



Status of the National Ignition Facility's Control and Information Systems

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Control and information systems have helped create NIF as a world-class experimental enterprise

- **Built one the world's largest control systems that has provided**
 - **Safe, reliable and highly available 24x7 operation of NIF**
 - **Nearly hands-off automation using 14 operators**
 - **Conducted thousands of experiments of numerous types**
 - **Using a modular, flexible and data-driven architecture that is very maintainable and expandable**
- **Provided the infrastructure and tools for safely building and operating NIF, and efficiently performing experiments by developing and integrating**
 - **An expansive set of Enterprise tools and Planning systems, and**
 - **Flexible, agile and data-driven analysis and visualization tools**
- **All running on a highly reliable and secure infrastructure of servers and databases interconnected by networks**

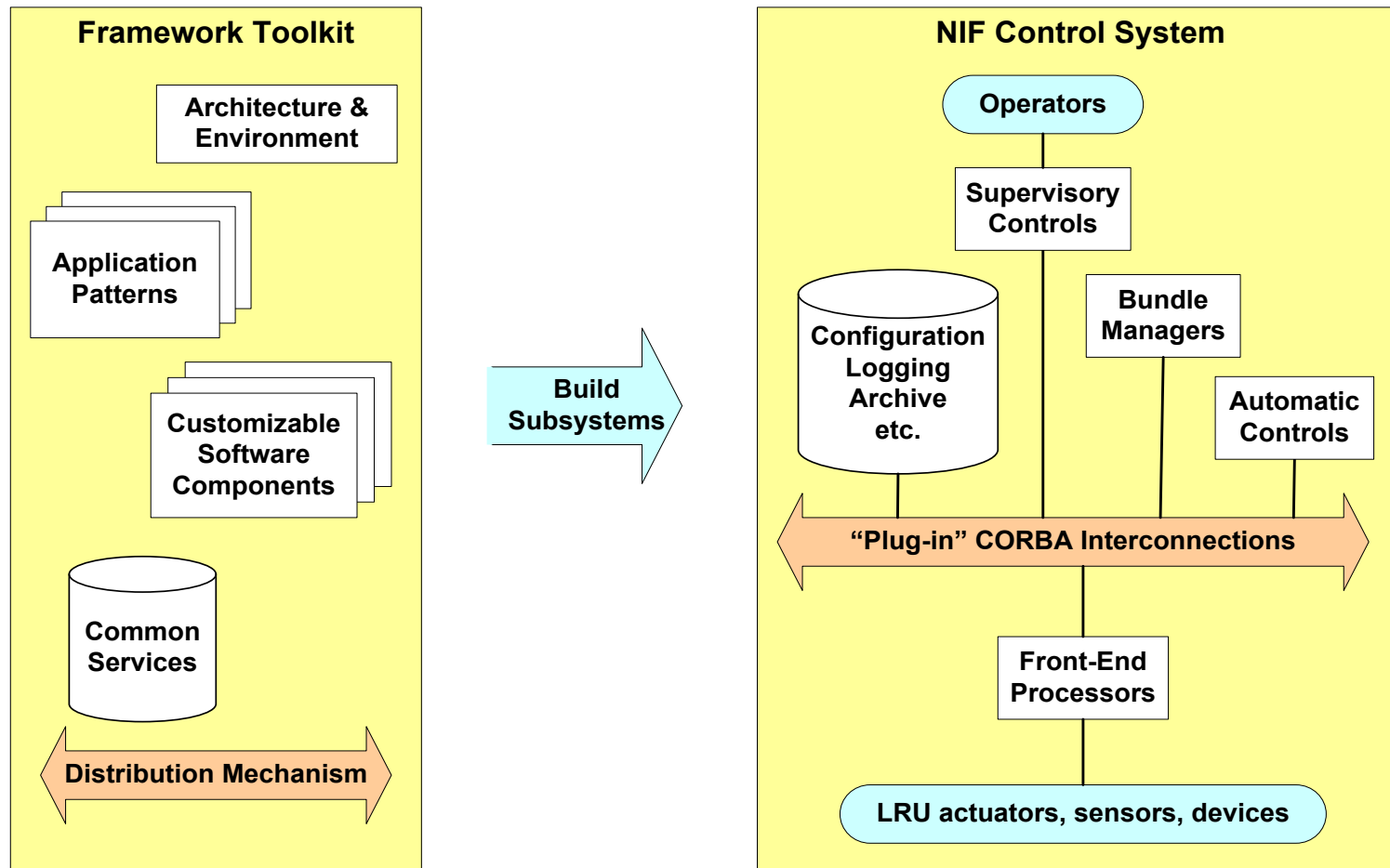
Integrated Computer Control System (ICCS) provides safe, reliable and highly automated 24x7 operation of NIF

