U.S. DEPARTMENT OF ENERGY

PNNL-19329

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Large Aperture Scanner (LAS)

Operations and Maintenance Manual

AM Jones
TE Hall

April 8, 2010

Pacific Northwest NATIONAL LABORATORY

Proudly Operated by Battelle Since 1965

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor Battelle Memorial Institute, nor any of their employees, makes **any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights**. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or Battelle Memorial Institute. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information,
P.O. Box 62, Oak Ridge, TN 37831-0062;
ph: (865) 576-8401
fax: (865) 576-5728
email: reports@adonis.osti.gov

Available to the public from the National Technical Information Service,
U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161
ph: (800) 553-6847
fax: (703) 605-6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/ordering.htm

This document was printed on recycled paper.

(9/2003)

PNNL-19329

Large Aperture Scanner (LAS)

Operations and Maintenance Manual

AM Jones
TE Hall

April 8, 2010

Prepared for
the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99352

Contents

Figures

Tables

1.0 Document Purpose

This document provides the basic operations and maintenance instructions for the Large Aperture Scanner (LAS) developed by Pacific Northwest National Laboratory (PNNL) for the National Institute of Standards and Technology (NIST).

The document begins with a summary of the overall system characteristics, followed by an overview of system safety considerations and the safety approach that has been adopted. An overview of the LAS system computation and control features is then presented.

The main portion of the document steps through the various aspects of system operation, including initial system setup, checkout, safe system configuration, normal system operation, response to off-normal conditions, and system disassembly. Additional sections of the document provide discussions of system maintenance and troubleshooting, equipment inventory and spare parts, and contact information.

This document is one part of the documentation provided for the LAS system. Other documentation is summarized herein and is referred to within this document at appropriate points.

2.0 System Characteristics

The LAS system was developed by PNNL for the National Institute of Standards and Technology in Gaithersburg, Maryland. The system produces high-resolution three-dimensional image data sets of various structures using low-power holographic radar imaging technology. The system builds on and extends previously existing technology to provide these unique capabilities.

The main system components are:

- The radar ***transceiver*** mounted to the high-speed ***shuttle*** on the scanner
- The slow-speed scanned ***carriage*** which rides along the scanner tube
- The scanner ***trailer*** that provides structural rigidity for transport and scan operations
- The computation workstation and control software that drives the scanner and transceiver, and collects and processes the resulting data.

A photo of the LAS system with the transceiver located at the top of the vertical axis scan range is shown in Figure 2.1.

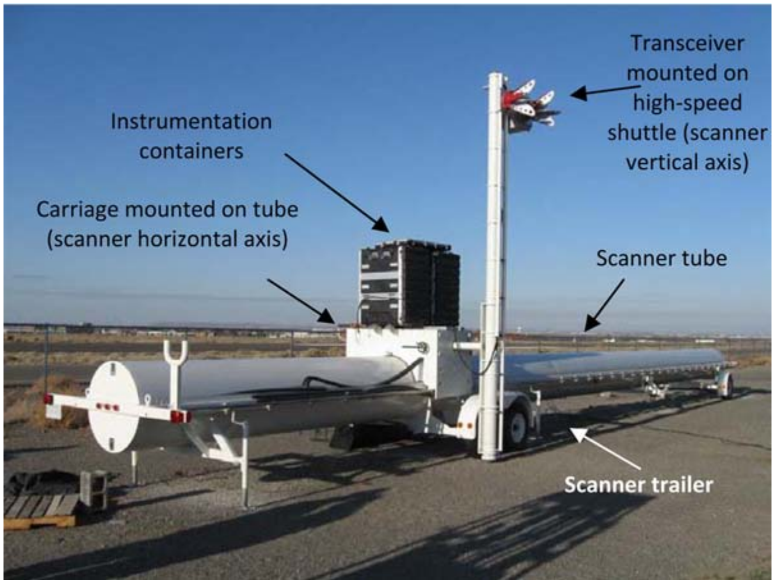

Figure 2.1. Front View of Large Aperture Scanner System

The LAS system is fully transportable, allowing it to be deployed and used at NIST or at other locations as required. The scanner portion of the system is contained within a trailer system which can be transported as needed, after which the system is assembled for use. Other system components such as the radar transceiver, an electric power source, calibration targets, and a computer to operate the system software must be transported in a separate trailer. The system can be assembled and readied for use in a couple of hours.

The LAS system produces three-dimensional volumetric radar images of objects which can be used for imaging studies. It incorporates an adjustable scan aperture of up to 66 ft of horizontal travel and 14.4 ft of vertical travel to allow for high-resolution near-field radar analysis of large objects. The current transceiver can operate in a frequency band from 200 MHz to 4.6 GHz.

The system is designed to operate either indoors or outdoors at temperatures above freezing and in sustained winds below 5 mph. Significant wind gusts present system safety concerns and jeopardize system accuracy. High humidity conditions will also cause problems, particularly if condensation occurs within the electronic equipment.

PNNL fabricated the radar transceivers and developed the system control and computation system, and specialty subcontractors fabricated other portions of the system for PNNL. The LAS system utilized an existing scanner subsystem originally fabricated by Brockman Precision Machine. Upgrades to the original scanner platform and installation of the control electronics, power supplies, cabling, and transceiver mounting hardware were completed at Brockman Precision Machine facilities.

3.0 Safety Considerations

The LAS system is designed for use by trained NIST staff in adherence to standard work safety practices as prescribed by NIST safety personnel. Operation of the LAS system will usually be confined to normal system operating conditions as defined in this documentation. Any variations from normal operating conditions are the responsibility of the system operator, and no such variations should be made without the explicit approval of the system operator.

Specific safety considerations relating to particular operational aspects of the LAS system are addressed in this document in the appropriate section by including embedded safety warnings and cautions clearly denoted to ensure that they can be identified by the reader. An example of an embedded safety consideration is as follows:

> ➢ LAS system operators must check for loosening of fasteners and other mechanical attachments resulting from vibration during system transportation prior to operation of the system, and to make any repairs to respond to the findings of this inspection.

General safety considerations related to the LAS system are as follows:

- A safety margin should be established around the scanner prior to assembly and operation of the scanner, and all personnel entering this safety margin should check in with the system operator before entry, so that the system operator is aware of their presence and their plans. The scanner operator should advise them of any particular safety concerns at that time.
- Untrained personnel should be escorted by a trained individual inside the designated scanner area to minimize the possibility of injury.
- Personnel should observe all safety guidance included in this documentation.
- During normal operations, all personnel should maintain at least a 10-foot lateral margin between themselves and the shuttle on the scanner beam when the vertical axis is energized.
- All personnel except for the operator should maintain at least a 6-feet margin to either side of the boom location when the boom is being elevated or lowered.
- Prior to operation of the system, the system operator should conduct an inspection of the system. The inspection procedure is given in Section 6.7.1.
- The system operator should provide a warning to personnel working in the area before activating the scanner system under computer control.
- Operation of the scanner is subject to site weather conditions. If outdoors, mechanical operation of the system should not take place in freezing conditions or in sustained wind speeds of greater than 5 miles per hour. The boom and other equipment should be placed in a safe configuration if storm conditions are anticipated.
- Personnel working on the elevated scanner platform should be aware of the possible fall hazard.
- All personnel working on or around the LAS system should report any safety concerns to the system operator.

- The LAS system has two sources of electrical power: a 120-Volt power cable and 240-Volt power cable. The two sources of power must be unplugged and controlled before performing work on related AC power systems.

All personnel working on or near the scanner should be familiar with the location and operation of the E-stops (emergency stop switches). There are two E-stops provided with the system and are shown in Figure 3.1 and Figure 3.2. One switch is permanently attached to the equipment in the instrumentation container and should be placed near the carriage so that it is easily accessible during scanning operations. The second switch plugs into the connector panel on the rear side of the scanner tube and should be placed near the computer that is controlling the system. Pressing either of the E-stops will immediately halt operation of the scanner. The scanner cannot be restarted until the E-stop is reset by pulling it out to the normal position.

- See detailed instructions in Section 6.8.3 for recovering from an E-stop event. Once engaging an E-stop condition, the E-stop switch should NOT be pulled out until power has been completely switched off. The uninterruptible power supply which provides temporary power inside the instrumentation container must NOT be powering the system. Otherwise, the system will continue executing the current scan program upon re-engaging the E-stop and its sudden movement may cause serious harm to personnel.

