LLNL-CONF-432171

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Target Diagnostic Control System Implementation for the National Ignition Facility

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May 17, 2010

High-Temperature Plasma Diagnostics
Wildwood, NJ, United States
May 16, 2010 through May 20, 2010

Target diagnostic control system implementation for the National Ignition Facility[*,a,b)]

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(Presented XXXXX; received XXXXX; accepted XXXXX; published online XXXXX)

The extreme physics of targets shocked by NIF's 192-beam laser are observed by a diverse suite of diagnostics. Many diagnostics are being developed by collaborators at other sites, but ad hoc controls could lead to unreliable and costly operations. A Diagnostic Control System (DCS) framework for both hardware and software facilitates development and eases integration. Each complex diagnostic typically uses an ensemble of electronic instruments attached to sensors, digitizers, cameras, and other devices. In the DCS architecture each instrument is interfaced to a low-cost Windows XP processor and Java application. Each instrument is aggregated with others as needed in the supervisory system to form an integrated diagnostic. The Java framework provides data management, control services and operator GUI generation. DCS instruments are reusable by replication with reconfiguration for specific diagnostics in XML. Advantages include minimal application code, easy testing, and high reliability. Collaborators save costs by assembling diagnostics with existing DCS instruments. This talk discusses target diagnostic instrumentation used on NIF and presents the DCS architecture and framework.

I. NIF TARGET DIAGNOSTICS

The physics requirements derived from The National Ignition Facility (NIF)[1] experimental campaigns are leading to a wide variety of target diagnostics along with differing diagnostic configurations for each experiment. To better understand the physics of energetics, laser-hohlraum interaction, hydrodynamics, and materials equation of state, a number of diagnostic capabilities have been deployed and commissioned. Diagnostics have some common and some unique control requirements. Optical diagnostics observe backscattered light from targets and provide insight into energy conversion and measure shock velocity. X-ray diagnostics can be either integrating to capture total energy or gated to capture a snap-shot of the target while experiencing laser-driven shock. Neutron imaging, neutron time-of-flight, and spectroscopy diagnose ignition experiments. Table 1 lists target diagnostics currently commissioned for NIF and Figure 1 shows optical and X-ray diagnostics on the chamber.

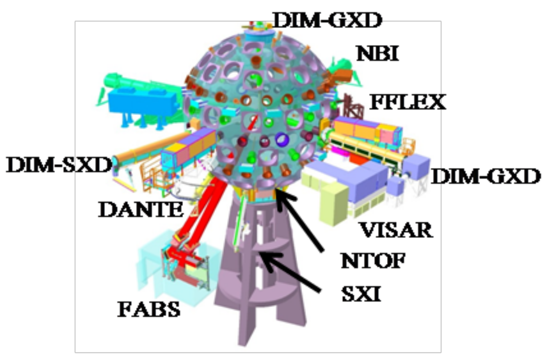

Figure 1. Optical and X-ray target diagnostics are deployed on the target chamber.

Table I. Target diagnostics commissioned for 2009 NIF experiments

Diagnostic System	
Positioner	Diagnostic Instrument Manipulator (**DIM**)
Optical	Full Aperture Backscatter (**FABS**)
	Near Backscatter Imager (**NBI**)
	Velocity Interferometer (**VISAR**)
X-Ray	Soft X-ray power diagnostic (**DANTE**)
	Hard X-ray Spectrometer (**FFLEX**)
	Streaked X-ray Detector (**SXD**)
	Gated X-ray Detectors (**GXD**)
	Static X-ray Imager (**SXI**)
Neutrons	Neutron Time-of-Flight (**NTOF**)

II. NIF CONTROL SYSTEM

The computer control system for NIF is comprised of several segments that utilize appropriate technology for implementation. The Industrial Control System (ICS) controls utilities such as vacuum, cooling and gas. The Safety Interlock System (SIS) assures that personnel are not in danger during operations. The Access Control System (ACS) is used to control and audit personnel traffic in the various laser and target areas. These three are implemented with commercial programmable

[a)]Invited paper published as part of the Proceedings of the 18th Topical Conference on High-Temperature Plasma Diagnostics, Wildwood, New Jersey, May, 2010.
[b)] This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 LLNL-CONF-432171.
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logic controllers. A much larger Integrated Computer Control System (ICCS) incorporates over 1,030 front-end processors, servers, and workstations to control, diagnose and fire the laser, as well as to integrate the suite of target diagnostics that are the focus of this paper[3].

