilities. One key aspect of the GISC approach is that the supervisors that provide the interface for basic operation of the robot to the user should be graphic and animated and should be based upon a "world model."

The world model is an accurate 3D computer model of the arm and its operating environment. The model of the arm is fully animated, and the environment includes the tank internal structure and surface of the waste. Each deployment of the LDUA will require a world model specifically tailored to the specific requirements of the deployment.

The purpose of the world model is to allow the operator to visualize the position and motion of the LDUA mast and arm relative to other objects in its work space. The work space consists of the tank dome and liner, the risers and other in-tank equipment, and the surface of the waste. The world model is also used to plan arm motions and to verify their correctness and freedom from collisions.

There are a limited number of video cameras in the tank, and because they are restricted in where they can be placed by the need to use existing tank risers, they will not always be in the best position to see the specific area where the arm must be operated. The operator can easily change the viewing angles and magnification of the world model on the 3D display of the Operations Workstation, and compare the views of the model with the views from the video cameras.

The world model has three principal interfaces which are: the user, the LDUA console for current joint values, and the World Model Converter Module for additional information about the contents and internal structures of the tank.

The world model will run on the Operations Workstation in the OCT. The Operations Workstation is a Silicon Graphics, Inc. Indigo 2 Extreme computer, running the IRIX version 5.2 operating system. The computer has the following peripherals: a 19-inch color monitor, mouse, keyboard, one gigabyte hard drive, four millimeter digital audio tape (DAT) drive, and two each three degree of freedom joysticks.

2.2 PRODUCT FUNCTIONS

The world model is a three dimensional model of the environment in which the mast and arm operate. The goal is to provide the following functions:

a. It helps the operator visualize the remote environment and tie together the disparate views provided by the remote mapping and remote viewing systems.

b. It allows the operator to safely operate the mast and arm in an otherwise uncertain environment full of potential obstacles.

c. It provided the mathematical model that serves as a frame of reference for analyzing all positional data.

2.3 USER CHARACTERISTICS

The LDUA world model software shall be designed for use by Tank Farm operators. 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 world model - 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 that are located in the OCT. The Arm Operator is responsible for operating the deployment subsystems (mast, arm, world model, etc.), and the End Effector Operator is responsible for operating the end effectors and

collecting data. The Arm Operator will be the primary operator of the world model software.

2.5.2 Operator Interfaces

The Operations Workstation provides three dimensional animated graphic display for visualizing the operation of the mast and arm via the world model. The operator may preview motion of the arm and check it for collisions. If the motion is acceptable and collision-free, the operator is given the option of having the system execute it as it was simulated. Hand controllers (such as joysticks) are connected to the Operations Workstation for teleoperation of the world model.

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.

2.5.3 Point of Control

The world model software does not need to implement the Point of Control (POC) strategy described in the LDUA functions and requirements (Reference 1). All commands issued to the mast and arm controller shall be filtered for appropriateness by the LDUA Console.

2.5.4 Tank Configuration Data

It is an extremely important assumption that sufficiently accurate information is available to construct an accurate model of the tank from drawings.

3.0 SPECIFIC REQUIREMENTS

3.1 VISUALIZATION REQUIREMENTS

It helps the operator visualize the remote environment and tie together the disparate views provided by the remote mapping and remote viewing systems.

3.1.1 Model Views

The world model software shall provide both orthographic and perspective views of the following elements of the operating environment:

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

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

c. 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.

d. A contour of the waste surface which shall be derived from the information provided by the mapping subsystems or other measurements of the waste surface.

The operator shall be allowed to select either an orthographic or a perspective view and shall be able to view the model from any angle or distance.

3.1.2 Camera Views

The world model software shall provide perspective views that simulate the views as seen through the following types of remote viewing systems:

a. An overview camera

b. An end effector mounted camera

c. The camera mounted on the shoulder of the arm

3.1.3 Directional Orientation

The world model software shall provide visual clues to the operator as to which direction is north, south, east, and west.

3.2 MOTION PREVIEW AND COLLISION DETECTION REQUIREMENTS

The world model software allows the operator to safely operate the mast and arm in an otherwise uncertain environment full of potential obstacles.

3.2.1 Motion Preview

The world model software shall allow all motion of the mast and arm to be previewed. The preview shall be effective for all of the types of motion control that the mast and arm can perform.

3.2.2 Collision Detection

During motion preview, the motion of the arm, mast, and end effector shall be checked for collision with any object within its operating envelope. If a collision is detected during preview, 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).

3.3 ACCURACY REQUIREMENTS

The world model software provides the mathematical model that serves as a frame of reference for analyzing all positional data.