Figure 3.1. Emergency Stop which Attaches to Connector Enclosure on Rear Side of Carriage Tube

Figure 3.2. Emergency Stop Permanently Connected to Instrumentation Container

4.0 System Computation and Control Features Overview

Full documentation for the LAS computation and control system is provided separately, with an introductory overview included here as an aid to understanding the overall operation of the system. The software provided to control the system, obtain the scan data, and process and analyze the resulting data is called the AhisWin Studio software, which operates on top of the Windows operating system. An overview of the AhisWin Studio software design is shown in Figure 4.1.

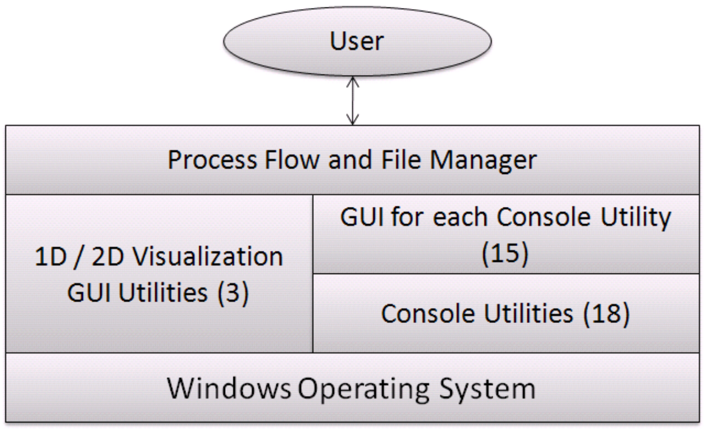

Figure 4.1. AhisWin Studio Software Design Overview

The user interacts with a process flow and file manager that provides executive control over the multiple utilities that control and monitor the LAS system. The interface is context sensitive, ordering processes logically and assisting the user with the complex process flow. Data management is structured to assist with processing and archiving of the data.

The LAS computation and control system is designed to be operated on a COTS Windows computing workstation. The workstation connects to the radar transceiver and scanner using an Ethernet cable for fast data transfer and serves three logical purposes during use of the LAS system. The first purpose is to operate as the data acquisition and scanner control interface.[1] The second purpose is to operate as the computation engine and perform the primary processing of the data. The third purpose is to provide visualization and analysis of the processed data.

An overview of the process flow for obtaining and processing scans using the LAS system is presented in Figure 4.2. Pre-scan activities provide for the calibrations needed. Actual scan operations involve setting up the object to be scanned, collecting data, processing data, and analyzing the results.

[1] Mechanical movement of the scanner can also be achieved manually using the handheld controller attached to the carriage on the scanner. Further details on the use of the manual controls are included in the system setup and operation descriptions presented later in this document.

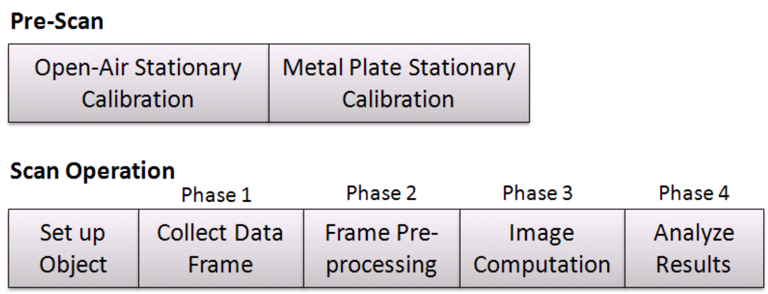

Figure 4.2. LAS Process Flow Overview

The data file organization concept used for the LAS system is shown schematically in Figure 4.3, and the nomenclature shown in this figure will be used throughout this documentation.

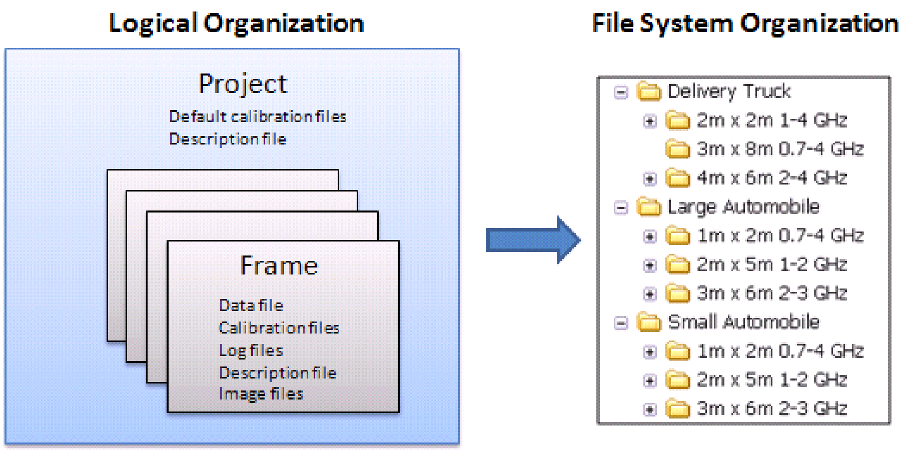

Figure 4.3. LAS Data File Organizational Concept

A ***project*** is intended to describe a unique test object or object configuration, encapsulating a common objective. Within each project, there may be multiple frames. A ***frame*** is intended to represent a single radar scan and the resulting dataset. The complete standalone dataset associated with a frame includes:

- Pre-scan calibration files
- Scan-time files
- Log files
- Resulting image files

In the overall process flow, the calibrations are performed first to provide the base data needed to understand and interpret the subsequent object scans. The two calibrations necessary to use the LAS system are (1) stationary calibration with no objects in the field of view of the antennas (2) stationary calibration of a flat metal plate at a known distance. It is recommended that the open-air calibration be performed with the scanner shuttle elevated to minimize possible reflections from the ground.

> ➢ Note: New calibration files must be collected if any transceiver parameters are changed. Examples of transceiver parameters include start and stop frequencies, number of frequencies, gain, polarization, and ramp speed.

Once the pre-scan calibration is completed, the overall process flow consists of several phases. Phase 1 is the collection of the data frame as shown in Figure 4.4. The scanner and the transceiver mounted on it are controlled to collect the radar data defining the target object. The collection of the data frame results in data files containing the object data. This data is then passed forward to the subsequent phases of the process.

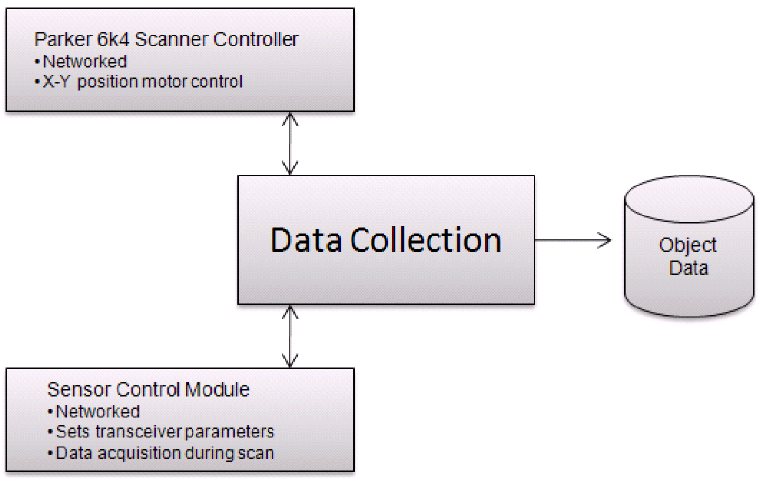

Figure 4.4. Phase 1 of Process Flow (Collect Data Frame)

The next step in the process flow is Phase 2, the frame pre-processing, as shown in Figure 4-5. In this phase, object data collected in Phase 1 is combined with the previously collected stationary calibration data.

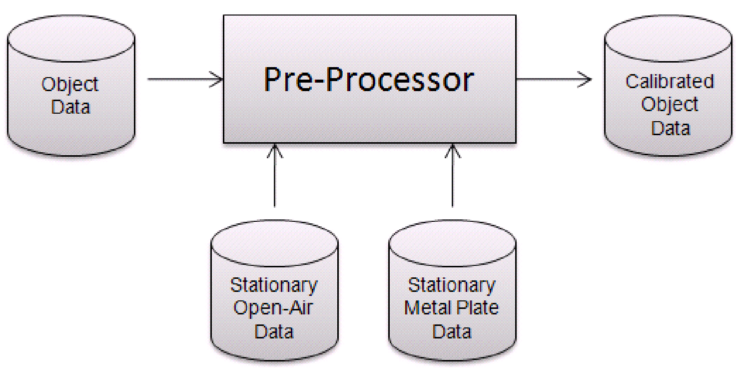

Figure 4.5. Phase 2 of Process Flow (Frame Pre-Processing)

In Phase 3, the calibrated frame data is processed to form an image. This phase is shown in Figure 4.6.

