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DATA MANAGEMENT FOR TRACKING OPTIC LIFETIMES AT THE NATIONAL IGNITION FACILITY

R. D. Clark*, L. M. Kegelmeyer
Lawrence Livermore National Laboratory, Livermore, USA

Abstract

The National Ignition Facility (NIF), the most energetic laser in the world, employs over 9000 optics to reshape, amplify, redirect, smooth, focus, and convert the wavelength of laser light as it travels along 192 beamlines. Underlying the management of these optics is an extensive Oracle database storing details of the entire life of each optic from the time it leaves the vendor to the time it is retired. This journey includes testing and verification, preparing, installing, monitoring, removing, and in some cases repairing and re-using the optics. This talk will address data structures and processes that enable storing information about each step like identifying where an optic is in its lifecycle and tracking damage through time. We will describe tools for reporting status and enabling key decisions like which damage sites should be blocked or repaired and which optics exchanged. Managing relational information and ensuring its integrity is key to managing the status and inventory of optics for NIF.

INTRODUCTION

The National Ignition Facility (NIF), the most energetic laser in the world, facilitates experiments that create temperatures and pressures that exist at the center of stars, giant planets and nuclear weapons. Roughly the size of three American football fields placed next to each other, NIF has two identical laser bays each containing two clusters of 48 beamlines. Laser light is propagated along these beamlines where mirrors, spatial filters and other devices amplify it from 1 billionth of a joule to 4 million joules and ensure the beams are correctly shaped. The beams are then grouped into 48 quads of 2x2 arrays and pass through the final optics assembly where they are converted from infrared to ultraviolet energy before entering the target chamber.

The laser energy travels nearly a kilometer before focusing on a 2mm fuel capsule (roughly the size of two grains of rice placed side by side). Along that path are thousands of serialized parts including over 6200 exchangeable frames (called LRUs) that house over 9000 optics that reshape, amplify, redirect, smooth, focus, and convert the wavelength of laser light as it travels along the 192 beamlines. The total surface area of the NIF optics is three-quarters of an acre - 40 times the surface area of the giant Keck telescope in Hawaii [1]. The optics are vital to NIF operations and are monitored and maintained throughout their lifetime.

DATABASE

Thousands of pieces of data are captured and stored on each of the NIF optics in an extensive Oracle Relational Database Management System (RDBMS) with Real Application Clusters (RAC). The RAC system allows multiple database instances to run in parallel accessing the same database storage [2]. The optics database has hundreds of tables, managing almost 300 GB of data, that details the entire life of each optic. Oracle Application Express (APEX) is used to provide a User Interface (UI) application for managers and operations personnel to access required data from across several different applications. The Production Optics Reporting and Tracking (PORT) tool consolidates this data, provides processing functionality, and generates customized reports to address the health and status of optics.

OPTIC PROCESSING

Optic States

An optic's journey includes being tested and verified, then prepared, installed, monitored, removed, and in some cases repaired and reused (Figure 1). Here we address data structures and processes that enable storing information about each step like where an optic is in its lifecycle, the calibration data that verifies the optic meets required specifications, and tracking damage through time. We will describe tools for reporting status and enabling key decisions like which damage sites should be blocked or repaired and which optics exchanged. Managing relational information and ensuring its integrity is key to managing the status and inventory of optics for NIF.

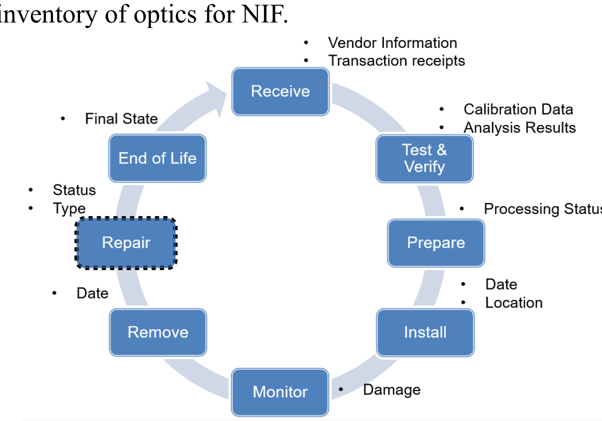

Figure 1: Optic Lifetime.

