**National Ignition Facility
Sub-System Design Requirements
Automatic Alignment System
SSDR 1.5.5**

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1.0 Scope

This System Design Requirement document establishes the performance, design, development, and test requirements for the Automatic Alignment System, WBS 1.5.5 which is part of the NIF Integrated Computer Control System (ICCS). This document responds directly to the requirements detailed in ICCS (WBS 1.5) which is the document directly above.

2.0 Applicable Documents

This section lists DOE orders, codes, and standards which are applicable to the NIF Integrated Computer Control System. The applicable portions of these documents apply. Applicable LLNL standards are being considered contingent upon the decision of final site selection.

2.1 Applicable NIF Project Documents

National Ignition Facility Functional Requirements and Primary Criteria, Revision 1.4, Mar 96.

2.2 Applicable US Government Orders and Standards

US. Government DOE General Orders:

DOE 5700.6C—Quality Assurance (flowdown from FRPC and SDR4)

US. Government DOE Orders relating to Safeguards and Security:

DOE Order 1360.2B, Unclassified Computer Security Program (nfd, Contract 48 required)

DOE Order 5300.4D, Telecommunications: Protected Distribution Systems (fd)

DOE Order 5639.6, Classified Computer Security Program (nfd, Contract 48 required)

2.3 Applicable National Consensus Codes and Standards

General Standards:

Do not apply to this section.

Safety Standards:

Do not apply to this section.

Software and Electronic Standards:

Ethernet	IEEE-802.3 Local Area Network for Data Communications
FDDI	Fiber Distributed Data Interface, ANSI Standard X3.139-1987
RS-232C	EIA Serial interface standard
RS-485	EIA Multi-drop serial interface standard
IEEE-488	Standard Digital Interface for Programmable Instrumentation, ANSI/IEEE Std 488.1-1987 and ANSI/IEEE Std 488.2-1987
VMEbus	IEEE-1014
RS-170	EIA Video interface standard
Ada 83	ANSI/MIL-STD-1815A-1983, programming language
Ada 95	International Standard ANSI/ISO/IEC-8652:1995, January 1995
X11	X Window System, Version 11, windows graphics standard, MIT X Consortium
OSF/Motif Motif	graphical user interface, Open Systems Foundation
Postscript	Text and graphics printing language, Adobe Systems Inc.
POSIX	IEEE-1003 portable application programming environment
TCP/IP	Protocol stack for network communications
OSI/ISO	Open Systems Interconnect protocol stack for network communications
OSF/DCE	Distributed Computing Environment, Open Systems Foundation
OSF/DME	Distributed Management Environment, Open Systems Foundation

2.4 Applicable LLNL Standards

Do not apply to this section.

2.5 Supporting Documentation Standards

Instrument Society of America, ISA-S5.1, Instrumentation Symbols and Identification

Instrument Society of America, ISA-S5.2, Binary Logic Diagrams for Process Operations

Instrument Society of America, ISA-S5.3, Graphics Symbols for Distributed Control/Shared Display

Instrumentation, Logic and Computer Systems

Instrument Society of America, ISA-S5.4, Instrument Loop Diagrams

Instrument Society of America, ISA-S5.5, Graphics Symbols for Process Displays

ANSI/IEEE Std 730.1-1989, IEEE Standard for Software Quality Assurance Plans

Software Guidelines Standards, Practices, and Conventions (Final DRAFT), Applications Development

Department, Lawrence Livermore National Laboratory, August 10, 1992

ANSI/IEEE Std 830-1984, IEEE Guide for Software Requirements Specification

ANSI/IEEE Std 1016-1987, IEEE Recommended Practice for Software Design Descriptions

ANSI/IEEE Std 828-1983, IEEE Standard for Software Configuration Management Plans

ANSI/IEEE Std 982.1-1988, IEEE Standard Dictionary for Measures to Produce Reliable Software