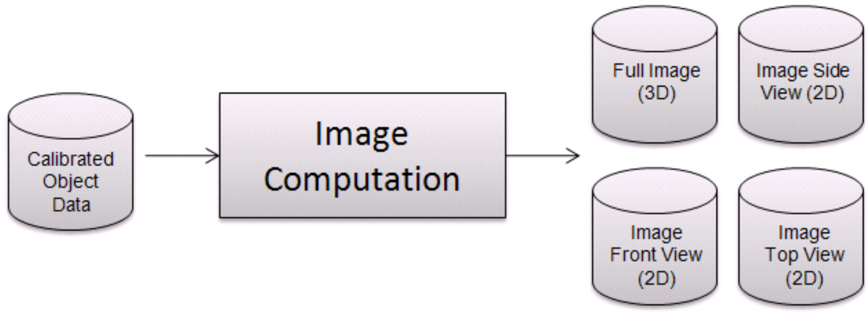

Figure 4.6. Phase 3 of Process Flow (Image Computation)

In Phase 4 of the process, the frame is analyzed to provide for image visualization using standard image file types. This phase is shown in Figure 4.7.

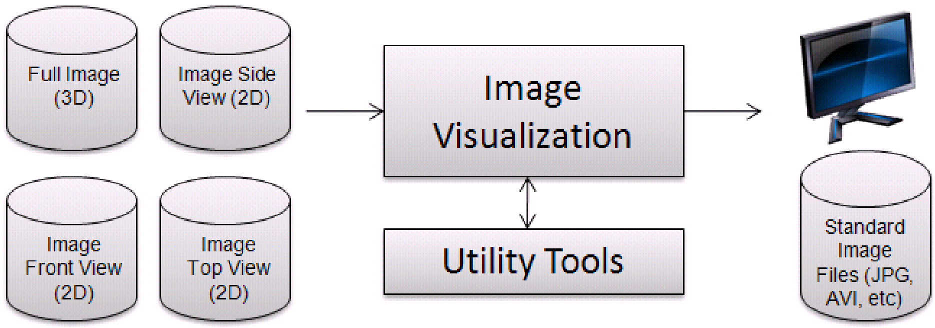

Figure 4.7. Phase 4 of Process Flow (Analyze Results)

Further details of each of these phases of operation are described in the LAS Software Handbook provided separately.

5.0 LAS Radar Transceiver Overview

The LAS transceiver contains the electronic components which allow the system to transmit and receive the radar signals which form the basis for the imaging process. The transceiver assembly consists of transmit and receive quad-ridged horn antennas, associated RF electronics, and sensor processor board. Front and side views of the LAS transceiver are shown in Figures 5.1 and 5.2. Labels located on the semi-rigid coaxial antenna feed cables indicate which antenna is used for transmitting signals and which antenna is used for receiving signals. The transceiver electronics are inside the enclosure behind the antenna mounting plate.

During scanning operations, the scanner control moves the transceiver rapidly along the vertical axis to collect the frequency-domain data used to form the three-dimensional image of the target. Upon return, the horizontal axis is slowly incremented and another vertical scan is performed. The result is a raster scan of the user-specified aperture to obtain the radar data at each sample point. The transceiver can operate at frequencies between 200 MHz and 4.6 GHz.

The system can be configured to utilize any combination of vertically or horizontally polarized electromagnetic signals. For example, the system can transmit and receive vertical polarization, or can transmit vertical polarization and receive horizontal polarization. This capability allows for characterization of an object using either linear co-polarized or cross-polarized signals. Refer to Section 6.7.2 for the procedure to select the desired polarization.

It is recommended that a transfer cart be used to safely move the transceiver when assembling and disassembling the system. Movement and positioning of the radar transceiver requires two persons since it is quite heavy and bulky.

> ➢ The transceiver assembly is heavy and should be carefully installed by two persons. Watch for pinching hazards when mounting the transceiver to the shuttle.

All electrical connections to the transceiver are made using the connector plate located on the rear side as shown in Figure 6.20. The connections are as follows:

a. two power cables for the radar and sensor processor board

b. an Ethernet cable for radar data transfer

c. 9-pin Dsub connector for encoder control

d. four BNC connectors for monitoring the complex (in-phase and quadrature) data, ramp voltage, and sync signal on the oscilloscope inside the instrumentation container.

Figure 5.1. Front View of LAS Transceiver Showing Quad-Ridged Horn Antennas, Electronics Enclosure, and Cabling

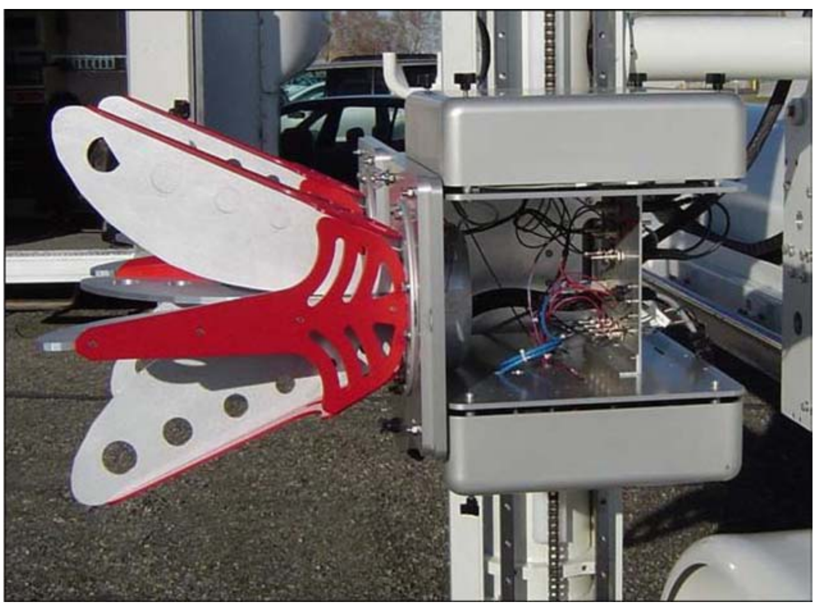

Figure 5.2. Side View of LAS Transceiver Showing Quad-Ridged Horn Antennas, Electronics Enclosure, and Connector Plate

6.0 System Operation

6.1 Overview of System Operation

The LAS system is designed to be transportable so that it can be moved to a given site to collect and analyze radar datasets of selected objects without the need to bring the objects to a fixed location. Before it can be used, the system must be properly prepared and transported to the desired site. The system is licensed for road transit.

Because the system contains a number of relatively delicate and relatively expensive components, care must be taken during transportation to avoid excessive vibration or rough handling which could compromise the system capabilities or jeopardize system safety. Once the system arrives at the desired location, it is set up and checked out. This includes erecting the scanner, connecting to AC power, connecting the scanner with the workstation used as the control system, checking the scanner for system integrity and proper operation, and mounting the transceiver on the scanner.

Normal operations consist of a set of calibrations followed by the collection and evaluation of scans (denoted as frames) of the selected object(s). Procedures are also provided for responding to off-normal conditions that may occur during the normal use of the system.

Once activities at a given location are completed, the system should be taken down and stowed in the transportation configuration, ready to be moved to the next location. Care must be taken to stow the system components in the proper configuration to avoid damage during transportation.

These system operations are described in greater detail in the following subsections.

6.2 Pre-Transport Preparation

Recommended activities prior to system transportation include the following:

- Develop the test plan to be used at the site
- Check the LAS system to ensure that it is ready for use
- Check inventory of spare equipment to confirm that items will be available if needed.

6.3 System Transportation

- ➢ Never climb on or hang from scanner boom to avoid injury and damage to the boom.

6.3.1 Preparation for Shipment

If the system is currently in the setup configuration, the scanner will need to be disassembled and placed in the stowed configuration for transportation, and any instrument trailer will need to be readied for transportation as well. In the stowed configuration:

- The scanner carriage is secured in place on the carriage tube using the locking pins.

- The scanner boom assembly is in a horizontal orientation and rests on the transport frame at the rear of the trailer. The boom support extension is in place on the end of the boom and rests on the U-shaped bracket on the scanner trailer.
- The support rod for the boom is removed and secured between the carriage rails.
- The instrument containers on the scanner platform are closed and locked.
- The leveling stands are removed and secured inside the scanner tube.

See Section 6.9 on System Disassembly for additional information regarding how to place the system in a travel-ready configuration.

> ➢ Care must be taken to ensure that all equipment is securely stowed to prevent damage during transportation.

6.3.2 In Transit

The scanner trailer should be checked periodically during transit to ensure that any tie-downs that are used remain secure to protect against possible shifting of system components.

It is anticipated that any instrument trailer will remain locked during transit, so that only external inspection of an instrument trailer will be possible during transit.

