STATUS OF THE NATIONAL IGNITION FACILITY (NIF) INTEGRATED COMPUTER CONTROL AND INFORMATION SYSTEMS

17th International Conference on Accelerator & Large Experimental Physics Control Systems (ICALEPCS)

October 5-11, 2019

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LLNL-PRES-791919

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

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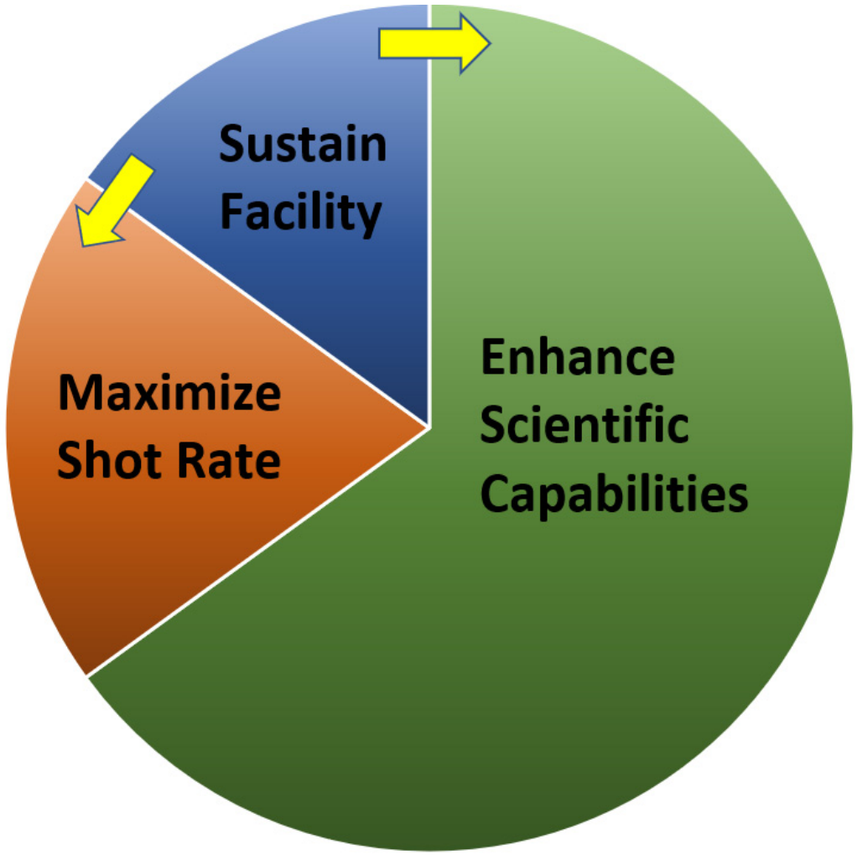
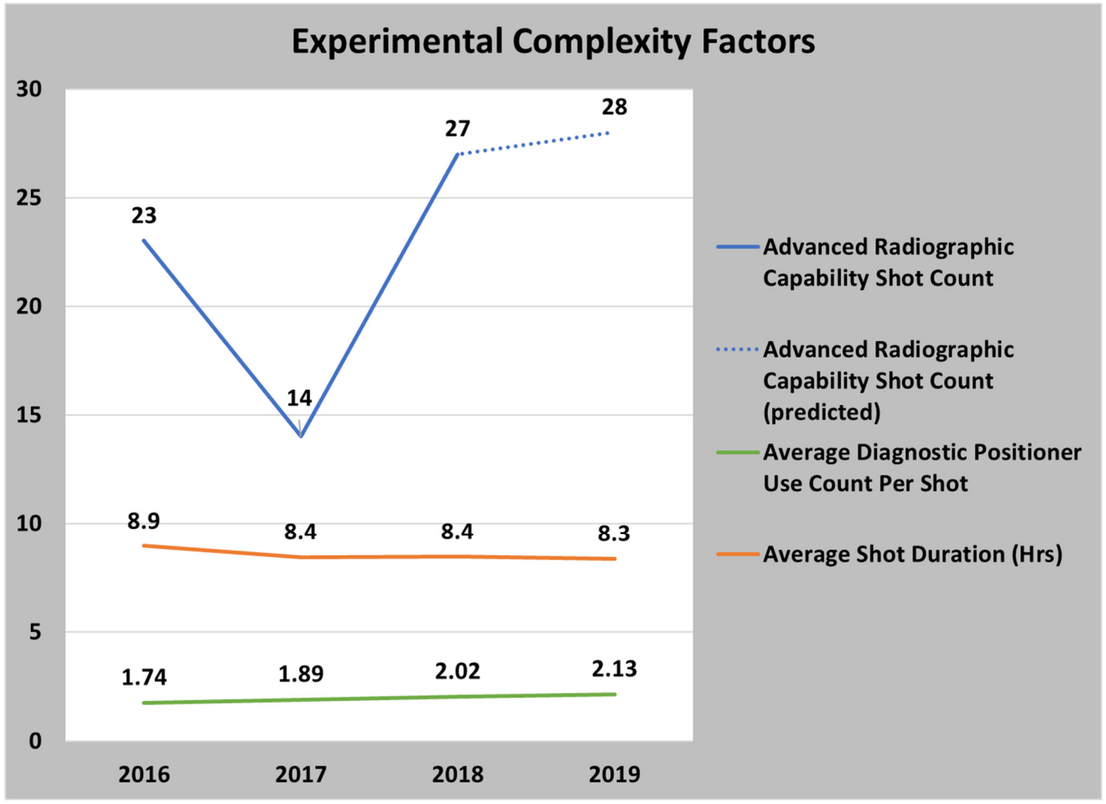
NIF celebrated its 10th year of full-scale operations this year with continued high shot rate and many new capabilities