ANSI/IEEE Std 982.2-1988, IEEE Guide for the Use of IEEE Standard Dictionary of Measures to Produce Reliable Software

The Software Productivity Consortium, Ada Quality and Style Guidelines for Professional Programmers

ANSI/IEEE Std 1063-1987, IEEE Standard for Software User Documentation

2.6 References

NIF-LLNL-95-044/L-15958-2, National Ignition Facility Quality Assurance Program Plan, September 1995

NIF-LLNL-94-017/L-15958-5, NIF Ancillary Software Quality Assurance Plan, January 12, 1994

NIF-LLNL-93058, National Ignition Facility Functional Requirements and Primary Criteria

3.0 Requirements and Verification

3.1.1 System Description

The automatic alignment system, using computer hardware and software, centers laser beams on component input apertures and then points the beams through to the next component. Beam focusing is also performed. Digital image processing methods, such as the weighted centroid, are employed to analyze the same sensor images as those observed by operators on TV monitors or windows on an operator console. Automatic alignment is composed of many sequential iterative loops, each of which is responsible for controlling one active component such as a mirror. Many loops in different beams are operated in parallel using specialized FEP units.

Sensors for the Automatic Alignment System are contained in Laser Control WBS 1.7.

3.1.3 System Diagrams

3.1.3.1 Image Processing Algorithms used for Automatic Alignment

Sensor Image Type	Image Features	Processing Algorithm
Spot or disk	X, Y position, area, radius and out-of-bounds point count	Centroid (thresholded or weighted) a very fast calculation
Multiple beams (i.e., spot images)	Array of centroid values	Blob analysis - tracks many simple objects at once
Templates (e.g., crosshairs)	X, Y position, match goodness value	Correlation matched filter - robust method
Gaussian beam profile	X, Y position, fitting error	Surface fitting - Gram/Schmidt procedure
Focusing	Area (centroid values checked)	Scanning centroid minimizing area - slow due to moving components

3.1.3.2 Auto Alignment Loop Diagram

Each automatic alignment loop is comprised of many synchronous and asynchronous functions.

3.1.3.3 Auto Alignment Loop Sequences

This diagram is conceptual and details will be designed during Title 2.

Input & output sensor loops

Target Area Sensor Loops

3.1.4 System Interfaces

The Automatic Alignment has interfaces to the following WBS systems:

WBS 1.5.1.2	Computer System (network)
WBS 1.5.2	Supervisory Software
WBS 1.5.3	Integrated Timing System
WBS 1.5.4	Safety Systems (permissives)
WBS 1.5.6.1	Video Distribution
WBS 1.7.1	Alignment Systems

3.1.5 Automatic Alignment System - WBS 1.5.5

Consists of WBSs:

1.5.5.1 Automatic Alignment Front-end Processors

1.5.5.2 Front-end Processor Software

3.2.00 Functional Requirements

The Automatic Alignment System shall:

- point and center laser transport system from fiber-optic front-end to output sensor
- adjust KDP angle to match beam pointing
- point harmonic alignment beams to target chamber sensor
- focus beams on target chamber sensor
- digitize video and provide image processing capability to determine beam references
- perform remote sequencing of motorized alignment components
- maintain historical log of alignment data
- provide non-volatile (disk) storage of parameters and image templates
- provide software development environment for specialized computer equipment
- be modular allowing support of partial system operation during startup or maintenance
- provide a classified processing system for automatic alignment using potentially classified images obtained from the Target Alignment Sensors and the Chamber Center Reference Sensor.

3.2.01 QA Level Requirements

The Automatic Alignment System shall adhere to Quality Level 3 specifications.

Reference for QA Level is the NIF QA Plan as stated in paragraph 2.6 of this document.

3.2.02 Full System Alignment Time

The Automatic Alignment System shall support an eight (8) hour shot interval. The design of the Automatic Alignment System shall not preclude later support of a four (4) hour shot interval. A supporting analysis document shall be supplied.