> ➢ Care must be taken during transportation to avoid excessive vibration or rough handling which could compromise system capabilities and/or system safety.

6.3.3 Upon Arrival

Upon arrival at the site, the scanner trailer should be inspected for any damage. This inspection should include the boom assembly, scanner carriage, and other components. Similarly, it is recommended that any instrument trailer and its contents be inspected to identify any damage incurred in transit. This inspection should include the transceiver assembly, PC workstation, and other components. Based on the results of these inspections, repairs should be made as necessary before proceeding to set up and use the system.

6.4 System Setup

The LAS system should be set up by two persons using the following procedure. Before beginning work, ensure that an appropriate safety perimeter has been established around the scanner. A ladder is required to safely access the scanner platform.

In the instructions below, the terms “left,” “right,” “front,” and “rear” are referenced to the view shown in Figure 6.1. For the purposes of this manual, the shuttle and transceiver are mounted on the “front” of the system.

Figure 6.1. Front View of LAS System with Jack Supports Engaged and Boom Stowed. (1) Shuttle boom in transport position; (2) Carriage with instrumentation containers; (3) Horizontal scanner tube; (4) Far right front jack support and trailer tongue assembly.

6.4.1 Requirements for Site Auxiliaries

Operation of the LAS system is dependent on electrical power supplied at the site.

6.4.2 Scanner Trailer Placement and Preparation

Select a location for placement of the scanner trailer that is relatively flat, close to and properly oriented to an area where the target object can be placed for evaluation. The selected location should be such that the scanner can be moved to that location without running over very rough or very uneven terrain, which could result in difficulties in aligning the trailer and, consequently, impact the accuracy of the scanner. The selected location should be sufficiently stable to provide a firm base for the leveling stands. The scanner trailer should be moved to the selected location, parked, and unhitched from the tractor.

6.4.3 Stabilize and Level the Scanner System

1. Remove the two trailer jack supports from inside the right end of the scanner tube and install them in the far right positions on the scanner tube frame. Install one of the jack supports on the front side of the tube frame and the other support on the rear side of the frame.

2. Remove the locking pins from the remaining six jack supports, rotate each support from a horizontal position to a vertical position, and re-insert the locking pins.

3. Increase the length of all support legs until the weight of the scanner frame is lifted from the wheels. This will ensure that the system will be properly supported and remain stable during scanning operations.

a. Rotate the crank on each jack support so that the bottom surface of the jack stand is in light contact with the ground.

b. Rotate the crank on each jack five turns until the desired height is achieved. Proceeding around the trailer, perform this operation two times in order to completely relieve the weight of the scanner system from the trailer axles and to ensure that the shuttle boom will not impact the ground when it is rotated into a vertical position.

4. Level and align the horizontal rails. The use of a digital leveling instrument is recommended to make certain that the carriage tube rails are horizontal. The system should now appear as shown in Figure 6.1. A closer view of the scanner carriage and shuttle boom is shown in Figure 6.2.

> ➢ The LAS scanner is a heavy system, and on certain ground conditions, some degree of settling may occur underneath it. It is important for the operator to be watchful of this possibility so that adjustments can be made as required.

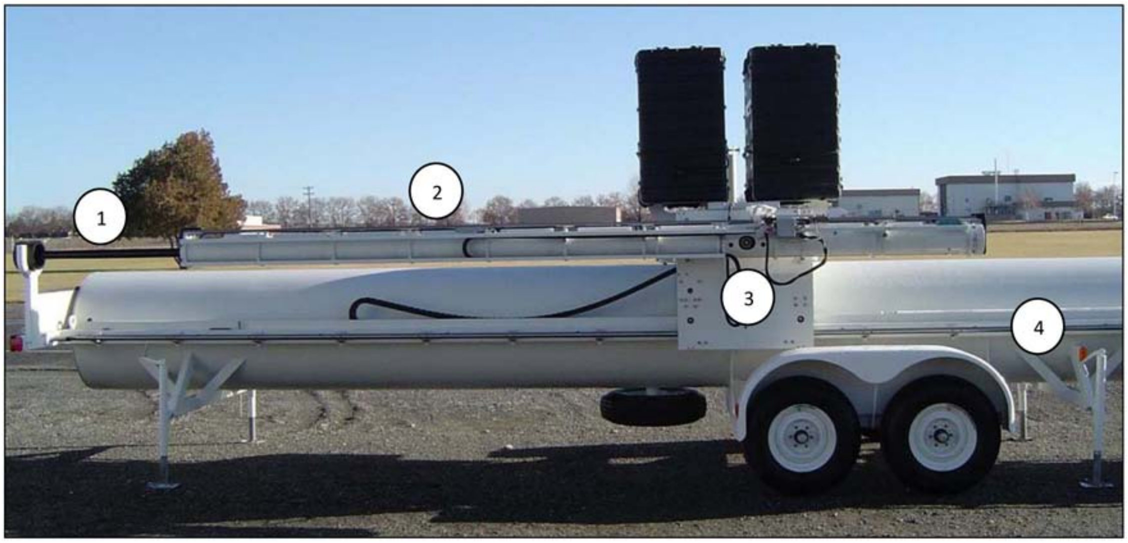

Figure 6.2. Front View of LAS System. (1) Support extension; (2) Shuttle boom; (3) Scanner carriage; (4) Front carriage rail.

6.4.4 Erect the Shuttle Boom

> ➢ Never climb on or hang from scanner boom to avoid injury and damage to the boom.

1. Locate the crank wheel on the left wall of the carriage shown in Figure 6.3. Rotate the crank wheel counter-clockwise to slightly elevate the shuttle boom until the support extension is no longer resting in the U-bracket.

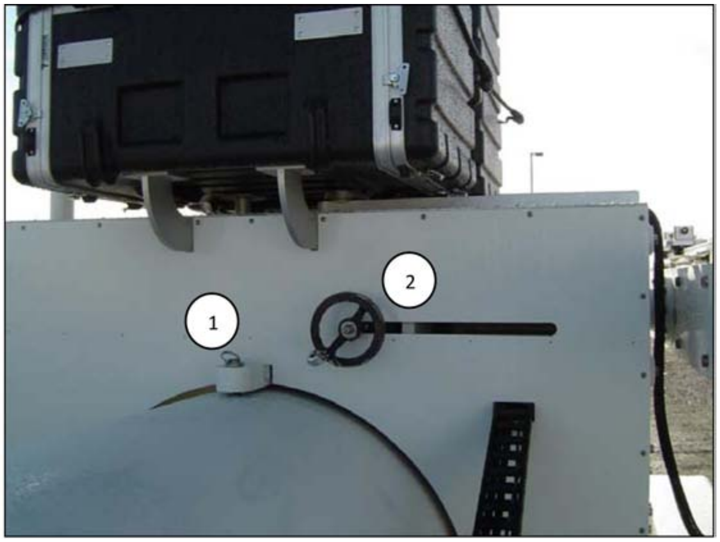

Figure 6.3. Left View of Carriage. (1) Left lock pin; (2) Left crank wheel.

2. Remove the support extension from the upper end of the shuttle boom by rotating the support extension counter-clockwise until it is free of its threaded connection. It will be necessary to insert a screwdriver handle or similar lever into the opening on the side of the support extension to initially loosen it from the shuttle boom. The shuttle boom should appear as shown in Figure 6.4.

Figure 6.4. Left Front View of Shuttle Boom with Support Extension Removed

3. Locate the rear crank wheel on the rear side of the carriage shown in Figure 6.5. Rotate the crank wheel counter-clockwise until the connecting rod reaches the limit of travel to completely extend the shuttle boom away from the carriage. Visually confirm on the front side of the scanner that the shuttle boom has sufficient clearance to travel along the carriage rails past the wheel fender. There should be approximately 3.5 inches of clearance between the fender wall and the shuttle boom.

Figure 6.5. Rear View of LAS System. (1) Scanner platform; (2) Rear crank wheel; (3) Rear carriage rail.

➢ Watch for pinching hazards during attachment of shuttle support rod.

4. Remove the shuttle support rod shown in Figure 6.6 from its storage location along the front carriage rail. Extend the support rod horizontally across the left end of the carriage tube as shown in Figure 6.6 and place the non-threaded end of the support rod into the bracket on the rear side of the shuttle boom. One person should support the support rod (while standing on the rear side of the scanner) and the other person should secure it into the bracket using the threaded bolt. A closer view of the bracket is shown in Figure 6.7. A light lubricating oil may be sprayed onto the contact surfaces in order to ease assembly, and the use of a hammer may be necessary to insert the bolt so that it reaches the threads. A hex wrench is needed to tighten the bolt into its final position.