3.3.1 Frame of Reference

The world model software shall provide a tank frame coordinate system with an origin that is in the same relative position for each tank. The origin of the tank frame shall be a point at the bottom center of the tank with the z axis perpendicular to the bottom of the tank and positive in the up direction. The y axis shall point to true north and the x axis shall point east.

Since the point chosen for the tank frame origin is physically inaccessible, the actual position of the LDUA equipment and tank structures that extend above-ground will be established by surveying from benchmarks within the Tank Farm. The location of the tank frame origin will be calculated with respect to these benchmarks based on construction data for the tank. It is an important assumption that there is sufficiently accurate information from the construction of the tank to establish such a relationship. It is also extremely important that the same transformation from benchmarks to tank origin be used each time the LDUA is deployed into that tank so that the data gathered from one campaign to another has a consistent frame of reference.

3.3.2 Arm Kinematics

The model of the LDUA mast and arm shall demonstrate accurate kinematic behavior.

3.3.3 Minimum Approach Distance

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.

3.4 EXTERNAL INTERFACE REQUIREMENTS

3.4.1 Operating Screens

Operating screens for the Operations Workstation (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

The world model software runs on the Operations Workstation and shall make maximum use of these features.

3.4.2 User Input Files

There are presently no user input files.

3.4.3 Hardware Interfaces

There are presently no hardware interfaces.

3.4.4 Software Interfaces

Other than the operating systems chosen for the control and data acquisition system (see Section 3.6.2), there is no requirement to interface with any specific software package.

3.4.5 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.

3.5 PERFORMANCE REQUIREMENTS

3.5.1 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 the user's request requires more than 5 seconds, visible indication of progress shall be provided (if possible). This requirement is stated as a goal rather than an absolute because it is not always practical or economical to achieve.

3.5.2 Number of Users Supported

The Operations Workstation is intended to support a single user (see Section 2.5.2).

3.6 DESIGN CONSTRAINTS

3.6.1 Programming Languages

The preferred languages for the application software shall be American Standards Institute (ANSI) Standard C or C++, supported by UNIX 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.

3.6.2 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, the POSIX.1 standard (IEEE P1003.1) version shall be preferred for LDUA application software. If POSIX is not practical, UNIX System V versions of system calls shall be preferred.

3.6.3 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 shall be used for file sharing. Other TCP/IP protocols may be used where appropriate.

3.7 ATTRIBUTES

3.7.1 Security

The Operations Workstation 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.

3.7.2 Maintainability

There are no specific requirements for the world model software that apply to maintainability - the maintainability of world model software will be assured as a 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.

3.8 OTHER REQUIREMENTS

3.8.1 Operations

3.8.1.1 Normal Mode Operations. The normal operating mode for LDUA shall be with all equipment powered up and the world model software running.

3.8.1.2 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 world model software. Process equipment (especially actuators) will be powered up or enabled after the world model software has been successfully initiated.

3.8.1.3 Shutdown Mode Operations. The world model 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 world model software.

3.8.1.4 Backup Mode Operations. Periodically, the Operations Workstation 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.

3.8.1.5 Recovery Mode Operations. Recovery from an Operations Workstation 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 world model software shall consist of restoring the files from their distribution media.

3.8.2 Site Adaptation

The world model 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

1. WHC-SD-TD-FRD-003, "Functions and Requirements for the Integrated Light Duty Utility Arm System," October 1993, Westinghouse Hanford Company, Richland, Washington.

2. WHC-SD-TD-SDP-001, "LDUA Software Development Plan, September 1994, Westinghouse Hanford Company, Richland, Washington.

3. ANSI/IEEE Std 830-1984, "IEEE Guide to Software Requirements Specifications," July 1984, The Institute of Electrical and Electronics Engineers, Inc., New York, New York.

DISTRIBUTION SHEET

To	From	Page 1 of 1
Distribution	K. L. Bennett	Date 1/25/96
Project Title/Work Order		EDT No. 140946
LDUA Project WHC-SD-TD-CSRS-002, "Computer Sofware Requirements Specification for the World Model - Light Duty Utility Arm System."		ECN No.

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
K. L. Bennett	N1-21	X			
B. A. Carteret	N1-21	X			
R. B. Conrad	H5-09	X			
D. S. Dutt	N1-21	X			
J. E. Ellis	N1-21	X			
L. F. Hill	S4-58	X			
G. R. Kiebel	N1-21	X			
M. R. Koch	R1-49	X			
M. W. Thornton	L7-05	X			
J. C. Tucker	K5-22	X			
LDUA File	N1-21	X			
Central Files (original +1)	A3-89	X			