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

16th International Conference on Accelerator & Large Experimental Physics Control Systems (ICALEPCS)

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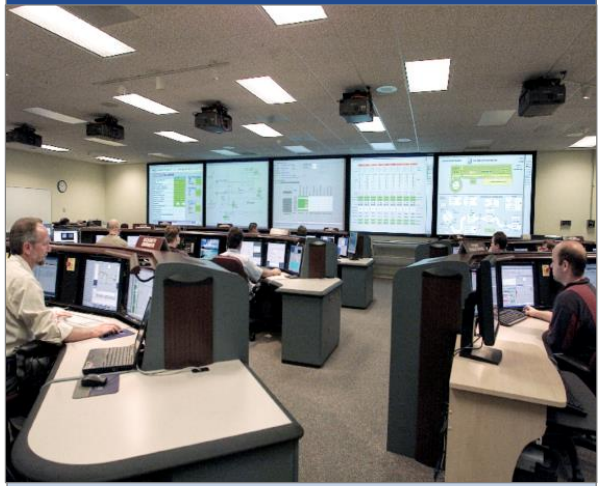
The NIF control system is the world's largest operational laser control system

- **Large scale**
  - 66,000 device control points
  - >1M I/O channels
- **Highly data-driven**
  - Device configuration
  - Experiment definitions, model & results
- **Highly distributed**
  - 35 Framework & Supervisory servers
  - 3 compute clusters (110 nodes)
  - 950 Front-End Processors
  - 900 embedded controllers
  - 2,400 processes
- **Highly automated**
  - 1.6M sequenced control point operations per shot cycle
  - 24x7 operation

NIF Control Room



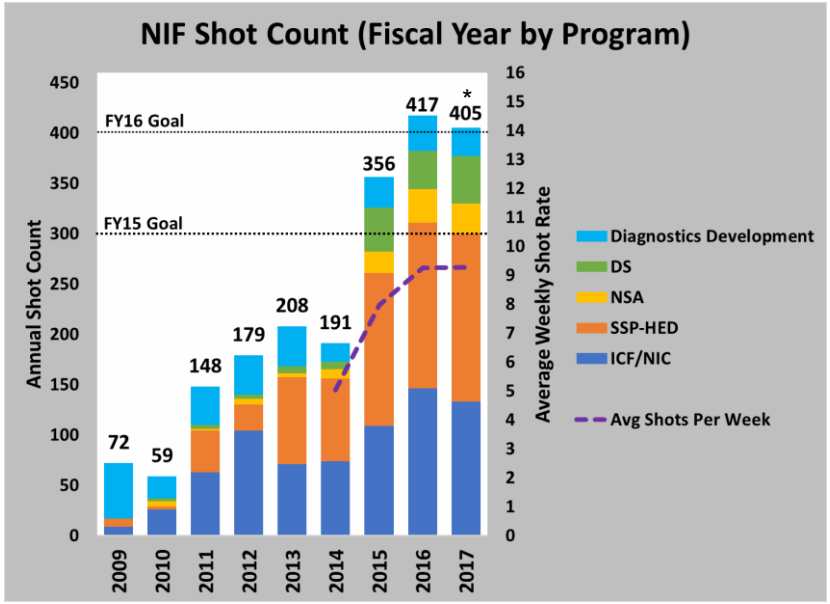
Automatic control of 192-beam shots is overseen by 14 operator stations

Major focus in recent years has been on increased shot rate, diagnostic capabilities and control system sustainability

NIF shot rate goals exceeded through focused efforts on improved operational planning and efficiency

- **Target Shot Rate Goals:**
  - FY15: 300 shots
  - FY16: 400 shots

- **Primary Focus Areas:**
  - More shot time
  - Improved experiment scheduling
  - Increased controls automation and optimization

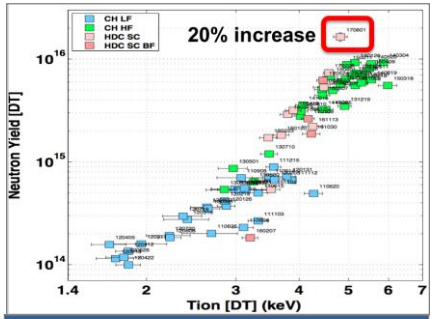


* As of 9/27/2017

More experiments has enabled a faster rate of learning, more exploration, and more users on the facility. Capability of 400 shots proven to be sustainable

Inertial Confinement Fusion (ICF) study accelerating resulting from increased experimental capacity