➢ Always use a ladder to safely gain access to the rear scanner platform.

5. Rotate the crank wheel on the left wall of the carriage counter-clockwise to rotate the shuttle boom into a vertical position. As the shuttle boom is rotated vertically, one person will need to guide the threaded end of the shuttle support rod over the instrumentation container so that the rod can be mounted into the vertical post on the rear side of the platform. The system should appear as shown in Figures 6.8 and 6.9. A closer view of the connection between the support rod and vertical post is shown in Figure 6.10.

Figure 6.6. Rear View of Shuttle Boom and Support Rod in Horizontal Position

Figure 6.7. Close-up View of Bracket which Connects Support Rod to Shuttle Boom

Figure 6.8. Front View of LAS System with Shuttle Boom in Vertical Position. (1) Shuttle support rod; (2) Transceiver mounting plate.

Figure 6.9. Rear View with Shuttle Boom in Vertical Position

Figure 6.10. Shuttle Support Rod Locked into Vertical Stabilizing Post

6. Use a level to position the shuttle boom vertically. If necessary, the rod length can be adjusted using the threads on the end connected to the vertical post.
7. Install the vertical axis brake on the front wall of carriage as shown in Figure 6.11.

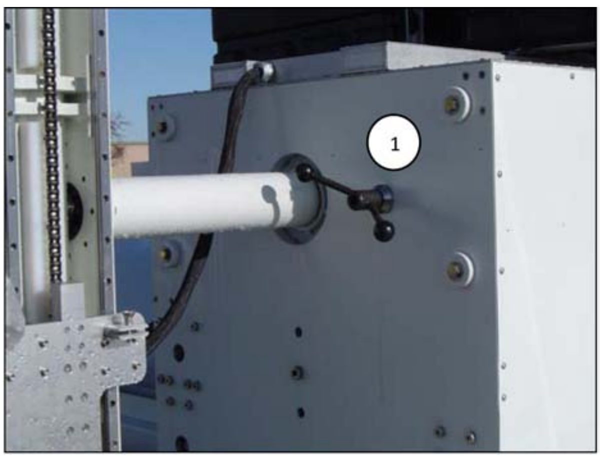

Figure 6.11. Right Front View of Scanner Carriage. (1) Vertical axis brake.

6.4.5 Establish Power and Control Connections to Scanner System

1. Locate the connector enclosure on the rear side of the scanner frame shown in Figure 6.12. Open the access door of the connector enclosure using a flat-blade screwdriver to rotate the key slot.
2. Insert the two AC power cables (110V and 220V) into the appropriately labeled connectors on the connector panel shown in Figure 6.13. The 110V connector is located on the left when facing the connector panel. These cables provide the AC power to operate the scanner.

Figure 6.12. Connector Enclosure Located on Rear Side of Carriage Tube

Figure 6.13. Connector Panel Inside Connector Enclosure

3. Insert the Ethernet network cable into the Ethernet connector in the panel. This cable transmits the data collected during scanner operations to the system computer. Connect the other end of the cable to the PC workstation which will be used to control the LAS system.

➢ Always use a ladder to gain access to the rear scanner platform.

4. From a standing position on the scanner platform, open the two instrumentation containers by unlatching the rear panels. As viewed from the rear scanner platform, the container on the right contains an oscilloscope which can be used to monitor the ramp, synchronization, and complex (I and Q) signals during data collection. The container on the left contains scanner equipment such as the servo motor drives, servo motor controller, and DC power supply. One E-stop and the handheld controller are also permanently connected to the equipment inside this container. The rear panels of the containers should be stored in a dry environment. Remove the emergency stop shown in

Figure 6.14 and connect it to the connector panel. The system will not operate unless this emergency stop is connected.

Figure 6.14. Emergency Stop which Plugs into Connector Panel on Rear Side of Carriage Tube

5. Locate the handheld controller and second emergency stop shown in Figures 6.15 and 6.16 and remove them from the instrumentation container. These controls are permanently connected to the scanner equipment. Place the handheld controller and emergency stop in a location where they can be easily accessed by an operator. Hooks are provided on the carriage for convenient access to these items.

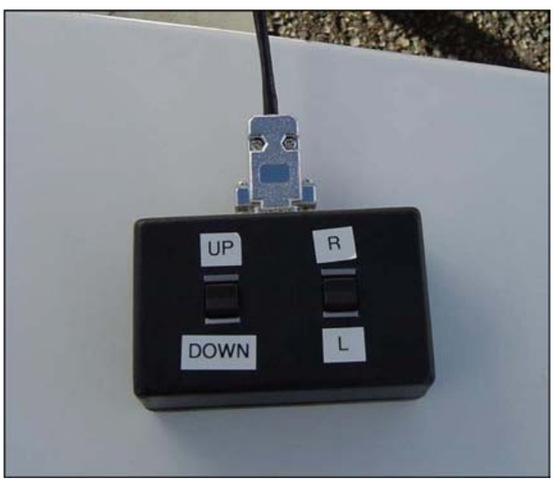

Figure 6.15. Handheld Controller for Scanner

Figure 6.16. Emergency Stop Permanently Connected to Instrumentation Container

6. Remove the carriage lock pin from each side of the carriage. These pins will prevent the carriage from moving along the tube in the horizontal direction. The left lock pin is shown in Figure 6.3.
7. Power on the system by placing both breaker switches located in the center of the connector panel (110V and 220V AC power) in the ON position. These switches are shown in Figure 6.13.

6.4.6 Install the Radar Transceiver

1. Use the UP/DOWN rocker switch on the handheld controller to position the transceiver mounting plate on the shuttle at a height convenient for mounting the transceiver. This is typically lower than chest height for the two persons mounting the transceiver onto the shuttle. The shuttle moves along the vertical shuttle rails in the direction indicated on the handheld controller. The transceiver mounting plate and shuttle are shown in Figure 6.17.
2. Remove the wing nuts and washers from the two bolts on the front edge of the transceiver mounting plate. Remove the two vertical pins from the mounting brackets on the rear side of the plate.

> ➢ The transceiver assembly is heavy and should be carefully installed by two persons. Watch for pinching hazards when mounting the transceiver to the shuttle.

3. Two people should carefully lift the transceiver into a position such that the horn antennas are side-by-side and directed away from the shuttle. The transceiver electronics enclosure should be located on the right when approaching the shuttle during the mounting process. Place the transceiver onto the mounting plate by guiding the two bolts through the two holes on the front edge of the plate. Insert the two tabs on the transceiver into the two brackets on the rear side of the plate. While supporting the transceiver in this position, secure the transceiver into place by fastening the nuts and washers onto the two bolts and inserting the vertical pins into the two mounting brackets. The transceiver should appear as shown in Figures 6.18 and 6.19.

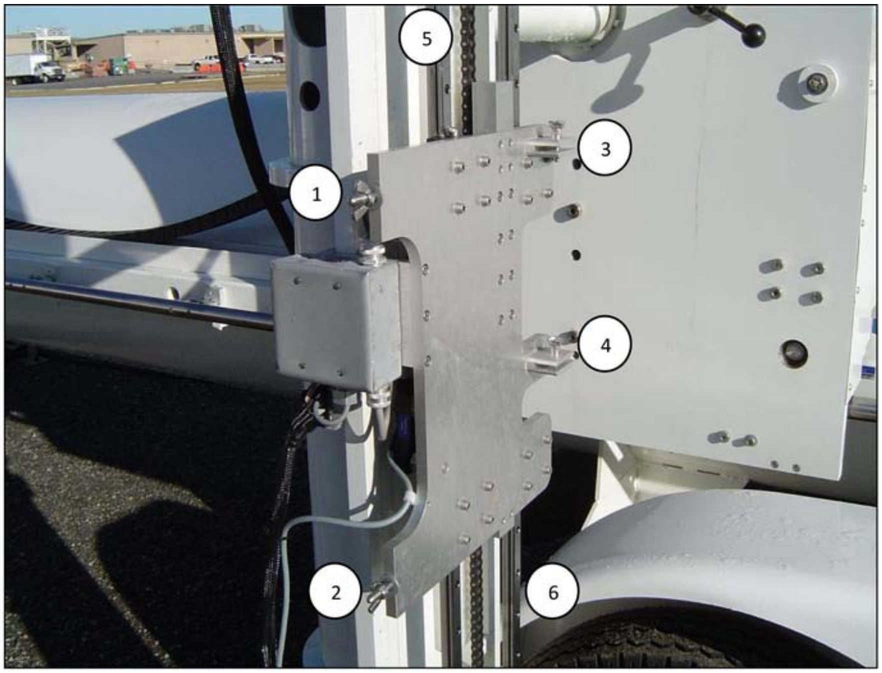

Figure 6.17. Transceiver Mounting Plate on Shuttle Rails. (1) Upper bolt; (2) Lower bolt; (3) Upper bracket; (4) Lower bracket; (5) Shuttle chain; (6) Shuttle rail.