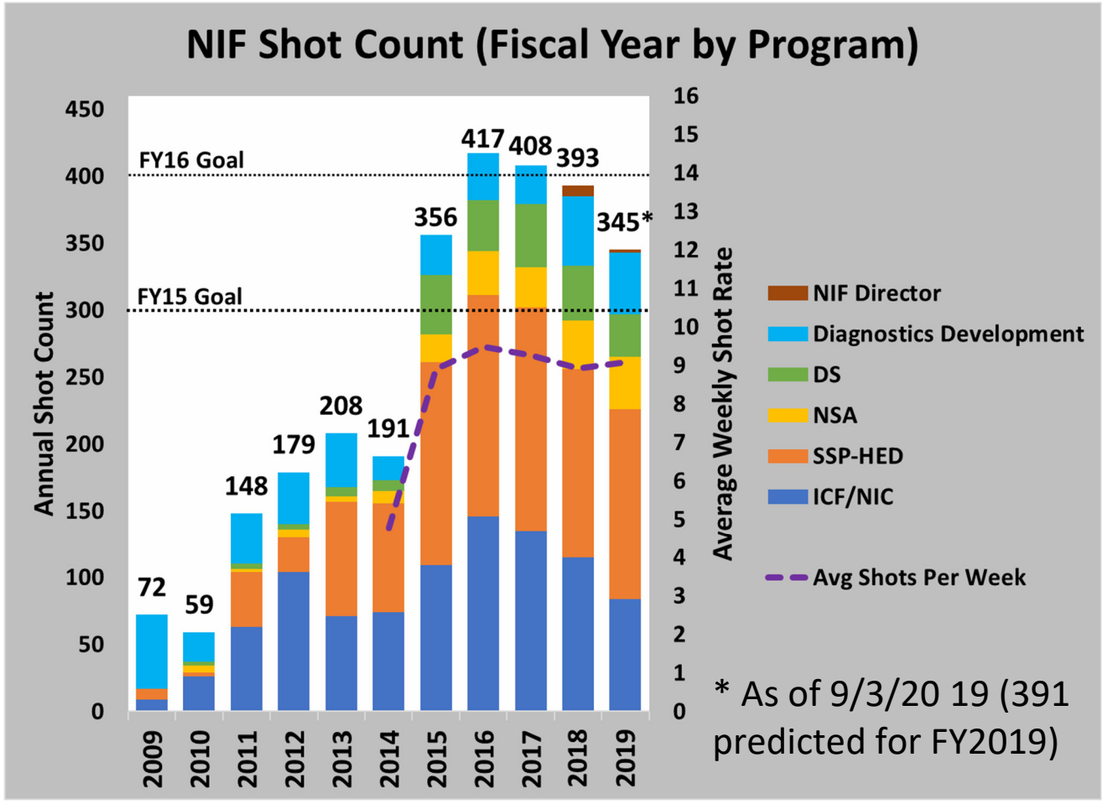
- **The NIF control system is very large scale and many components original to the initial system designs**
  - 66,000 device control points
  - 2300 front-end and embedded distributed processors
  - 50+ compute and supervisory servers
- **While primary priorities remain unchanged balance has shifted to minimize risks to continued operations**
  - Sustainability has always been both a facility and controls investment area however an increased emphasis is being placed on this area to avoid falling behind