*clark94@llnl.gov

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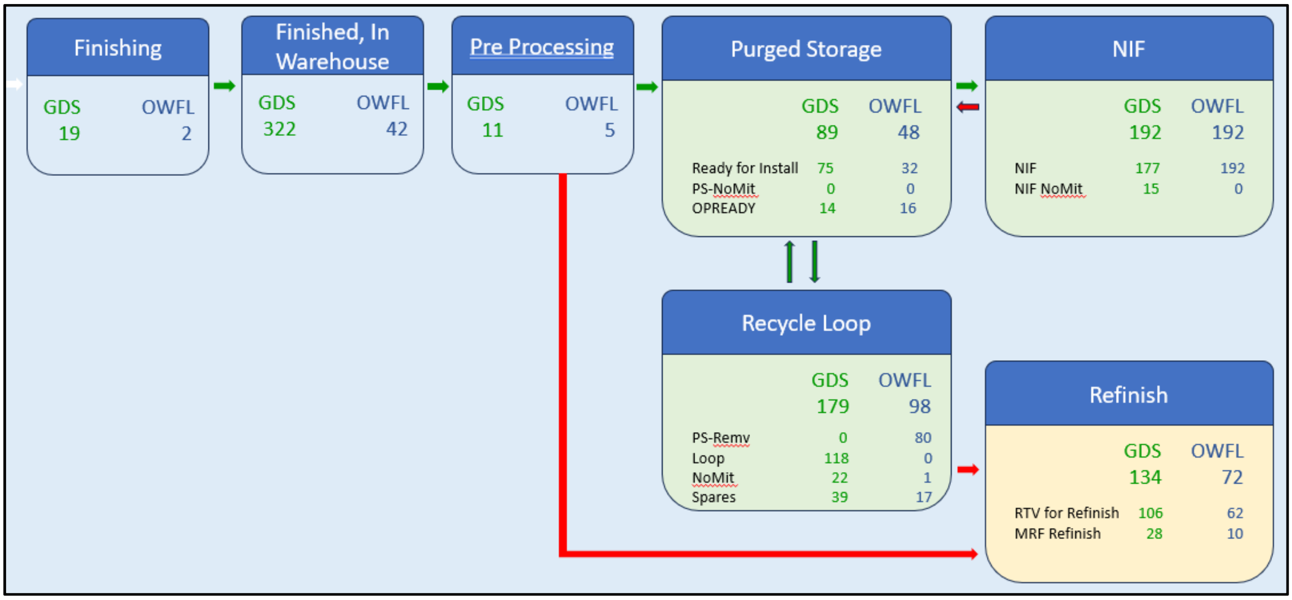

Figure 2: Optic Processing States.

The status of an optic describes where it is in its overall lifecycle. Different states specify whether the optic is at the vendor, actively being processed, sitting in inventory, assembled and ready to be installed, currently installed in NIF, or has been disposed of. The damage and blocker count feed into the exchange process and can be a gauge for process improvement. Optic processing begins when the optic arrives on-site and continues until the optic is retired. Tracking the optic state identifies the number of optics available for use at any given time. Figure 2 shows an example of potential optic states.

Work Orders

Optics transition from one state to another by way of a Work Order (WO). The WO identifies things like what type of work will take place, the facility where the work will take place, when the work is schedule to begin and when the work is completed. Figure 3 provides a simplified layout showing how a given optic can have multiple WOs which can contain one or more steps. Each step can require specific actions that need to be completed before advancing to the next step. Additional data (e.g., images, calibration data, etc.) can be associated to the WO providing a complete picture of what has transpired during the course of a specific activity.