Total time for a full laser system automatic alignment, including operator interactions (if required) shall not exceed 1 hour.

3.2.03 Closed Loop Descriptions

Approximately 15 loops shall be defined on a per-beam basis. (when data is available)

3.2.04 Full System Verification Time

The Automatic Alignment System shall complete a system verification in 30 minutes or less. Verification implies only part of the loops are checked, and that few loops need adjustment.

3.2.05 Average Loop Process Time

Average time to close a single loop shall not exceed 15 seconds. A typical loop is assumed to be comprised of analyzing one reference image and three beam images (i.e. 3 iterations).

3.2.06 Digitized Image Resolution

Image Processing in the Automatic Alignment System shall operate on a 480 lines by 512 pixel image. Image processing shall make use of gray-scale image data to achieve sub-pixel accuracy where needed. This requirement supports alignment performance and analysis specified in WBS 1.7.1.

3.2.07 Video Used By Automatic Alignment

The Automatic Alignment System shall use the same video images that are used by operators. This allows unambiguous verification by operators.

3.2.08 Pulse Sync

The Automatic Alignment System shall utilize a timing pulse which is supplied by Integrated Timing System WBS 1.5.3 to properly time the frame-grabs and video processing to the pulsed laser source.

3.2.09 FEP Software Requirement Specification

The detailed requirements of the Automatic Alignment System FEP shall be documented in a separate Software Requirements Specification. The SRS shall include functional requirements for FEP-resident user interfaces, data processing, alarm processing, data logging, trending, device drivers, embedded controller interfacing, or other special hardware requirements.

The SRS shall also include performance or other dynamic requirements as well as other architectural requirements that may imply system partitioning. The FEP SRS shall describe functional requirements that are expected to be implemented by either the supervisory software or other collaborating FEPs.

All FEPs shall conform as much as possible to a common design for the implementation of functional requirements that are shared by more than one instance of an FEP.

3.2.10 Lifetime, Replaceability and RAM

3.2.10.1 Lifetime,

Lifetime: The Automatic Alignment System shall operate for 30 years.

3.2.10.2 Replaceability

Any portion of the Automatic Alignment System which cannot reasonably be designed for 30 year lifetime shall be designed to be replaced or repaired at reasonable cost in a timely manner consistent with the overall availability of the System.

3.2.10.3 Reliability

The Automatic Alignment System shall have an overall reliability of 99.94%. Reliability is defined as the probability of meeting the minimum requirements of the experiment per no-yield shot.

3.2.10.4 Availability

The Automatic Alignment System shall have a shot availability of at least 99.06%. The Automatic Alignment System is unavailable when it is undergoing unplanned maintenance. Unplanned maintenance includes failure detection and active repair as well as logistic and administrative downtimes.

3.2.10.5 Maintainability

The Automatic Alignment System shall have a scheduled maintenance plan that fits within an overall annual plant goal of 69 days. The unplanned maintenance goal is 2.5 days per year. Opportunistic maintenance activities are performed between shots and during other system downtimes.

3.2.11 Environmental/EMI Requirements

3.2.11.1 Environmental, Temperature and Humidity

The Automatic Alignment System shall be capable of operating in the temperature and humidity previously specified for the laser and target area building. In general, the Automatic Alignment System components are capable of operating in a standard commercial temperature and humidity of 5C to 40C (41 to 104F) and 20% to 80 % RH non-condensing when installed in their appropriate enclosures.

3.2.11.2 Environmental, Plenum Approved/CL2 Cabling

All Automatic Alignment System cabling installed in air plenums shall use plenum approved cabling. Otherwise controls cabling shall conform to CL2 specifications.