Controls for target diagnostics are managed as part of ICCS high-level architecture. However, target diagnostics has a unique requirement for self-contained standalone operation of the diagnostic outside of the supervisory environment. This also permits diagnostics to be operated or calibrated in facilities other than NIF. A loosely coupled interface to the ICCS hardware and software helps meet this requirement.

III. DIAGNOSTIC CONTROL SYSTEM

A. DCS architecture

The controls and data acquisition for the suite of diagnostics used for early NIF experiments followed a very traditional, though very formal, computer controls development process. Each diagnostic was controlled by a Diagnostic Control System (DCS) computer controller. The various power supplies, cameras, digitizers/scopes, referred to as instruments used by a diagnostic, were interfaced to a single computer controller. Each controller was a 4U (7 in.) high rack mountable computer with a disk running Windows XP™. A single software application written in Java, a modern object-oriented language was written to control each target diagnostic.

Although the DCS diagnostic based architecture worked well during the early NIF campaign of experiments, the overall control system development and maintenance costs were high. After the early NIF experiments, we had an opportunity to review lessons learned and adopt a controls approach to better serve the needs of NIF target diagnostics in the coming years while still providing the needed performance and reliability.

The Goals established for this new approach to controls development included:

- Reduced hardware and software costs
- Increased efficiency by reusing software
- Improved verification and test case coverage
- Faster development turnaround for new diagnostics

The Diagnostic Control System (DCS) architecture was developed to achieve these goals. A diagnostic's supporting instruments (i.e., power supplies, cameras, and/or digitizers) are each supported by a dedicated computer controller with generic DCS software customized to that instrument. Figure 2 illustrates this architecture for the Dante soft X-ray spectrometer diagnostic. The Dante diagnostic uses one DCS controller with software and interface hardware specific to the power supply and 20 more controllers with software and interface specific to the oscilloscope.

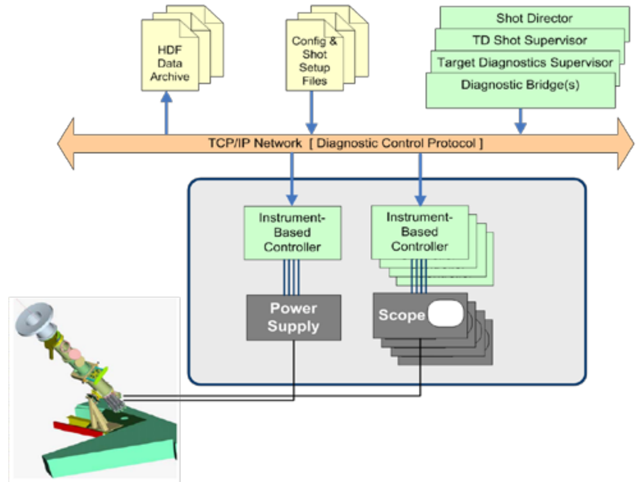

Figure 2. Diagnostic control system architecture as applied to Dante diagnostic

The various DCS computers are located in standard 19-inch electronic racks in one of four diagnostic mezzanines adjacent to the NIF Target Area shielding wall, along with the power supplies and digitizers. Computers are connected to the ICCS network through network switches in the diagnostic mezzanine. These controllers are diskless and boot from a file server over the network. Experiment data collected from cameras and digitizers by each controller is sent to the file server for processing and archiving.

B. Software framework

The DCS framework is an objected-oriented Java-based modular software library that provides all the major functions necessary to create controls software for a specific target diagnostic. Figure 3 illustrates the DCS Framework, which instantiates objects that perform the following common functions.

