TARGET DIAGNOSTIC INSTRUMENT-BASED CONTROLS FRAMEWORK FOR THE NATIONAL IGNITION FACILITY (NIF)*

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The extreme physics of targets shocked by NIF's 192-beam laser are observed by a diverse suite of diagnostics including optical backscatter, time-integrated and gated X-ray sensors, and laser velocity interferometry. Diagnostics to diagnose fusion ignition implosion and neutron emissions are being planned. Many diagnostics will be developed by collaborators at other sites, but ad hoc controls could lead to unreliable and costly operations. An instrument-based controls (I-BC) 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 I-BC 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. I-BCs are reusable by replication and reconfiguration for specific diagnostics in XML. Advantages include minimal application code, easy testing, and better reliability. Collaborators save costs by assembling diagnostics with existing I-BCs. This paper discusses target diagnostic instrumentation used on NIF and presents the I-BC architecture and framework.

NIF TARGET DIAGNOSTICS

The physics requirements derived from NIF 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 are needed. 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 planned for NIF and Figure 1 shows optical and X-ray diagnostics on the chamber.

Table 1: Target diagnostics planned for NIF experiments

Diagnostic System	
Optical	Full Aperture Backscatter
	Near Backscatter Imager
	VISAR Velocity Interferometer
X-Ray	Dante X-ray Power & Imager
	Hard X-ray Spectrometer
	X-ray Streaked Detector
	X-ray Gated Detectors
	Static X-ray Imager
	Hard X-ray Imager
Neutrons and Gammas	Neutron Time-of-Flight & Yield
	Neutron Imaging
	Gamma Bang Time
	Magnetic Recoil Spectroscopy
	Activation
	DT Yield

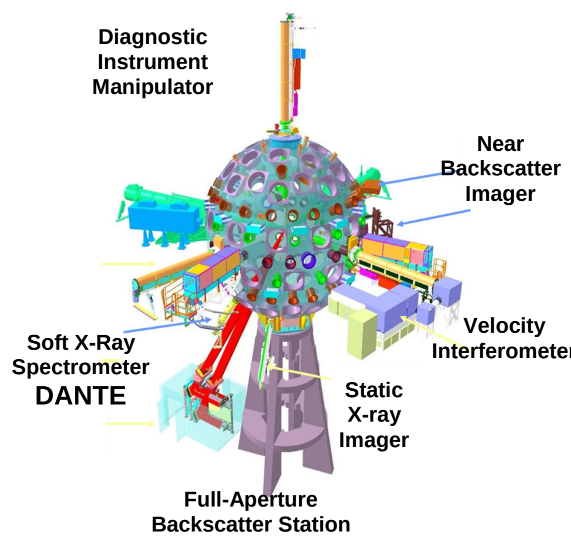

Figure 1: Optical and X-ray target diagnostics are deployed on the target chamber.

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

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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 logic controllers. A much larger Integrated Computer Control System (ICCS) incorporates over 750 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 [1] [2].

Controls for target diagnostics are managed as part of ICCC 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.

INSTRUMENT-BASED CONTROLS

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 Instrument-Based Controls (I-BC) 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 I-BC computer controller with generic I-BC software customized to that instrument. Figure 2 illustrates this architecture for the Dante soft X-ray spectrometer diagnostic. The Dante diagnostic uses one I-BC controller with software and interface hardware specific to the power supply and 18 more I-BCs with software and interface specific to the oscilloscope.

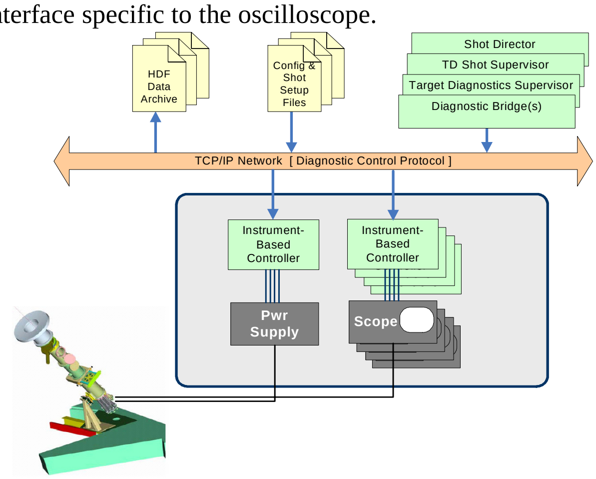

Figure 2: DANTE soft X-ray spectrometer control system.

The various I-BC 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. I-BCs are connected to the ICCS network through network switches in the diagnostic mezzanine. I-BCs are diskless and boot from a file server over the network. Experiment data collected from cameras and digitizers by each I-BC are sent to the file server for processing and archiving.

SOFTWARE FRAMEWORK

The I-BC framework is an objected-oriented and 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 I-BC Framework, which instantiates objects that perform functions such as:

- Reading xml configuration and setup files
- Data-set management
- Creating Hierarchical Data Format (HDF) data archive files
- Automatically generating remote graphical user interfaces on operator consoles
- Providing access to device drivers
- Implementing the Diagnostic Control Protocol (DCP) that loosely couples I-BCs to the ICCS control system

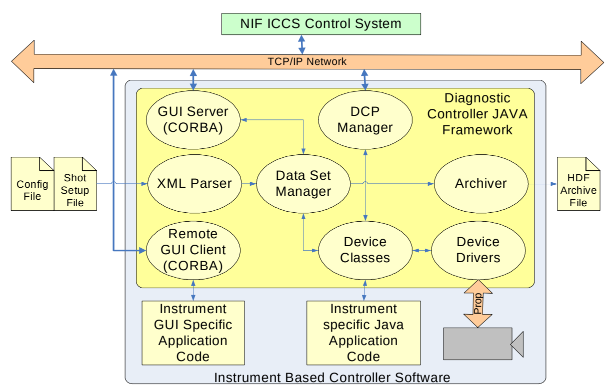

Figure 3: Framework for I-BC software ties instrument applications to ICCS supervisory controls.

XML Parser

The XML parser object reads and validates the I-BC 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.

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.

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 data is processed by the data analysis team.

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 executes 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.

Device Classes

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

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.

TARGET DIAGNOSTIC SUPERVISOR

The ICCS Target Diagnostic subsystem software is written in Ada to execute on Sun Solaris servers. It is composed of Diagnostic Bridge software and supervisory and shot control software. Diagnostic Bridges translate messages from each I-BC in DCP protocol into ICCS CORBA objects. The Target Diagnostic Supervisor uses these bridges to provide status and control of each I-BC, and groups the set of I-BCs 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 [3]. Instrument Configuration for a specific diagnostic and shot combination, is established in a configuration file by the diagnostic responsible engineer.

SUMMARY

Development and testing of I-BCs 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 I-BC supported instruments, the cost of bringing future diagnostics on-line will be reduced. The modular I-BC approach has enabled closer cooperation between diagnostic hardware engineers and the I-BC software developers and testers [4]. Similarly, the team is expected to be more responsive as development time for new diagnostics is reduced through reuse of standardized power supplies, cameras, and scopes/digitizers.

The chosen hardware and software architecture is expected to meet the requirements and goals derived from target diagnostics' needs as well as from ICCS interface requirements. Already, the Static X-ray Imager and the Diagnostic Instrument Manipulator containing the X-ray Streaked Detector diagnostics have been brought on-line and will be used in November experimental campaigns. Over the next two years, 151 instrument-based controllers will be deployed to support ignition experiments beginning in 2010.

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