- Positive results from ICF experimentation accelerating need for increased use of cryogenic DT ‘layering’ target manipulator
- Increased use of single ‘layering’ positioner would impact current shot rate



NIF ICF neutron yield vs energy

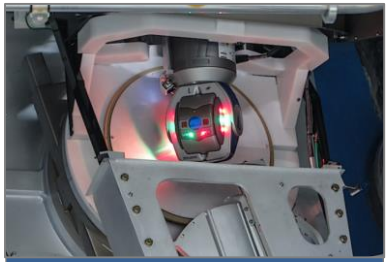

First TanDM positioner preparing for target shot

- 2 new NIF dual target/diagnostic positioners (TanDM) added
- Supports increased ICF experimentation with exclusive use of ‘layering’ positioner
- Shot rate preserved by alternating non-layered experiments between other positioners

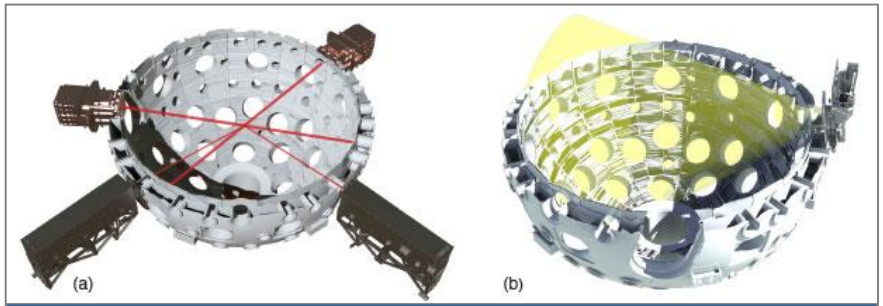
First TanDM already in operational use with second being commissioned and available early next fiscal year

New diagnostic alignment capability improves operational efficiency

- **Advanced Tracking Laser Alignment System (ATLAS)**
  - Measures 6D position/orientation of diagnostic payload using multiple reflectors mounted on snout *
  - Used in scripted semi-automated alignment process **
  - Replaces need for previous opposed port alignment system (OPAS) and human intensive image analysis



ATLAS mounted on NIF Target Chamber



(a) Previous OPAS, and (b) ATLAS alignment system fields of view

For further detail:

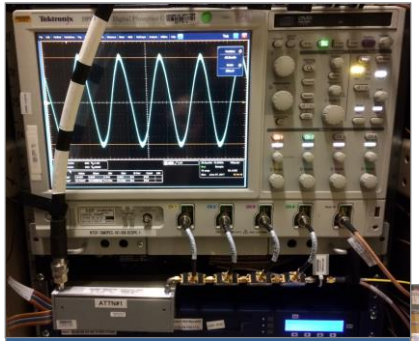
* **MOCPL02 (Wilson):**
Integrating Diverse Systems

** **TUMPA01 (Fedorov):**
User Interfaces and User eXperience

System is fully commissioned and in operational use with diagnostic alignment tolerance requirements (0.5mm) significantly exceeded

Diagnostic configuration and setup efficiency improvements reduce NIF shot to shot turnaround

- Remote control attenuators and filter wheels implemented on south pole Neutron Time of Flight (NToF) detector
- Upgrade fully automates diagnostic setup, eliminating manual diagnostic reconfiguration between shots
- Saves time during shot operations and eliminates human error



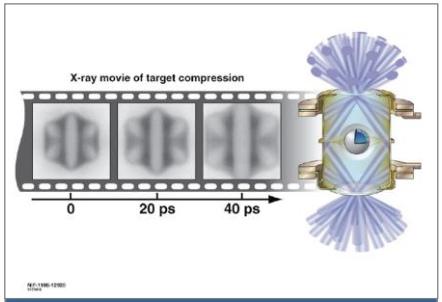
Remote Attenuators

Remote Filter Wheels

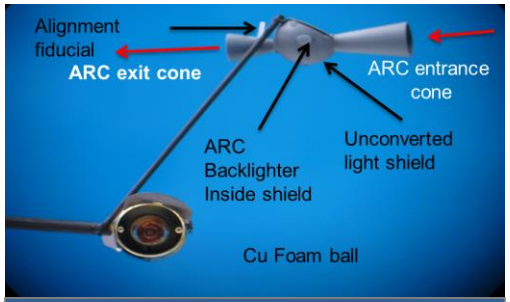
One of the many identified automation efficiencies implemented contributing to achieving the shot rate milestones