3.2.11.3 EMI Requirements

All Automatic Alignment System electronic equipment shall be designed or purchased to tolerate, where warranted, an operating environment of 50 V/m external electrical field and 0.1 A/m external magnetic field without adverse effects. (ref ANSI C95.1-1991)

3.2.11.4 Ionizing Radiation

Ionizing Radiation effects are an issue only inside the target room. Inside the target room careful consideration shall be given to the radiation and EMI effects as described in "Radiation and EMI Effects in the NIF Environment", UCRL-ID-118202.

3.2.12 Segmented and Concurrent Operation

The Automatic Alignment System shall be capable of operating the NIF in a segmented mode with the segments functioning concurrently in different configurations. As an example, a portion of the laser may be under maintenance or construction and the rest of the laser operational. The Automatic Alignment System shall support the area under construction with appropriate test sequences, diagnostics and construction debugging tools, while simultaneously supporting shot sequences on the operational segment of the laser.

3.2.13 Human Factors

The Automatic Alignment System shall be designed in an ergonomic fashion to ensure that reliability during operation and maintenance is sustained at a level consistent with meeting overall availability and reliability objectives. Consistency in displays, warnings, and human interfaces should be maintained throughout the Laser System and, if possible, throughout the NIF facility (i.e. GUI displays, access ports, tooling). The requirement is related to paragraph 3.2.530 of this document.

3.2.14 Documentation and Records

The Automatic Alignment System shall provide sufficient documentation to comply with the NIF Quality Assurance Plan, and DOE Order 5700.6C, Quality Assurance, Criterion-4 Documents and Records, which states: "Documents shall be prepared, reviewed, approved, issued, used and revised to proscribe processes, specify requirements or establish design. Records shall be specified, prepared, reviewed approved and maintained."

Examples of documents that should be controlled include drawings, data files, calculations, specifications, computer codes, purchase orders, vendor supplied documents, procedures, work records and data sheets and test records. Revisions should be reviewed by the organizations that originally prepared and approved the documents. Controlled documents should be distributed to those doing the work.

3.4 Logistics

3.4.1 Maintenance

As a part of the design/construction project, the Automatic Alignment System shall provide all equipment required to inspect, service, and maintain all subsystems within the Integrated Computer Control System to meet the maintainability and availability requirements. Maintenance equipment shall include all handling fixtures, lifting equipment, and other special tools not otherwise available within the NIF, that are necessary to perform any planned (scheduled or unscheduled) maintenance activity.

3.4.2 Spares

As a part of the design/construction project, the Automatic Alignment System shall provide an initial complement of spare parts as required to activate the system.

6.0 Revision Record

<u>Rev letter</u>	<u>Date</u>	<u>Change by</u>	<u>Description</u>
A	12Mar96	Severyn	Convert to FileMaker, update
A	30May96	Severyn	Post Mid Title-1 update
2	09Aug96	Severyn	para 2.6, Update to new QA Reference. para 3.2.00, Add classified processing system for auto-alignment images para 3.2.01, Update QA levels to 1996 stds.
2	20Aug96	Severyn	para 2.2, was TBD, added ref. to DOE QA document, and refs. to Computer Security DOE Orders because of classified/unclassified operation). para 2.3, General and Safety sections were TBD, changed to not applicable. para. 2.4, was TBD, changed to not applicable.
2	28Aug96	Christensen	Convert to Word
2	29Aug96	Severyn	Call rev B=rev 2 for Sherpa, shrink diagrams to fit. Deleted phrase "Automatic Alignment System" from many para. titles to be consistent in titles. Updated Table of Contents to reflect this change. No text change.
2	05Sep96	Severyn	para 3.1.3.2 Updated Loop Diagram, "Digitize & Preprocess" becomes "Preprocess". per PVA. para 3.1.3.3, Added "This diagram is conceptual and details will be designed during Title 2." per PVA.
2	05Sep96	Severyn	para 3.2.06 replaced "...accuracy shall be within ± 1 pixel in X and ± 1 pixel in Y", with "...shall make use of gray-scale image data to achieve sub-pixel accuracy where needed." per Bliss.