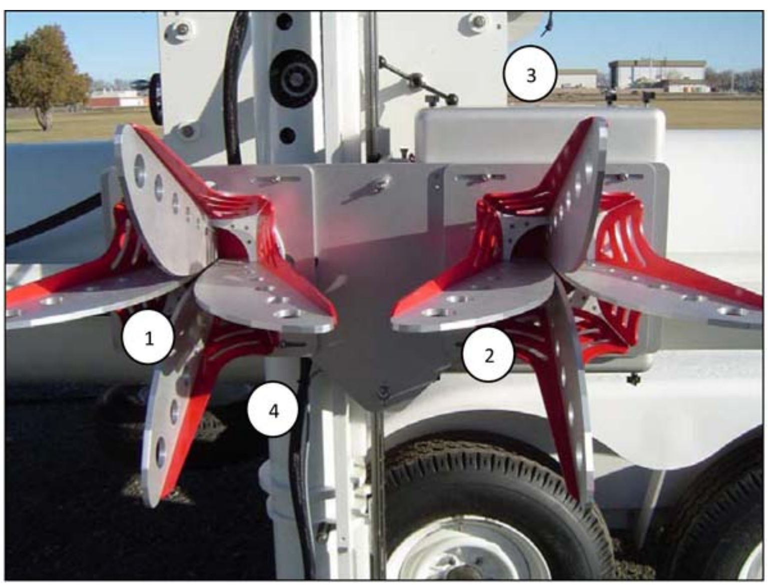

Figure 6.18. Front View of Mounted Transceiver. (1) Transmit antenna; (2) Receive antenna; (3) Electronics enclosure; (4) Cable assembly.

Figure 6.19. Rear View of Mounted Transceiver Showing Upper and Lower Pins which Attach Tabs to Brackets

4. Route the transceiver cable assembly and encoder cable attached to the shuttle boom up through the opening behind the antenna mounting plate to the rear side of the transceiver for connection to its connector panel. Be certain to carefully route the wires through so that there is little slack in the cables to avoid a snag hazard when the shuttle moves along the vertical rails. It is best to route the cables between the antenna mounting plate and the connector plate.

5. As shown in Figure 6.20, make the following connections between the transceiver and scanner:

   a. Attach the four BNC connectors for the in-phase (I) radar signal, quadrature (Q) radar signal, ramp and scope synchronization monitor functions.

   b. Insert the Ethernet cable into the Ethernet connector.

   c. Attach the encoder control cable to the D-connector.

   d. Attach the four-pin and three-pin power connectors to the panel. These connections provide power to the sensor processor board and radar electronics.

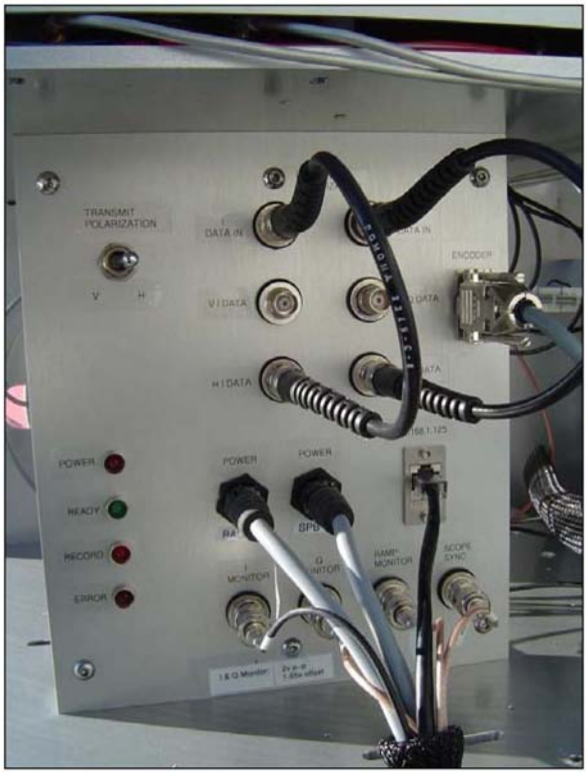

Figure 6.20. Transceiver Connector Panel Located on Rear Side of Transceiver

6. Select the desired transmit polarization using the flip switch on the upper left side of the transceiver connector panel. The system can transmit vertically or horizontally polarized signals.
7. Select the desired receive polarization using the two patch cables on the transceiver connector panel. The system can receive vertically or horizontally polarized signals. The configuration shown in Figure 6.20 is set for horizontal polarization. In order to select vertical polarization, the patch cables should be connected to the ports labeled “V I data” and “V Q data” instead of the “H I data” and “H Q data” ports. Refer to Section 6.7.2 for detailed instructions on selecting the transmit and receive polarizations.

6.4.7 Confirm Proper Alignment of Scanner

1. Use a level to confirm that the carriage rails (horizontal scan axis) are positioned in a horizontal orientation. If necessary, adjust the length of the jack supports on the front and rear sides of the scanner tube frame.
2. Use a level to confirm that the shuttle rails (vertical scan axis) are positioned in a vertical orientation. If necessary, adjust the angle of the shuttle boom using the left crank wheel and/or the length of the shuttle support rod using the threads at the connection to the vertical stabilizing post.
3. The system is now ready to begin scanning operations and should appear as shown in Figure 6.21.

Figure 6.21. LAS Scanner in Configuration Ready to Begin Scan Operations

6.4.8 Set up Control Computer

1. Connect the other end of the Ethernet cable plugged into the connector enclosure on the rear side of the scanner to the PC workstation which has the AhisWin Studio software installed. The computer should be located in a safe location near the scanning area.
2. Power up the PC workstation which has the AhisWin Studio software application installed.
3. Place the emergency stop switch shown in Figure 6.14 next to the computer so that scan operations can be quickly stopped if necessary.

6.5 Post Transport System Checkout

6.5.1 Mechanical Operations Checkout

- Re-check leveling
- Check carriage rails before moving carriage
- Check carriage movements
- Check shuttle rails and brake before testing shuttle movements
- Check shuttle movements

> ➢ System operators need to check for loosening of fasteners and other mechanical attachments resulting from vibration during system transportation, prior to operation of the system, and to make any repairs to respond to the findings of this inspection.

6.5.2 Electrical Power Checkout

System operators need to ensure that all electrical systems on the scanner are working properly before proceeding with operations.

➢ System operators need to comply with standard safety practices relating to electrical power.

6.5.3 Scanner Control Checkout

1. Confirm basic scanner operation

- Make sure the handheld controller is accessible
- Apply power to the scanner trailer system
- Make sure all E-Stop switches are pulled out (disengaged).
- Use the handheld controller to manually move both the vertical shuttle and horizontal carriage
- Motion in both axes indicates that the motor controllers are properly working

2. Verify communications to the motor controller from the computer system

- Log into the computer which has the AhisWin Studio software installed.
- Open a command shell window using Start -> Run -> cmd
- At the command prompt, enter "ping 192.168.1.30" without the quotation marks. This command sends test data packets to the IP address used by the motor controller to determine if it is alive.
- Verify that the response message states that all packets were received and not lost. A response message of "Request timed out" indicates that the motor controller is not connected to the computer.

6.5.4 Verify Sensor Control Module Connectivity

- If not already logged in, log into the computer which has the AhisWin Studio software installed.
- Open a web browser such as Internet Explorer and enter "192.168.1.125" without the quotation marks into the address bar.
- Press the button labeled "Waveform Test and Review" to collect a stationary waveform.
- View the waveform that is collected and verify that it is reasonable.
- This validates the operation of the transceiver.

6.5.5 Perform Data Collection on Simple Object

- Rotate the boom in the vertical position if it is not already in a vertical position.
- Mount the transceiver on the shuttle if it is not already mounted.
- Place a simple but non-symmetrical object approximately 2 meters from the transceiver. An example object would be a cylinder on a ladder.

- Login to the computer and open the ‘AhisWin Studio’ application that is on the desktop. Start an AhisWin Studio project (refer to the LAS Software Operations Manual).
- Collect a small aperture (2.5 meters by 2.5 meters) data set.
- View the ‘.cvf’ that is generated as it is being scanned. Verify that it is reasonable.
- Reconstruct the image without calibration files. The image should be reasonably sharp.
- This validates the operation of the transceiver and scanner together.

> ➢ Note: People walking into the scanning area and/or movement of the objects being scanned during scan operations will interfere with the ability of the system to properly image the objects.