Priorities continue to be sustaining a high availability for conducting experimentation, further advancing our scientific capabilities, and an increasing focus on modernizing the laser, controls and infrastructure

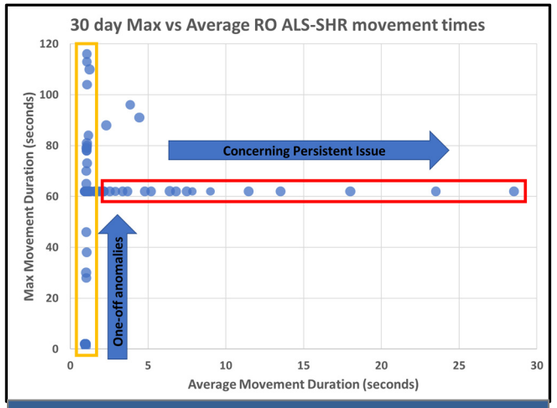
Continued control system efficiency enhancements have been key to maintaining a high annual shot rate on the NIF



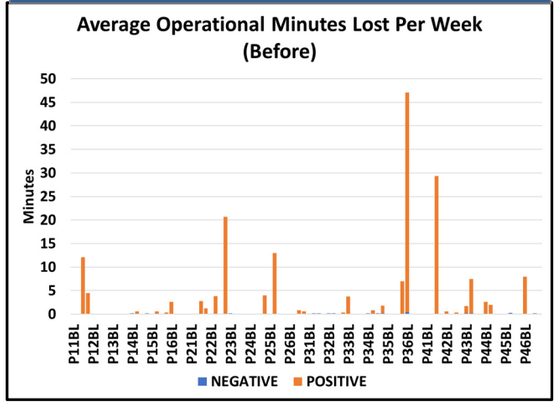


As more complex capabilities and experimental configurations are supported improvements in efficiency are critical to offset their increased operational costs

Metrics collection, analysis and visualizations have been exceptionally important to identify shot rate efficiency areas



Anomalous data pattern & cost



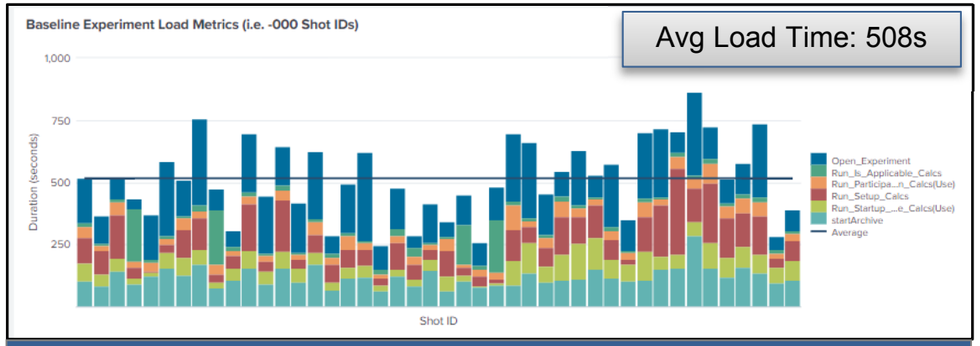
- **Little things matter, especially on repetitive actions!**

Example 1

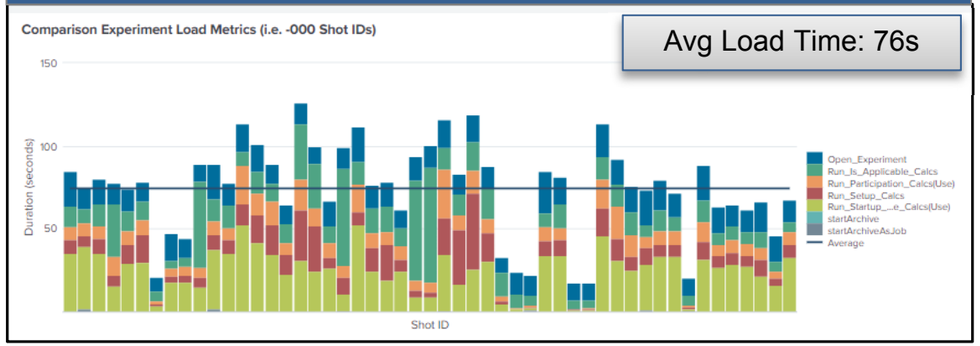
Anomalous binary shutter limit switches, coupled with automated software recovery cost > 45 minutes of lost operational time weekly

Example 2

Control system heavily leverages an Oracle database for experiment configurations and laser setup calculations. Using bind variables and improved indexes has reduced cost by 88% saving 19 minutes per shot