A special type of WO is used when an optic is installed on NIF. Because NIF routinely operates at energies that can damage optics, a process was put in place that allows for optics to be repaired, thus extending their lifetime. This process is called the NIF Optics Recycle Loop [3]. It is a multi-step process that involves monitoring the damage sites while the optic is installed; scanning the optic with a microscope when it is removed from NIF and mitigating the damage sites before placing the optic back on NIF

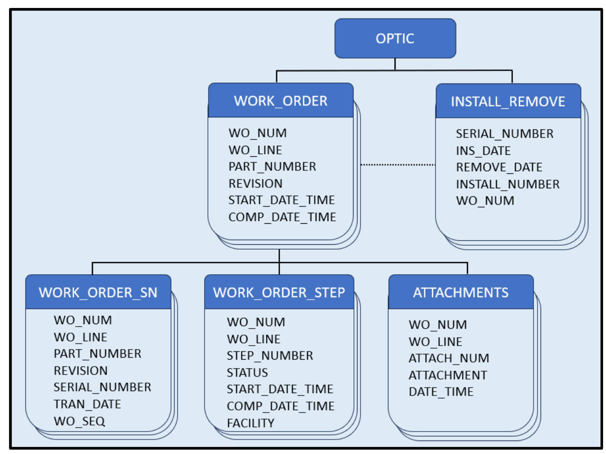

Figure 3: Work Order Tracking Architecture.

Recycle Loop

Due to the number of optics exchanged on a regular basis, database procedures were implemented to improve efficiency and ensure data integrity. A weekly exchange plan is uploaded into the database, via a csv spreadsheet, identifying the type of optic that is being exchanged and the NIF beamline the work is taking place in. Stored procedures then automatically create an exchange task that is used as input for the exchange process. The Production Control manager uses the UI to select the appropriate tasks and initiates the selection process (see Figure 4). Stored procedures identify the optic(s) that will be removed and the LRU/optic combination(s) that will replace them based on the location specified in the exchange plan, the currently installed optic for that location, and the available inventory.

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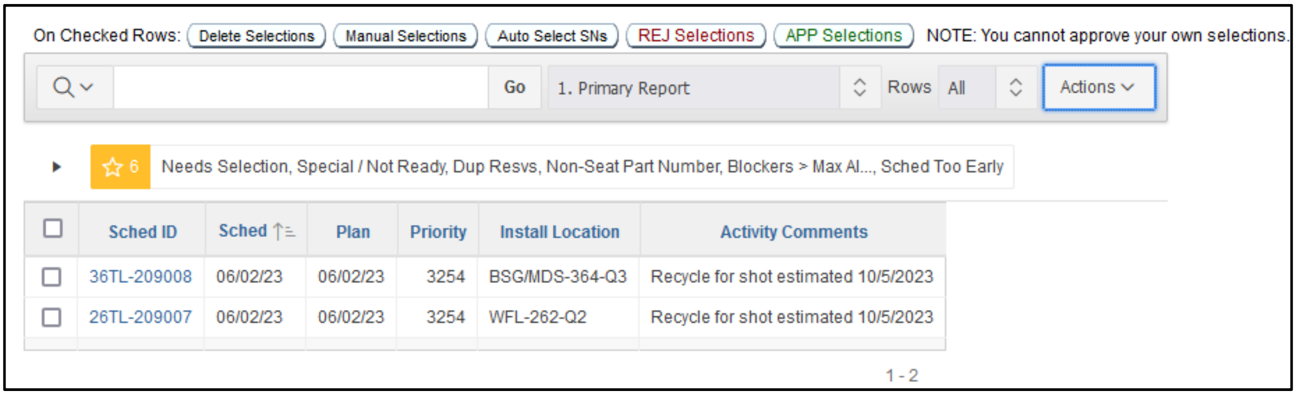

Figure 4: Optic Exchange Tasks Ready for Selection.

