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**National Ignition Facility
Sub-System Design Requirements
Integrated Timing System
SSDR 1.5.3**

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August 28, 1996

Lawrence
Livermore
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Integrated Timing System
SSDR 1.5.3

Revision 2
28 August 1996

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1.0 Scope

This System Design Requirement document establishes the performance, design, development, and test requirements for the Integrated Timing System, WBS 1.5.3 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:

None apply to this document.

2.3 Applicable National Consensus Codes and Standards

General Standards:

None apply to this document.

Safety Standards:

ANSI Z-136.1 (1993) (flowdown from FRPC and SDR4) and ANSI Z-136.2 (1988) Laser Safety Standards.

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

LLNL NIF Grounding Plan, L-17346-1 (signal isolation)

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 System Definition

3.1.1 System Description

The Integrated Timing System provides all temporally-critical hardware triggers to components and equipment in other NIF systems.

3.1.3 System Diagrams

3.1.3.1 Time Transfer, Epoch Distribution

Time Transfer is used to provide Facility Master Timing,
Epoch Distribution for Local Timing.

3.1.3.2 Facility Master Timing

Facility Master Timing is used to maintain each Local Clock in synchronism with the NIF Master Clock.

3.1.3.3 Local Timing Distribution with Feedback

Local Timing Distribution monitors ITS modules as well as Client Equipment feedback to assure performance and aid in recovery from component failure.

3.1.4 System Interfaces

The Integrated Timing System has interfaces to the following WBS systems:

<u>NIF System</u>	<u>WBS</u>	<u>Type of Interface</u>			
		<u>Fast Triggers</u>	<u>Precision Triggers</u>	<u>Fiducials</u>	<u>Control</u>
Optical Pulse Generation MOR	1.3.1.1	x	x	x	
Optical Pulse Generation Preamplifier	1.3.1.2	x			
Optical Pulse Generation Controls and Diagnostics	1.3.1.4	x			
Pockels Cell System Controls and Diagnostics	1.3.3.3	x			
Power Conditioning Control and Diagnostics	1.3.4.5	x			
Operations Computer System	1.5.1.2				x
System Integration Software	1.5.2.1				x
Supervisory Control Software	1.5.2				x
Shot Director Controls and Status SW	1.5.2.7				x
Automatic Alignment FEPs	1.5.5.2	x			
Television Distribution	1.5.6.1	x			
Energy Diagnostics Data	1.7.2.4	x			
Power Diagnostics Data System	1.7.2.5	x		x	
Wavefront Control	1.7.3.3	x			
Time Resolved X-ray Imaging System	1.8.3.2		x	x	
Soft X-ray Imaging System	1.8.3.3		x		
X-ray Streaked Slit Camera	1.8.3.5	x		x	
Target Diagnostics Data Acquisition	1.8.3.6	x		x	
Timing/Fiducial Laser Systems	1.8.3.7	x	x	x	
Target Diagnostics Control Room	1.8.3.11	x			

3.1.5 Major Subsystems

The Integrated Timing System (ITS) consists of WBS sections:

WBS 1.5.3.1 Facility Master Timing

Distributes a precise frequency reference and the Time-of-Day to multiple local sites throughout the NIF. Maintains the Time-of-Day at each site to a relative accuracy of better than 1 nanosecond for the Fast Timing component and 30 picoseconds for the Precision component. The output of Facility Master Timing supplies Local Timing Distribution.

WBS 1.5.3.2 Local Timing Distribution

Interfaces to Facility Master Timing at each local site. Utilizes the outputs of Facility Master Timing to generate electrical and optical triggers at programmable, precise times. These triggers are distributed to other NIF system components, generally in other WBS areas. Both Fast and Precision levels of performance is provided as required.

WBS 1.5.3.3 Integrated Timing Fiducial

Generates and distributes optical and electrical fiducial signals that are used by other NIF systems to time among multiple diagnostic transient recorders. These fiducials must maintain a very stable relative temporal stability.

3.2.01 Functional Requirements

The Integrated Timing System shall:

- supply timing signals to the OPG-Master Oscillator Room
- supply shot reference timing signals to:
 - target diagnostics instruments and FEPs
 - laser diagnostics temporal instruments, beam profile video digitizers and energy measuring FEPs
 - MOR and preamplifier controls
 - plasma Pockels cell controls
 - power conditioning power supplies
 - automatic alignment pulsed video capture trigger
 - wavefront controls
- provide distributed optical fiducial system for cross-timing between instruments
- provide distributed electrical fiducial system for cross-timing between instruments
- distribute timing signals to laser- and target-area equipment
- simulate timing signals for dry-run checkouts
- self-diagnose system operation
- provide FEP software and I/O subroutine library

3.2.02 Optical Fiducial Distribution System

The Optical Fiducials are used in conjunction with diagnostic recording equipment to temporally overlay measurement records. Optical fiducials shall have a maximum variation (worst case sum of jitter and timing walk) of 20 picoseconds or less over a period of 168 hours.