Before and after durations of database calculation

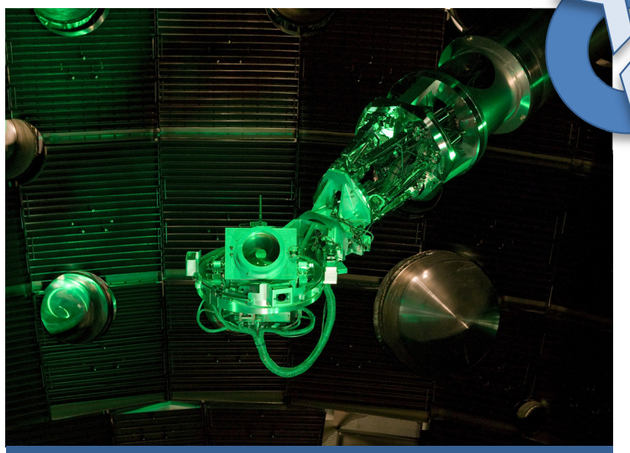


Our continued investment in data analysis continues to pay dividends and many of our analyses have laid the foundations for continued application in a predictive manner using machine learning

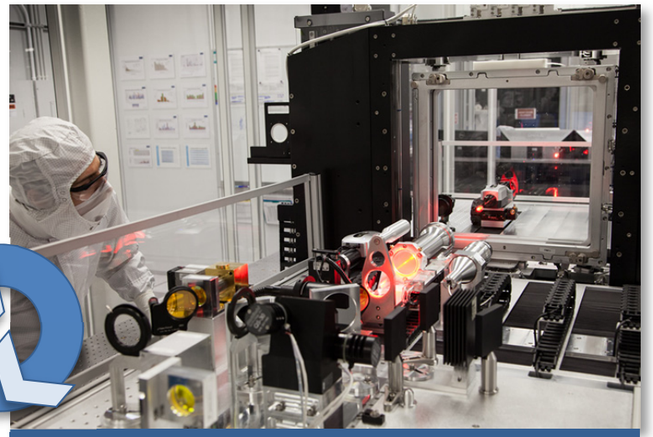
The NIF support & supply operations play an equally important role in maintaining a high shot rate

- Due to NIF's high power and energy levels a comprehensive optics management process is required to ensure continued availability of high performing optics
- As NIF shot rate has increased the controls, processes and techniques for these optics processing facilities also required significant optimization to handle the increased throughput of optics inspection and repair
- Many of these efficiencies have only possible through advancements in application of machine learning techniques

Optics Inspection Advances
In depth overview provided in THCPL02 - Evolution of Machine Learning for NIF Optics Inspection



Final Optics Inspection Camera (FODI)