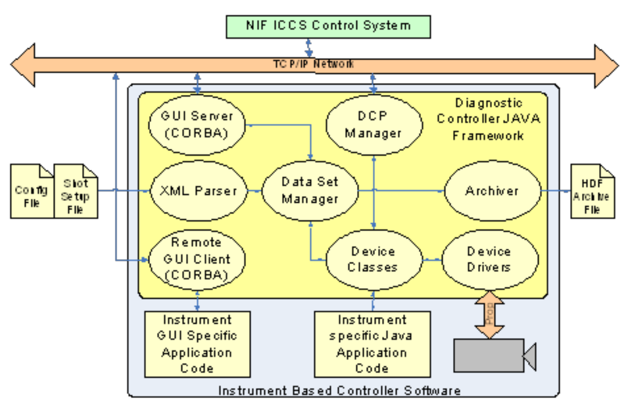

Figure 3. Diagnostic control system framework

1. XML Parser

The XML parser object reads and validates the DCS XML configuration file at controller startup. This file defines parameters such as hardware configuration, data-set definitions, and instrument specific commands. Upon request from ICCS, the setup files are parsed and validated using a data schema. The setup files contain controller specific commands that are stored in the Data-set Manager and executed during defined controller states or during NIF shot countdown ticks.

2. Data-set Manager
The Data-set Manager is the data broker for the controller that acquires, stores, and makes available data defined in the instrument-specific Java code for the device, GUI and Archiver.

3. Data Archiver
Upon an archive request from ICCS, the Archiver gathers the data stored in Data-sets and creates a structured HDF file at the specified location. The archived data is then processed by the data analysis team.

4. GUI Client / Server
The GUI Server provides remote access to the controller data using the Data-set Manager. The GUI client creates XML messages and sends them to the GUI Server via CORBA. The GUI Server parses the XML to execute control sequences or make data available to the GUI client. An automatic tabular-form GUI is created based on the available Data-sets. Optionally, a customized GUI application can be written to implement more complex GUI requirements.

5. Device Classes
The device classes are the API calls that the instrument application code must implement to provide instrument-specific functionality.

6. DCP Manager
The DCP Manager implements the Diagnostic Control Protocol for the controller. It accepts state transition commands from ICCS, implements the controller state machine, executes commands defined in XML files, and sends high-level status and state information back to the ICCS control system.

IV. TARGET DIAGNOSTIC SUPERVISOR

The ICCS target diagnostic subsystem software is written in Ada to execute on Sun Solaris servers. It is comprised of target diagnostic Front End Processor containing Diagnostic Bridges, supervisory and shot control software. Diagnostic Bridges translate DCP protocol messages from each DCS instrument into ICCS CORBA-distributed objects. The target diagnostic supervisor uses these bridges to provide status and control of each DCS instrument, and groups the set of instruments for the diagnostics they support. The target diagnostic supervisor also provides the primary operator interface at the Target Diagnostic console in the control room. The shot supervisor executes macro steps that are defined in a shot model for participating diagnostics on any given shot. Instrument configuration for a specific diagnostic and shot combination is established in configuration files by the responsible diagnostic engineer.

V. OUTLOOK AND SUMMARY

Development and testing of DCS controllers is focused on the instrument and is comprehensive in supporting all features of the instrument. Developers are allowed to specialize on instrument types—families of power supplies; model lines of cameras and oscilloscopes. This is leading to efficiencies in development and fielding controls for target diagnostics.

By standardizing DCS-supported instruments, the cost of bringing diagnostics on-line has been reduced. The modular DCS approach has enabled closer cooperation between diagnostic hardware engineers and the DCS software developers and testers. Similarly, the team has become more responsive as development time for new diagnostics has been reduced through reuse of standardized power supplies, cameras, and scopes/digitizers.

The chosen hardware and software architecture has met the requirements and goals derived from target diagnostics' needs as well as from ICCS interface requirements. 20 diagnostics composed of 144 DCS instruments including SXI, FFLEX, Dante, FABS, NBI, NTOF, and the Diagnostic Instrument Manipulator containing the X-ray Streaked Detector and Gated X-ray Detector diagnostics have been brought online and were utilized in 2009 experimental campaigns. Over the next year, 20 additional diagnostics will be brought online consisting of an additional 118 DCS controllers. These will be deployed to support ignition experiments beginning in 2011.

VI. DISCLAIMER

VII. *AUSPICES STATEMENT

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

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