Optical Fiducials are required by users in WBS 1.8.3 (Target Diagnostics) and WBS 1.7.2 (Laser Diagnostics) to meet power-balance requirements of the NIF with sufficient stability to cross time instruments to within 20 picoseconds. i.e. 20×10^{-12} seconds. The Optical Pulse Generation System (WBS 1.3.1) may also use optical fiducials. These fiducials are derived from and synchronized to the MOR reference beam, provided by WBS 1.3.1.1.

Optical Fiducials are used by Target Diagnostics and Laser Diagnostics, in cases where System Requirements mandate the highest temporal stability.

3.2.03 Electrical Fiducial System

ITS shall provide electrical fiducials for the same general purpose as the optical fiducials. (para. 3.2.02.) Groups of instruments which require cross-timing of signals shall receive fiducials from a common fiducial generator. There may be more than one group of such instruments, each group supplied by a single fiducial generator. Electrical fiducials originating from a common fiducial generator shall have a maximum variation among outputs (worst case sum of jitter and timing walk) of 50 picoseconds or less over a period of 168 hours. Electrical fiducials originating from different fiducials generators shall have a maximum uncorrected variation among outputs of 100 picoseconds or less over a period of 168 hours.

3.2.04 Fast Timing System Specs

The Fast Timing System provides triggers to other NIF systems with sufficient performance that they may satisfy their SDR's. The performance specifications of the Fast Timing System are:

3.2.04.1 Fast Timing Range

Range of adjustment shall be at least from 100 milliseconds prior to 100 milliseconds after the Optical Pulse is generated in the MOR.

3.2.04.2 Fast Timing Resolution

Timing adjustment resolution shall be 1 nanosecond or shorter.

3.2.04.3 Fast Timing Jitter

Short-term temporal variations (jitter), measured over a period of 100 milliseconds, shall be no greater than 100 picoseconds rms.

3.2.04.4 Fast Timing Wander

Long-term temporal variations (wander), measured over a period of 7 days, shall be no greater than 500 picoseconds peak-to-peak.

3.2.04.5 Fast Timing Jitter/Wander Combined

The above two specifications (3.2.04.3 and 3.2.04.4) will probably be replaced by a spectral specification such as Allan Variance or Time Deviation to reflect performance over varying periods.

3.2.05 Extended Range Triggers

The Extended-Range Timing System provides triggers to other NIF systems with sufficient performance that they may satisfy their SDR's. It supplements the Fast Timing System by providing timing over a wider range of adjustment but at a reduced accuracy.

3.2.05.1 Extended Range Trigger Range

Range of adjustment shall be at least from 2 seconds before to 2 seconds after the Optical Pulse is generated in the MOR.

3.2.05.2 Extended Range Trigger Resolution

Adjustment resolution shall be no greater than 100 milliseconds.

3.2.05.3 Extended Range Trigger Jitter/Wander

Short-term (jitter) and long term (wander) temporal variations shall be no greater than 1 millisecond maximum.

3.2.05.4 Extended Range Trigger Typical Users

These triggers are used by the Plasma Pockels Cell (WBS 1.3.3) for a pre-ionizer and possibly by other systems to control mechanical shutters.

3.2.05.5 Extended Range Trigger, Range Exceeded

Events outside of the range of the Extended Range Triggers are performed by sequencing software (SSDR 1.5.2 para 3.2.10).

3.2.06 Precision Timing Specs

The Precision Timing System provides triggers to other NIF systems with sufficient performance that they may satisfy their SDR's. It supplements the Fast Timing System by providing a higher performance trigger when required to meet Functional Requirements. The performance specifications of the Precision Timing System are:

3.2.06.1 Precision Timing Range

Range of adjustment shall be at least from 500 nanoseconds after to 3000 nanoseconds after the Optical Pulse is generated in the MOR.

3.2.06.2 Precision Timing Resolution

Adjustment resolution shall be 50 picoseconds or shorter.

3.2.06.3 Precision Timing Jitter

Short-term temporal variations (jitter), measured over a period of 100 milliseconds, shall be no greater than 20 picoseconds rms.