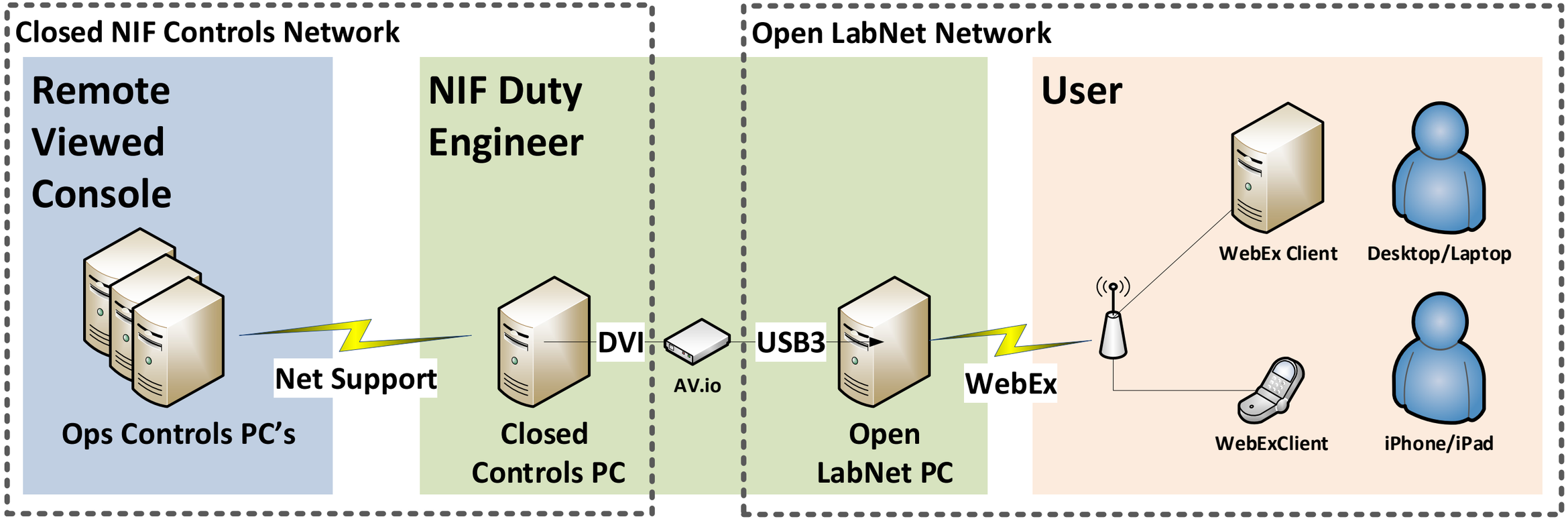
Optics Processing Station

Optics Repair Advances
In depth overview provided in MOPHA146 - Optimizing the Automated Control System for Repairing Optics at the National Ignition Facility

These control systems represent a small fraction of the vast array of auxiliary systems required to keep NIF efficiently operating at high performance

Secure remote read-only access to NIF provides experimenters and support staff greater efficiency and visibility

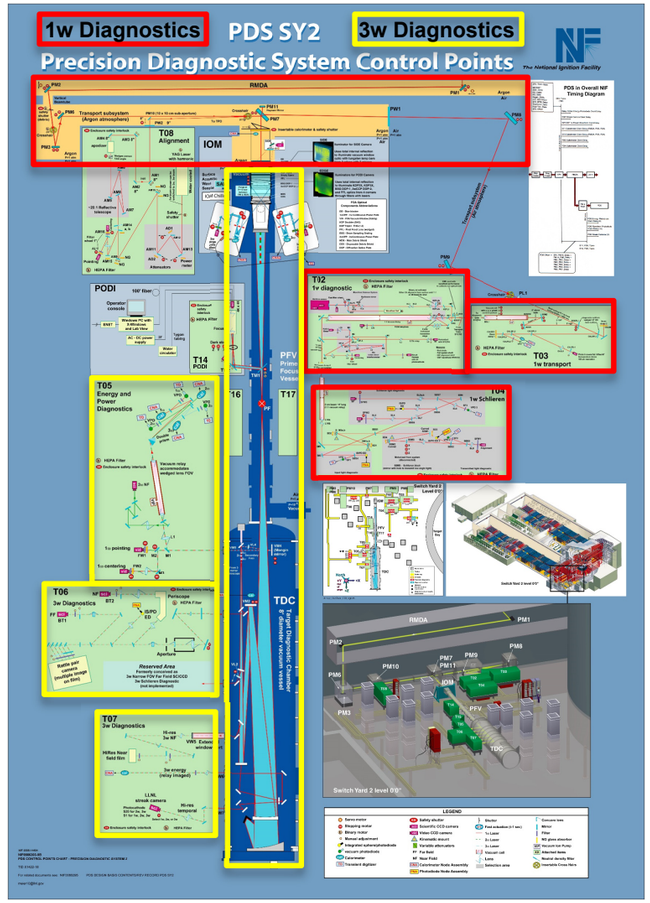
NIF Operations Remote Console Viewing Architecture Overview



Video only data link guarantees security of local operation while leveraging existing COTS products (NetSupport, AV.io, WebEx) kept deployment costs to a bare minimum

As facility enters its second decade of operation a renewed focus has been placed on increasing the NIF power & energy

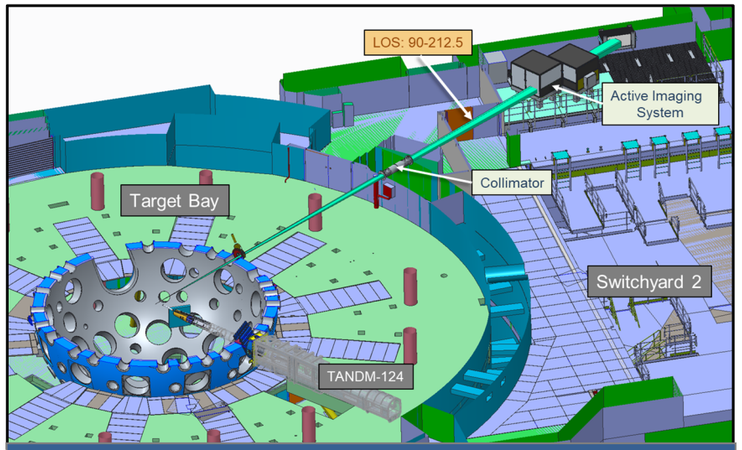
- **The original full beam laser diagnostic testbed, used for designing and qualifying the NIF final optics assembly, is in the midst of recommissioning and upgrade:**
  - **The Precision Diagnostic System (PDS) provides an extensive array of laser diagnostics to increase understanding of laser and optical effects that limit the power and energy delivered on the NIF.**
  - **Upgrades include extension to select 1 of 4 NIF beams for diagnosis (previously only 1 beam) in addition to upgraded higher resolution and time-resolved diagnostic equipment.**
  - **The beam selection and 1w diagnostic package upgrades were commissioned this year with the remainder of the 3w diagnostic package upgrades scheduled for completion early next calendar year.**
  - **Over 350 active control points are required for PDS in addition to automated alignment loops and shot cycle integration for operational efficiency.**