6.6 “Safe System” Configuration

6.6.1 Purpose of the Safe System Configuration

A safe scanner system configuration has been identified and is intended to provide for the following:

- Safe overnight storage while operating outdoors
- Response to inclement weather conditions while operating outdoors

It is not recommended that the system be left in upright and active configuration during any of the above conditions.

6.6.2 Placing the System in Safe Configuration

To place the system into safe configuration, the following activities are recommended:

- Remove the radar transceiver from the shuttle and store in a secure, protected environment.
- Move the scanner carriage to the home position on the scanner trailer and insert locking pins.
- Place handheld controller and E-stops inside their instrumentation container. Close and lock both instrumentation containers.
- Protect scanner cable connectors by covering them with plastic bag. Attach plastic bag containing covered connectors to shuttle boom using tie-wraps with opening pointed downward in order to avoid moisture contacting the connectors.
- Remove all connections to the system connector panel shown in Figure 6.13.
- Protect other equipment and cables as appropriate for the conditions.
- If the inclement weather conditions include the risk of lightning strikes, pivot the shuttle boom to a nominally horizontal position. Note that this requires the removal of the support rod from the vertical stabilizing post on the rear platform, which is shown in Figure 6.10.

> ➢ System operators need to be aware of potential pinch-points during activities to secure boom in safe system configuration.

6.7 Normal System Operation

6.7.1 LAS System Operation Checklist

Table 6.1 summarizes the recommended actions which should be performed before each daily use of the LAS system. Following these steps will extend system lifetime and allow the operator to quickly determine if issues exist that would prevent continued usage of the system.

Table 6.1. LAS System Operation Daily Checklist

Description	Comments
Perform visual walk-around inspection	Identify anything unusual or that has obviously changed since the last usage of the system.
Inspect mechanical fasteners and attachment points	Tighten and/or repair as needed
Inspect condition of drive chain	Confirm proper alignment and tension as well as chain condition; adjust or replace as required
Inspect electrical connections	Confirm there are no loose connections or possible electrical hazards, and tighten and/or repair as needed
Inspect system leveling	Ensure all jack supports are firmly planted on firm surface
Inspect scanner leveling and adjust as necessary	Ensure scanner is level and scanner rails are horizontal
Inspect scanner horizontal and vertical drive motors	Check for proper function
Inspect condition and cleanliness of shuttle tracks on boom	Rub down shuttle tracks with alcohol and apply light oil lubricant as needed
Clean and lubricate carriage rails	Rub down carriage rails with alcohol and apply light oil lubricant as needed
Inspect mounting of transceiver on scanner shuttle	Ensure transceiver is securely mounted to shuttle
Confirm good weather conditions before initiating scanner operations	Ensure that system will not be operated in freezing conditions nor in windy conditions that could damage scanner or jeopardize system accuracy

6.7.2 Selecting Transmit and Receive Polarization

Polarization is defined by the path traced out the electric field vector as the electromagnetic radar wave propagates through space. In the case of linear polarization, the electric field trajectory is oriented along a single direction as the wave travels through space. The LAS system can operate using any combination of vertical and horizontal polarizations.

The use of vertical or horizontal transmit polarization is selected using the toggle switch labeled “Transmit Polarization” located on the rear panel of the transceiver. The use of vertical or horizontal receive polarization is selected using the two short patch cables connected to the rear panel of the transceiver. Again, any combination of transmit and receive polarizations may be used during data collection and the polarization selection should be part of the test plan.

One end of the receive polarization patch cables must always be connected to the “I Data In” and “Q Data In” ports. The connection on the other end of the patch cables determines whether the system receives vertical or horizontal linear polarization. The configuration shown in Figure 6.20 is set for receiving horizontal polarization since the patch cables are connected to the ports labeled “H I data” and “H Q data”. In order to receive vertical polarization, the patch cables should be connected to the ports labeled “V I data” and “V Q data” instead of the “H I data” and “H Q data” ports.

6.7.3 Pre-Scan System Calibration

There are two stationary files that need to be collected prior to object scan time. These calibration files should be collected for each frequency setting once during the test. A separate set of calibration files must be collected for each unique set of transceiver parameters such as start frequency, bandwidth, polarization, and frequency sampling. It is suggested that the most efficient way of collecting the calibration is to perform all calibrations together so that the calibration fixture only needs to be manipulated once. The calibration files include:

1. Open-air (baseline data)
2. Flat metal plate (phase calibration)

The procedure for collecting the pre-scan calibration files can be found in the LAS Software Operations Manual.

6.7.4 Radar Data Collection

The procedures for normal data collection can be found in the LAS Software Operations Manual. The transceiver collects data during each upward-moving vertical scan of the aperture and sends the data to the workstation during the return (downward) trip. There are several cues which indicate that data collection is in progress: (a) an audible beep is emitted at the beginning and end of each upward-moving scan, and (b) the Record light on the rear panel of the transceiver flashes while the transceiver is transmitting and receiving signals.

6.7.5 Data Processing

The AhisWin Studio application assists the operator in the logical data reduction process. Refer to the LAS Software Operations Manual and AhisWin Studio User’s Guide for detailed instructions regarding these operations.

6.7.6 Image Analysis

Multiple visualization utilities have been supplied with AhisWin Studio. Refer to the LAS Software Operations Manual and AhisWin Studio User’s Guide for detailed instructions regarding these operations.

6.7.7 End of Day Closeout

The LAS system may be operated indoors or outdoors, depending upon the situational requirements. End-of-day system shutdown procedures are given here for both of these environments.

6.7.7.1 End-of-Day Closeout for Indoor Operations

- Move transceiver shuttle to lower portion of boom (approximately chest height).
- Return carriage to home position on scanner tube and insert locking pin located on each side of carriage. The locking pins prevent the carriage from moving along the tube.
- Turn off electrical power to the scanner system by placing both power switches in the connector panel shown in Figure 6.13 to the OFF position.

6.7.7.2 End-of-Day Closeout for Outdoor Operations

- Place system in safe configuration as described in Section 6.6.2.

6.8 Responding to Off-Normal Conditions

6.8.1 Response to Inclement Weather Conditions

If the LAS system is operated outdoors, the system should be placed in safe configuration in response to poor weather (wind, rain, snow, or risk of lightning strike).

6.8.2 Response to Loss of Electrical Power

The LAS system is powered through the 110VAC and 220VAC electrical connections in the connector panel on the rear side of the scanner tube. An uninterruptible power supply inside the instrumentation container provides backup power to a portion of the 220V equipment for 30 seconds in the event of 220V power failure. Table 6.2 lists the system behavior and necessary response to outages which occur while the system is at rest as well as during scan operations. The following definitions apply to Table 6.2.

- **System reboot**: The act of turning power off to all 110V and 220V equipment by placing both breaker switches in the connector panel in the OFF position for at least 45 seconds, then turning all power back on by placing both switches in the ON position.
- **Communications failure**: Loss of network communications between the computer and scanner. Can be due to power loss at computer, network switch failure, or disconnected network cable.
- **Momentary loss of 220 V**: When the system loses and regains 220V power within 30 seconds. This is the amount of time that some of the 220V components are backed up by the UPS located inside the instrumentation container.

Table 6.2. LAS Behavior and Operator Response to Loss of Electrical Power

Event	System Behavior	Operator Response
Loss of 110V while scanning	Completes current scan line and stops. Handheld controller will not operate system.	Re-establish 110V power and reboot system
Loss of 220V while scanning	Scan stops immediately. Handheld controller will not operate system.	Re-establish 220V power and reboot system

Momentary loss of 220V while scanning	Scan stops immediately. Handheld controller will not operate system.	Reboot system
Loss of both 110V and 220V while scanning	Scan stops immediately. Handheld controller will not operate system.	Re-establish 110V and 220V power and reboot system
Communications failure while scanning	Completes current scan line and stops. Handheld controller will not operate system.	Re-establish communications link and reboot system
Loss of 110V while at rest	Remains at rest	Re-establish 110V power
Loss of 220V while at rest	Remains at rest. Handheld controller will not operate system.	Re-establish 220V power
Momentary loss of 220V while at rest	Remains at rest. Handheld controller will not operate system.	Reboot system
Loss of both 110V and 220V while at rest	Remains at rest. Handheld controller will not operate system.	Re-establish 110V and 220V power
Communications failure while at rest	Remains at rest	Re-establish communications link

6.8.3 Response to Emergency Stop Event

If an emergency stop is activated during scanning operations, the system must be powered down in order to completely return the scanner controller to its initial state. Otherwise the software program will resume execution after disengagement of the emergency stop and the scanner may move unexpectedly. In order to place the system in its initial state and recover from an E-Stop event, perform the following steps:

1. While the emergency stop is engaged (activated), place the 220V breaker switch in the connector enclosure in the OFF position.
2. Monitor the LED lights in the instrumentation container until the uninterruptible power supply (UPS) inside the container is no longer providing power to the scanner electronics. This condition can be recognized when all LED lights are off. ***Note: the UPS typically provides power for approximately 30 seconds after the breaker switch has been moved to the down position, so this will likely be the minimum waiting period.***
3. After confirming that the power has been removed from all equipment in the instrumentation container, disengage the emergency stop by pulling out the E-stop switch. Reapply power to the system by placing the 220V breaker switch in the connector enclosure in the ON position.