Advanced Radiographic Capability (ARC) update

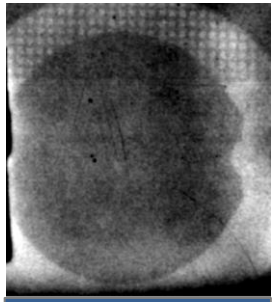
- Petawatt class 1ω short pulse laser (2-50ps) used for multi-frame high x-ray backlighting (1.5kJ * 4) of ultra-dense targets during the compression phase
- Very complex controls: 1.6k controls per ARC beamline, vs 1k per NIF
- Original ARC front end laser system replaced with high-contrast free-space laser system to meet stability and pre-pulse requirements
- ARC providing first radiographic data for complex hydrodynamic experimentation



Radiography concept



ARC target design

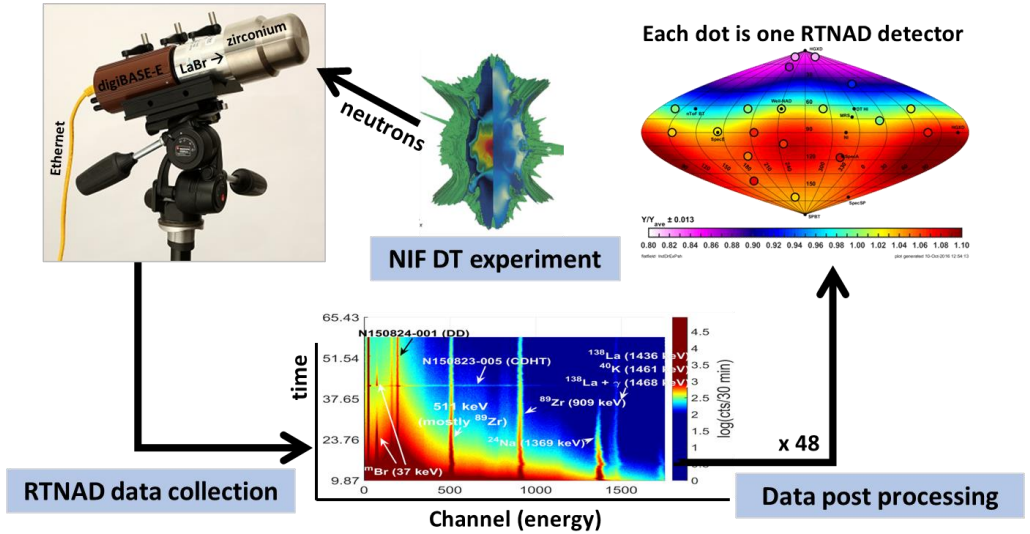


First ARC data

Significant improvements have been made to ARC system performance and expect to have capability fully commissioned by the end of next fiscal year

Real Time Neutron Activation Detectors (RTNAD) improves understanding of target implosion symmetry

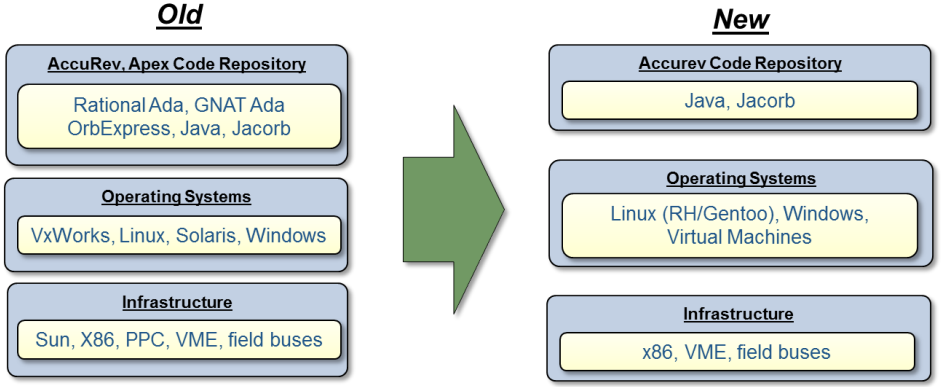
- 48 detectors distributed symmetrically around NIF target chamber
- Neutron emissions counted from activated Zr caps in each detector post shot
- Post processing of data set (~20GB) reconstructs symmetry of implosion



System in final stages of commissioning and diagnostic data will be great benefit to improved understanding and tuning ICF implosion symmetry

Multi-year NIF controls software and infrastructure upgrade nearing completion

- Supporting NIF for 20 years has required investment for sustainable software, infrastructure and processes
- ~80% control software (3.5M SLOC) ported from Ada to Java. Each ‘port’ produced unit/integration test suite to improve future maintainability
- ~70% control processes converted
- CORBA middleware has been very effective in supporting phased delivery