The goal of the PDS diagnostic packages is to assist in defining the laser design changes necessary to increase the energy and power beyond the current NIF baseline of 2.1MJ and 500TW

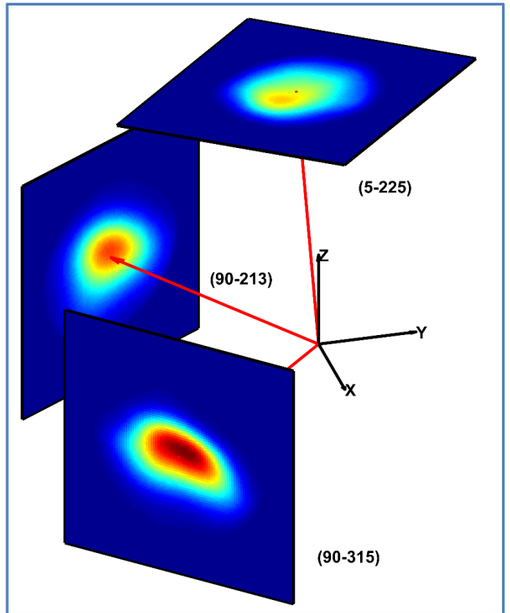
Continued diagnostic enhancements provide support for advancing Inertial Confinement Fusion (ICF) study

- A new 3rd axis (90-213) of our Neutron Imaging System (NIS) deployed this year has provides additional dimension of insight into the overall characterization and symmetry of the fuel assembly during shots.



2nd phase adds 26 meter line-of-sight active diagnostic suite

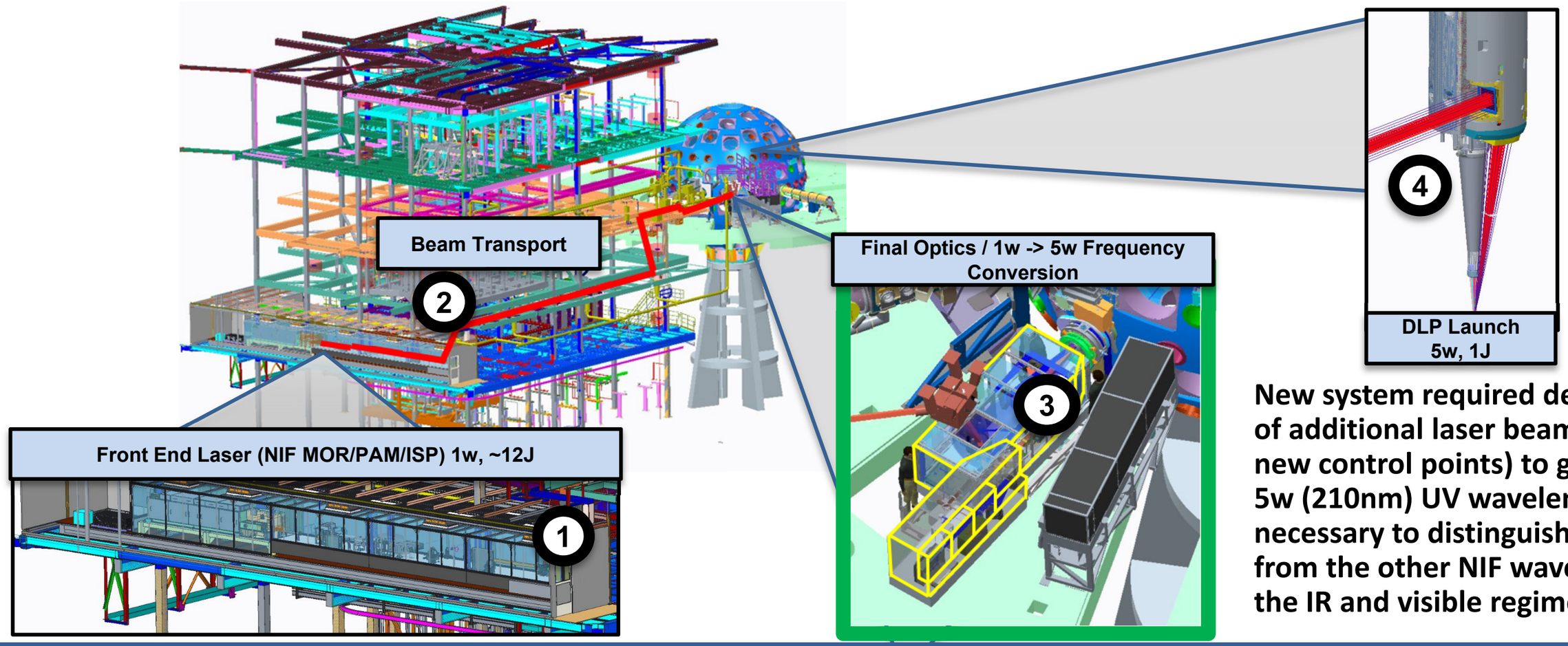
- A second phase, requiring significant facility infrastructure modifications, is planned next year to upgrade the image-plate system with an extensive suite of active controls.
- Enhancements will add primary and down-scattered neutron and gamma imaging diagnostic capabilities which will further increase ICF target understanding at bang time.