3.2.06.4 Precision Timing Wander

Long-term temporal variations (wander), measured over a period of 7 days, shall be no greater than 100 picoseconds peak-to-peak.

3.2.06.5 Precision Timing Jitter/Wander Combined

The above two specification (3.2.06.3 and 3.2.06.4) will probably be replaced by a spectral specification such as Allan Variance (AVAR) or Time Deviation (TDEV) to reflect performance over varying periods.

3.2.07 Independent Operation

The Integrated Timing System shall meet all specifications independent of most other NIF systems. However, the ITS depends on the following systems to meet specifications:

- Building environment and electrical power requirements must be met.(ref SDR001)
- The Supervisory Control System must be able to communicate with the ITS FEP.
- Non-operability of the MOR will result in all timing signals being self-consistent but may not be synchronized to the MOR laser pulses.
- Non-operability of the MOR may result in loss of all fiducials (both electrical and optical).

3.2.08 Segmented and Concurrent Operation

The ITS 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 ITS 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.

3.2.09 Safety

The Integrated Timing System may contain Class IV lasers. If so, the system shall conform to the applicable eye-hazard safety requirements to mitigate the possibility of eye exposure to an uncapped laser diode or unterminated active fiber source. Applicable standards include ANSI Z-136.1 (1993) and ANSI Z-136.2 (1988).

3.2.10 Master Timing Signal Trigger

The Integrated Timing System shall supply the OPG with a master timing signal at a rate of 960 Hz. This rate shall be used by the OPG to generate optical pulses to the remainder of the NIF laser.

3.2.11 TV Frame Enables

The Integrated Timing System shall supply the Television Distribution System (WBS 1.5.6.1) with approximately 130 triggers for use as TV frame enable triggers to capture pulsed laser images on video cameras.

3.2.12 Laser Diagnostics Energy Photodiodes Triggers

The Integrated Timing System shall supply the Laser Diagnostics system with approximately 192 Fast Timing signals for digitizer gating. This allows gating photo diode signals such that only the laser pulse duration is integrated, gating out ASE, flashlamp, and reflected light.

3.2.13 Laser Diagnostics Energy Calorimeter Triggers

The Integrated Timing System shall supply the Laser Diagnostics system with approximately 32 Fast Timing signals for calorimeter recording triggers.

3.2.14 Laser Diagnostics Temporal Photodiode Triggers

The Integrated Timing System shall supply the Laser Diagnostics system with approximately 56 Fast Timing signal for digitizer triggering. The ITS shall also supply approximately 48 electrical fiducial and approximately 8 optical fiducial signals.

3.2.15 Target Diagnostics Triggers

The Integrated Timing System shall supply the Target Diagnostics system with approximately 50 Fast, approx. 20 Precision, approximately 25 Electrical and approximately 10 Optical Fiducial Timing signals.

3.2.16 Power Conditioning Triggers

The Integrated Timing System shall supply the Power Conditioning system with approximately 244 Fast Timing signals to activate Pulse Power Switches. (WBS 1.3.4)

3.2.17 Pockels Cell Trigger

The Integrated Timing System shall supply the Pockels Cell system with approximately 192 Extended Range Timing signals and approximately 288 Fast Timing signals. (WBS 1.3.3)

3.2.18 OPG, Master Oscillator Triggers

The Integrated Timing System shall supply the Master Oscillator with approximately 4 Precision and approximately 25 Fast Trigger signals.

3.2.19 OPG, PAM Triggers

The Integrated Timing System shall supply the PAM with approximately 1920 Fast Trigger signals.

3.2.20 Wavefront Control Triggers

The Integrated Timing System shall supply the Wavefront Control system with approximately 32 Extended-Range Trigger signals.

3.2.21 Target Plane Diagnostics Triggers

The Integrated Timing System shall supply the Target Plane Diagnostic with approximately 50 Fast Triggers and approximately 20 Electrical Cross-Timing signals.

3.2.22 FEP Software Requirement Specification

The detailed requirements of the Integrated Timing 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.

3.2.23 QA Level Requirements

The Integrated Timing System shall adhere to the following Quality Level specifications. Reference for QA Level is the NIF QA Plan as stated in paragraph 2.6 of this document.