SN	LRU	Part Number	WO	Status	Location	Completed	Completed Date	Completed Time
97121		AAA96-111-02			WH_ITT	Trans to Vend	8-Nov-12	94632
97121		AAA96-111-02	VW11102	C			19-Jul-12	100032
97121	12112231	AAA06-222	DW10999	C			6-Jul-12	163130
97121	12112231	AAA06-222	AW108755	C	OMF	MITLSM	2-Jul-12	202600
97121		AAA96-111-02	PW108665	C	OPF	IMSLS	29-Jun-12	64800
97121		AAA96-111-02	PW108665	C	OPF	COAT	26-Jun-12	62900
97121		AAA96-111-02	PW108665	C	OPF	STRIP5	25-Jun-12	143200
97121	12221123	AAA06-313	IW107113	C	NIF	REMOVE	14-Jun-12	162900
97121	12221123	AAA06-313	IW107113	C	NIF	INSTALL	3-Apr-12	64909

Figure 5: Optic History.

Checks have been built into the procedures to evaluate each replacement candidate to ensure it meets beamline and optic-specific criteria, relieving the Production Control manager of the need to manually review and select each optic to ensure conformance. Once the optic(s) has been selected, the WO can be generated signifying the installation work can begin. Once installed, the optics periodically undergo inspection to determine the number and size of any damaged sites [4]. The results of the Optic Inspection (OI) analysis are stored by optic/beamline per inspection and grouped per site through time. This data is used to generate reports and metrics that allow the loop and production managers to keep tabs on the health of specific optics as well as the overall optic path.

As a damage site grows, it can be blocked on-line as needed. When the number of sites exceed the total damage threshold for a given optic, it is removed from NIF and is routed, via a WO, for a scan on an automated microscope that can detect damage sites down to 5-10 microns [5]. Data captured during the microscopy scan is funnelled into a database procedure that uses additional inspection results to generate a complete list of sites to be repaired along with a prediction of the percent scatter if that repair plan is executed.

If the plan meets requirements, the optic is then routed for mitigation. When the optic has been repaired, the mitigation results are used to trend not only the number of sites mitigated on specific optics, but also the number of sites and the number of each mitigation protocol used per optic group. This can show the effectiveness of a proof-of-concept demonstration and/or laser performance changes to the overall optic loop.

After the optic is mitigated, it is then placed back in inventory and awaits the next opportunity to be placed back on NIF. Figure 5 shows an optic history sample for SN 97121 beginning when it was installed on 3 Apr 2012, as it was processed, and then transferred to the vendor.

DATA INTEGRITY

Data integrity is a critical component of managing NIF's relational database. It ensures we can identify where an optic is at any given time, reconstruct what processing an optic underwent, perform trending analysis, predict optic performance, and maintain inventory rates. A number of checks and balances have been put in place to maintain data integrity and ensure a stable database environment. First, referential and check constraints are implemented at the table level to verify and validate data being inserted and/or updated in the database. Triggers are used to auto-populate fields and maintain accurate historical logs used for data forensics. In conjunction with that, validation is added to the UI providing feedback to the users regarding invalid data.

Second, a multi-level software deployment process has been put into place that allows development to be done in an environment completely separated from the test and

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production environments. A configuration management system keeps track of database-related changes. Script(s) generated for each change are applied and thoroughly tested in the test environment before being applied to production. Finally, scheduled jobs are run in the production environment on a regular basis to detect irregularities and notify the proper team(s) to investigate and rectify the situation, as needed.

CONCLUSION

The NIF optics database stores decades of detailed data to provide high-level insight on the overall status of optics, as well as detailed information on individual optics and adhoc reporting to address analysis concerns. Management relies on quality data and a stable environment to make key decisions on how best to maintain the optics to support the NIF shot cycle. As we continue in the age of ignition, managing the optics is becoming increasingly important.

ACKNOWLEDGMENT

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