3rd axis of neutron imaging

ICF continues be a major focus of the NIF and these diagnostic enhancements provide significantly increased scientific understanding to guide the facility's path to fusion ignition

The new Optical Thomson Scattering (OTS) diagnostic will provide improved understanding of plasma effects within target at shot time

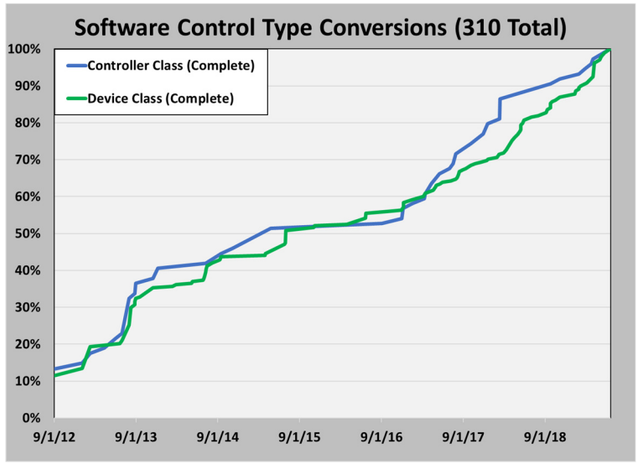


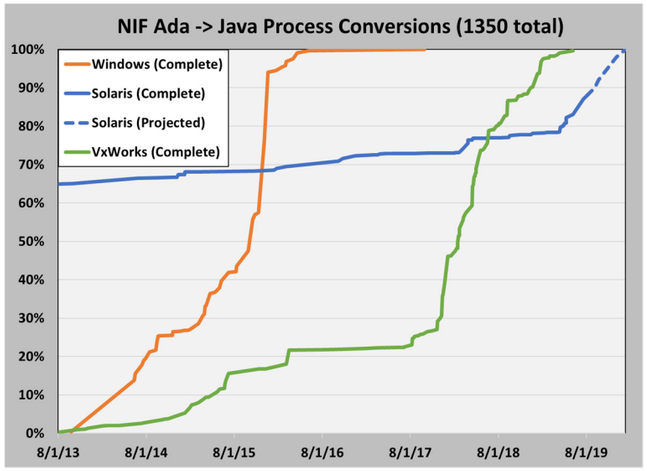
New system required deployment of additional laser beamline (300 new control points) to generate the 5w (210nm) UV wavelength necessary to distinguish the signal from the other NIF wavelengths in the IR and visible regimes

The new OTS laser and diagnostic have completed controls deployment are in their final stages of commissioning and expected to by scientifically operational by the end of the year

NIF controls successfully near completion of multi-year software and infrastructure upgrade

- Supporting NIF for 20 years has required investments for sustainable software, infrastructure and processes.
- All control software (3.5M SLOC) now converted from Ada to Java. Each conversion additionally produced automated unit & integration test suites to increase quality and improve future efficiency and maintainability.
- Remaining few Solaris process conversions to complete deployment and commissioning this year.
- CORBA middleware has been exceptionally effective in supporting phased facility delivery.