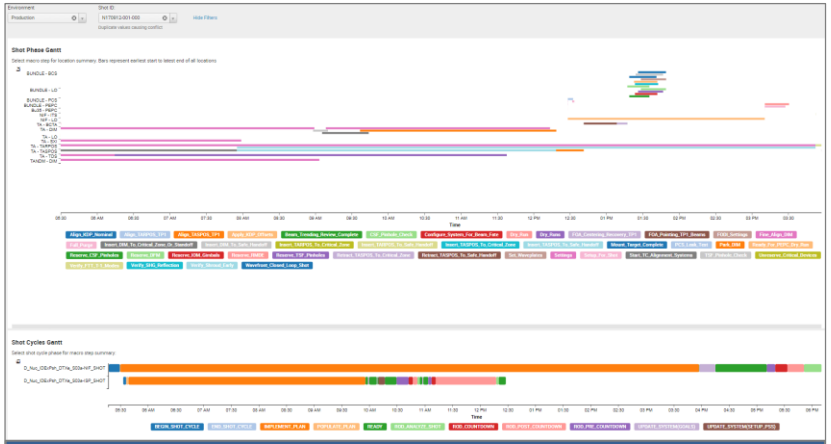
For further detail:

- **THCPL06 (Fishler):**
  Systems Eng., Project Mgmt

Completion of upgrade is expected to complete end of next calendar year

Increased data analytic techniques have improved controls monitoring and preventative maintenance

- Expanded use of Splunk® for rapid analysis, alerting and visualization of control system data
- Seamless aggregation of controls configuration data, shot archive data and process diagnostic logging, available in near real time
- Examples of use:
  - Multi-level Gantt of each NIF shot cycle used for identifying efficiency improvements
  - Predictive analysis of amplifier capacitance degradation as leading indicator of potential failure
  - Real time alerts on off-normal motor controller resets

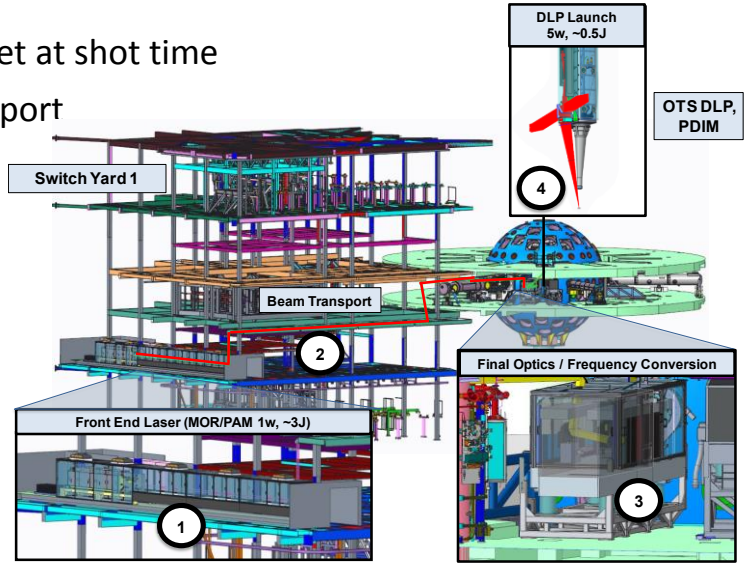


Gantt visualization of NIF shot cycle

Greater detail of current and future use cases will be presented in TUCPA02 (Fedorov) in Data Analytics track

NIF continues expansion of scientific capabilities in the upcoming year

- **New Optical Thomson Scattering (OTS) system presently under construction**
  - Provides 1J 5ω deep-UV probe beam and diagnostic to assist with greater understanding of hohlraum physics
  - Provides insight of plasma density effects around target at shot time
  - New NIF beamline and control system required to support OTS laser system
- **Focus on increased NIF power and energy**
  - Improved optic processing
  - Restoration of Precision Diagnostic System (PDS) to aid commissioning
- **Continued shot rate improvements**
  - Goal of reducing shot to shot by 30%



OTS System Overview

Conclusion

- The NIF control system is critical for the effective and efficient continued advancement of various physical areas of study supported by the facility
- Shot rate improvements were completed and goals exceeded while maintaining a flat funding level
  - Improvements proven to be sustainable for future years
- Many new laser and diagnostic capabilities, some large scale, have been deployed and commissioned for operational use further expanding the experimental value being provided by the facility
- Major control system and infrastructure modernizations are close to completion resulting in a sustainable position for continued evolution of capabilities and operation of the NIF facility for the next 20 years

Thank you for your consideration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