WBS 1.5.3.1 Facility Master Timing	Q-Level 3
WBS 1.5.3.2 Local Timing Distribution	Q-Level 3
WBS 1.5.3.3 Integrated Timing Fiducial Beam	Q-Level 3

3.2.24 Environmental/EMI Requirements

3.2.24.1 Environmental, Temperature/Humidity

The Integrated Timing System shall be capable of operating in the temperature and humidity previously specified for the laser and target area building. In general, the ICCS 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. These temperature and humidity are the maximum ranges expected in equipment racks. However to maintain full timing specifications, the ITS equipment requires stability within a rack of ± 2.5 C. Therefore ITS equipment should be located in racks with no other heat producing equipment that needs frequent servicing.

3.2.24.2 Environmental, Plenum Approved/CL2 Cable

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

3.2.24.3 EMI Requirements

All Integrated Timing 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)

3.2.24.4 Environmental, 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.

3.2.25 Shot Abort

When performing a shot or dry run sequence, the Integrated Timing System shall cease emitting timing signals within 110 milliseconds after receiving a T-1 ABORT signal.

3.2.26 Lifetime, Replaceability and RAM

3.2.26.1 Lifetime

Lifetime: The ITS shall operate for 30 years.

3.2.26.2 Replaceability

Any portion of the ITS 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.

3.2.26.3 Reliability

The ITS shall have an overall reliability of 99.88%. Reliability is defined as the probability of meeting the minimum requirements of the experiment per no-yield shot.

3.2.26.4 Availability

The ITS shall have a shot availability of at least 99.03%. The ITS is unavailable when it is undergoing unplanned maintenance. Unplanned maintenance includes failure detection and active repair as well as logistic and administrative downtimes.

3.2.26.5 Maintainability

The ITS shall have a scheduled maintenance plan that fits within an overall annual plant goal of 69 days. The unplanned maintenance goal is 2.6 days per year. Opportunistic maintenance activities are performed between shots and during other system downtimes.

3.2.27 Recovery From Abnormal Event

The time required for the Integrated Timing System to recover from any abnormal event shall be less than the maximum times cited below, as a function of the expected yearly frequency of occurrence of the event.

Expected Frequency of Occurrence Per Year, F	Maximum Recovery Time
$F \geq 1$	24 hours
$1 > F > 1e-2$	1 week
$1e-2 > F \geq 5e-4$	3 months

Probabilities listed in DOE-STD-1020-94 shall be used for natural phenomena.

For frequent events, the maximum allowed recovery time may be restricted by availability requirements to be less than that shown in the table above.

3.2.28 Human Factors

The ITS 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)

3.2.29 Documentation and Records

The ITS 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 Integrated Timing System shall provide all equipment required to inspect, service, and maintain all subsystems within the Integrated Timing 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 Integrated Timing System shall provide an initial compliment 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	06Aug96	Severyn	para 2.6, update QA Plan ref. para 3.2.23, update QA values to Aug. 1996 criteria para 3.2.03, purged TBDs by putting in real specs from Jay W. para 3.2.11, purged TBD, changed quantity to 130 Frame Enable Trigger and applied these to TV Dist system, as it will do fanout of Frame Enable.
2	20Aug96	Severyn	para 3.2.25, purged TBD on T-1 Abort signal. para 2.2 was TBD, added ref to DOE QA Order and noted that no Safeguards & Security items apply to this document. para 2.3 Gen Stds was TBD, changed to not applicable. Safety Stds was TBD, changed to add ANSI Z136.1 and .2 para 2.4 was TBD, added ref. to NIF Grounding Plan (Signal Isolation).
2	27Aug96	Christensen	Convert to Word 6.0.1
2	27Aug96	Severyn	Minor indention fixes, no text change. Make this rev 2 to match Sherpa. Deleted "Integrated Timing System" from title of paragraphs. This was an artifact of a "pre-version A". Now not needed as this whole document in now ITS.
2	28Aug96	Severyn	Para 3.2.10, Deleted last sentence which was an OPG timing accuracy requirement of better than 50 ps. Gaspare and I checked and an equivalent reqmt. does exist in the OPG SSDR 1.3.1, para 3.2.1.06 which is a 10ps requirement. The requirement correctly belongs in OPG and not ITS.
2	28Aug96	Severyn	Para 3.1.4 Delete Image Diagnostics Data System WBS 1.7.2.6 as this function (as related to the Timing System) has been combined into WBS 1.5.6.1. Para 3.1.4, Add "Fiducial x" to Power Diagnostics Data System WBS 1.7.2.5 (inadvertently left out). Para 3.1.4, Add Supervisory Control Software WBS 1.5.2 to the list and an "x" in the Control column for this new item. (inadvertently left out).