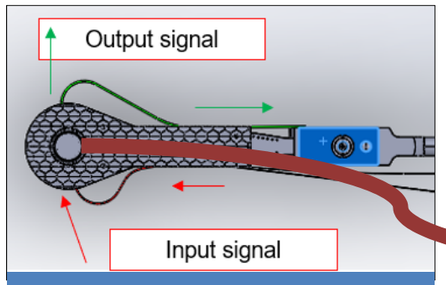
For further detail on challenges and lessons learned:

- **WEDPL01 (Fedorov):** Control System Upgrades
- **WEAPP02 (Casey):** Control System Infrastructure

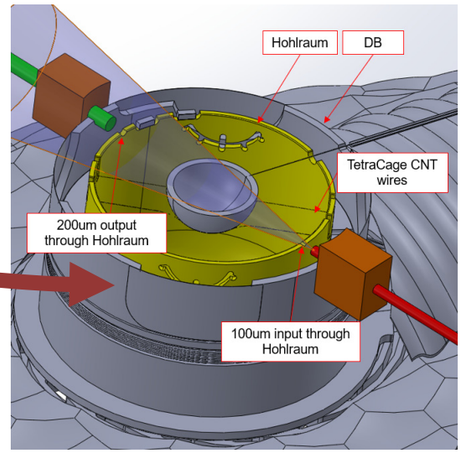
Completion of upgrade is expected to end of this calendar year. This migration lays the foundations for our continued control system evolution next focusing on elimination of majority of Windows OS Video processors

Looking forward, NIF controls are continuing to aid the pursuit of ignition in addition to ensuring a sustainable research platform

Reduction of engineering features on targets in support of ICF

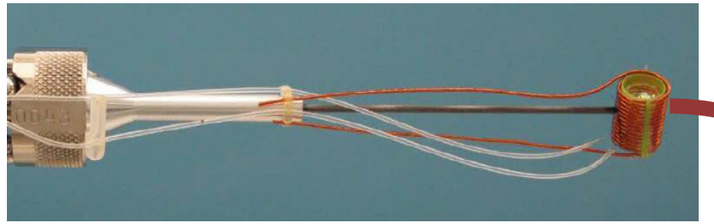


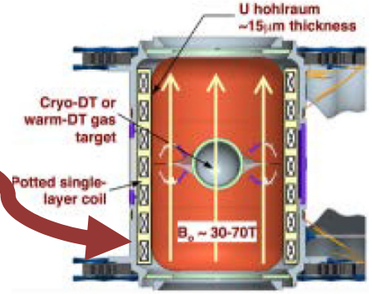
Example NIF Target



Example Tetra-Cage Target Design

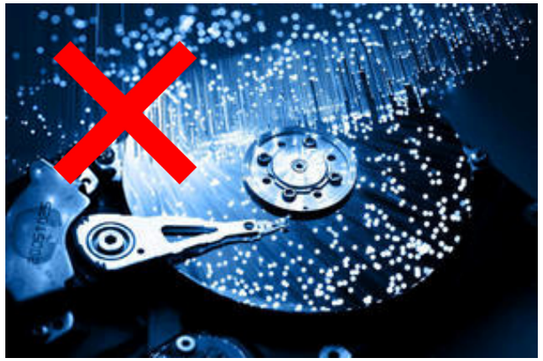
Alternative methods to boost yield on ICF targets





Extending Magnetized Targets to Hohlraums for improved confinement of fusion alpha particles

Improved controls sustainment and maintainability



- **Migration to diskless Linux for 600+ Video servers**
- **Reduced maintenance and improved configuration management over existing Windows XP systems**

FactoryTalk by ROCKWELL AUTOMATION

- **Upgrade of all PLC servers and UI's from RSView32 to FactoryTalk**
- **Phased delivery will provide improved support and expandibility**

Conclusion

- The NIF control system is critical for the effective and efficient continued advancement of various physical areas of study supported by the National Ignition Facility.
- Controls efficiency improvements continue to be required to sustain a constant NIF shot rate and offset the additional operational cost of new scientific operational capabilities.
- Many new laser and target diagnostic capabilities have been deployed and commissioned for operational use with an increased focus on supporting a power and energy increase on the NIF and advancing to the goal of fusion ignition.
- A successful major NIF control software modernization completes this year resulting in improved sustainability. Focus is now shifting to other aging controls such as embedded controllers and imaging infrastructure and operating systems.

Thank you for your consideration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