- Once engaging an E-stop condition, the E-stop switch should NOT be pulled out until power has been completely switched off. The uninterruptible power supply which provides temporary power inside the instrumentation container must NOT be powering the system. Otherwise the system will continue executing the current scan program upon re-engaging the E-stop and its sudden movement may cause serious harm to personnel.

6.9 System Disassembly

When the use of the system at a particular site is complete, it needs to be disassembled and properly stowed to be ready for transport. This procedure is essentially the reverse of the process for assembling the system, as described previously in Section 6.4. Refer to Section 6.4 for the details of each step. A summary of the required operations are as follows:

1. Position transceiver and shuttle to location on shuttle boom which is approximately chest-height. ***Note: The shuttle boom should never be rotated to a horizontal position (see step 13 below) with the transceiver shuttle at the lowest end of the boom. This will likely break the chain.***
2. Remove and properly store radar transceiver for transport
3. Secure transceiver cables to shuttle boom using tie-wraps or similar restraints
4. Power down and properly store PC workstation for transport
5. Remove all power and control cables from scanner system and properly store for transport
6. Close and lock connector panel on rear side of scanner tube
7. Remove vertical axis brake from front side of carriage and properly store for transport
8. Insert locking pins to secure carriage into fixed “home” position along scanner tube
9. Place handheld controller and both E-stops inside instrumentation container
10. Close and lock both instrumentation containers
11. Remove shuttle support rod from vertical stabilizing post bracket on scanner platform
12. Return shuttle boom to closest position to scanner carriage using rear crank wheel
13. Rotate shuttle boom to nearly horizontal position using left crank wheel, taking care to guide shuttle support rod around instrumentation container
14. Remove shuttle support rod from shuttle boom and properly store between carriage rails
15. Attach support extension to shuttle boom
16. Rotate boom to horizontal position using left crank wheel until extension rests in U-bracket
17. Lower jack supports until scanner rests on wheels
18. Remove jack supports on far right end of scanner tube and store inside tube for transport
19. Rotate and lock remaining six jack supports into horizontal position for transport

- Never climb on or hang from scanner boom to avoid injury and damage to the boom.
- System operators should be aware of potential pinch-points during disassembly and stowage of scanner.

7.0 System Maintenance

While not in use, the LAS system should be inspected on a weekly basis using the checklist given in Table 7.1. Any issues that are discovered should be promptly addressed to avoid damage to the system and possible injury to personnel. In addition to the LAS system inspection, any external power sources should be checked to make sure they are operating correctly.

Table 7.1. LAS System Inspection and Maintenance Checklist

Description	Comments
Perform visual walk-around inspection	Identify anything unusual or that has obviously changed since the last usage of the system.
Inspect mechanical fasteners and attachment points	Tighten and/or repair as needed
Inspect condition of drive chain	Confirm proper alignment and tension as well as chain condition; adjust or replace as required
Inspect electrical connections	Confirm there are no loose connections or possible electrical hazards, and tighten and/or repair as needed
Inspect scanner horizontal and vertical drive motors	Check for proper function
Inspect condition and cleanliness of shuttle tracks on boom	Rub down shuttle tracks with alcohol and apply light oil lubricant as needed
Clean and lubricate carriage rails	Rub down carriage rails with alcohol and apply light oil lubricant as needed
Inspect mounting of transceiver on scanner shuttle	Ensure transceiver is securely mounted to shuttle if it is currently attached to system

- Any personnel who perform maintenance and/or repairs of the LAS system should adhere to all related NIST safety procedures. It is assumed that all personnel who conduct any necessary repairs are properly trained in accordance with NIST standard safety protocols and practices.

8.0 Equipment Inventory and Spare Parts

It is anticipated that the operators of the LAS system would be prepared to deal with the possible need for repairs of standard electrical and electronic equipment, should such repairs become necessary. Electrical and mechanical drawings are provided in electronic form for the various components of the LAS system as described in Section 10.1. No spare items are provided as part of the delivery of the LAS system.

In the event that key components should fail in the field, it may be difficult to continue with the planned operation of the system. Therefore, it is suggested that the test plan for any use of the LAS system in time-critical circumstances include a review of the provided drawings in order to obtain assurance that repairs can be made or replacement parts can be procured if necessary.

9.0 Contact Information

The following PNNL staff members serve as the primary and backup technical point of contact for the LAS system.

Role	Name	Telephone Number	Email Address
Primary Technical POC	Tom Hall	509-375-2411	tom.hall@pnl.gov
Backup Technical POC	Clink Knopik	509-372-4041	clint.knopik@pnl.gov

10.0 Summary of LAS Documentation and Reference Material

In addition to this documentation, a full range of documentation for the LAS system has been developed and provided. This other documentation is summarized here. All documentation is supplied electronically with the AhisWin Studio software distribution. The files are located in the folder entitled "C:\Program Files\AhisWin Studio\Reference" after installation, and they also can be found in "\program files\AhisWin Studio\Reference" on the distribution CD.

10.1 Drawings and Related Files

A set of mechanical and electrical drawings and related files (component lists) is provided for LAS subsystems. The drawings are "as-built" and are accompanied by a reference system to help users locate the needed information. All of this information is provided electronically with the AhisWin Studio software distribution.

The drawings are located in sub-folders of "C:\Program Files\AhisWin Studio\Reference\LAS Documentation". The drawings have been compiled using a variety of drawing applications.

10.2 Technical References

A number of technical reference papers have been compiled as part of the LAS system documentation. These are provided electronically in "C:\Program Files\AhisWin Studio\Reference\Papers".

10.3 Component Manuals and Information Sheets

Manuals and information sheets are provided for major system components that were purchased rather than fabricated. These files are located in sub-folders of "C:\Program Files\AhisWin Studio\Reference\LAS Documentation" and "C:\Program Files\AhisWin Studio\Reference\Manuals".

10.4 LAS Software Documentation

The full documentation for the software that is used for computation and control of the LAS system is included electronically in the form of online help within the AhisWin Studio software interface.

10.5 LAS Software Operations Manual

A separate document entitled "LAS Software Operations Manual" is provided as the primary user's guide for routine operation of the LAS system computation and control software. It includes descriptive procedures for common operations and usage of the system.

11.0 Glossary of Terms

AhisWin Studio The software provided by PNNL for operating the LAS scanner and processing the resulting data.

Boom Assembly The portion of the mechanical scanner consisting of the boom and the transceiver shuttle. The boom is permanently attached to the carriage and is extended away from the carriage and rotated to a vertical position to perform scanning operations.

Brockman Precision Machine and Design
Fabricator of the trailer that supports the LAS mechanical scanner. Located in Kennewick, Washington.

Carriage The portion of the mechanical scanner that holds the boom assembly and travels horizontally along the scanner trailer rails.

Emergency Stop (E-stop) Switches
The two switches provided with the scanner to provide for an immediate stop of the scanner equipment. One E-stop switch is permanently attached to the equipment inside the instrumentation container and the other E-stop switch must be connected to the control box for the scanner to function.

Frame Data files for a single radar scan and the resulting dataset.

GUI Graphical User Interface, a software interface for user interaction and control of the system.

Instrument Trailer An enclosed trailer containing the computer system and other instrumentation used to operate the scanner and collect data if the scanner is operated in an outdoor environment. If used with the system, the instrument trailer should also used for storage of the transceiver and other equipment when they are not in use and during transportation.

O&M Operations & Maintenance

PNNL Pacific Northwest National Laboratory

Project Data files for a set of frames encompassing a unique test object or object configuration.

Scanner The mechanical system that moves the transceiver in a controlled manner over a rectilinear area to collect a set of data.

Shuttle The wheeled platform assembly that travels along the rails on the boom assembly, to which the transceiver assembly is attached for use.

Synthesizer A major component of each transceiver that generates the necessary frequencies for a given scan.

12.0 Index

Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by **Battelle** *Since 1965*

U.S. DEPARTMENT OF
ENERGY

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99352
1-888-375-PNNL (7665)
www.pnl.gov