- **Control 66,000 points using**
 - 2,400 processes
 - 1,800 computers
- **Align and fire 192 lasers**
 - <50 microns on target
 - <30 psec timing
- **Automatic shot controls**
 - 4–8 hours shot-to-shot
 - 24x7 Hands-off operation using 14 operators
 - Conducted over 2,500 system shots to date
- **Assure**
 - Substantial machine safety

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

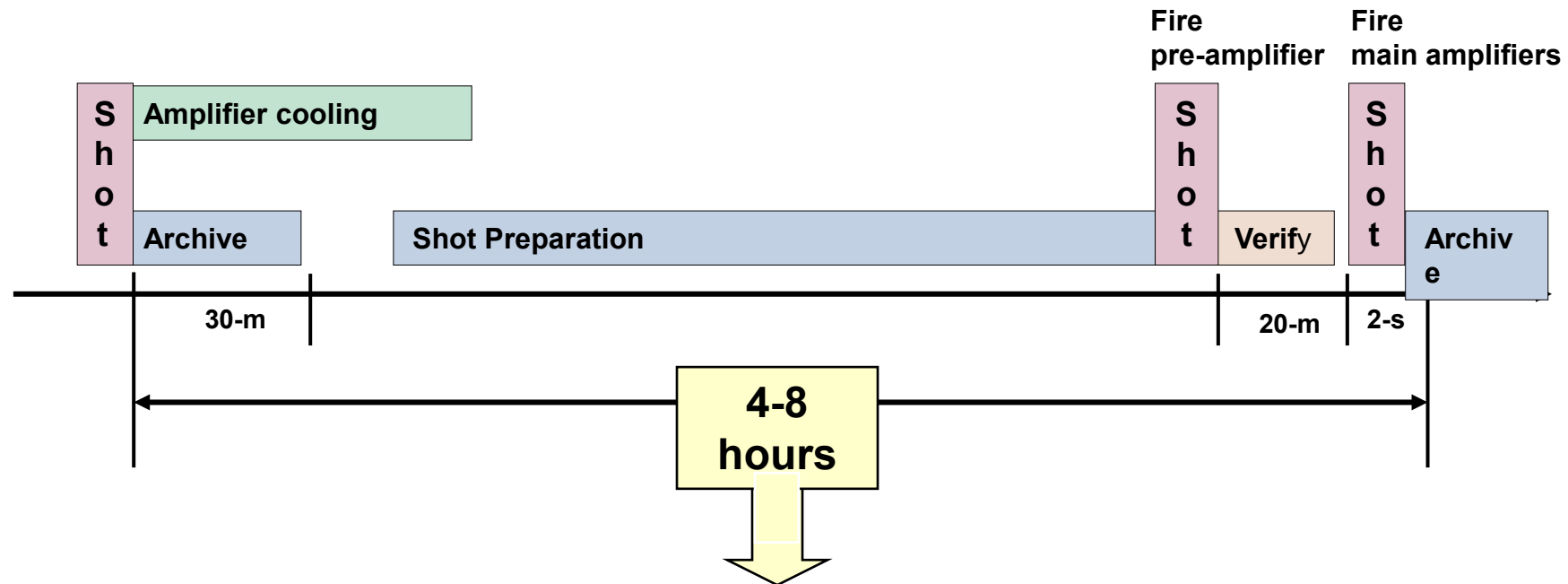


The ICCS software framework is an object-oriented toolkit for large-scale control systems



The framework's open architecture has facilitated key technology expansions and upgrades

ICCS primary requirement is to automatically align, fire and diagnose laser shots every 4-8 hours



Automated Shot Cycle

- Acquire campaign shot goals from laser physics model
- Perform automatic alignment and wavefront correction
- Configure diagnostics and laser performance settings
- Conduct countdown (software:4-min and timing:2-sec)
- Assess shot outcome and archive shot data

Model-based automated shot control has been in routine use for several years for laser commissioning and target shots

To ensure personnel and machine safety, Industrial control systems and Safety Systems use industry standard PLCs to monitor and control safety interlocks and utilities

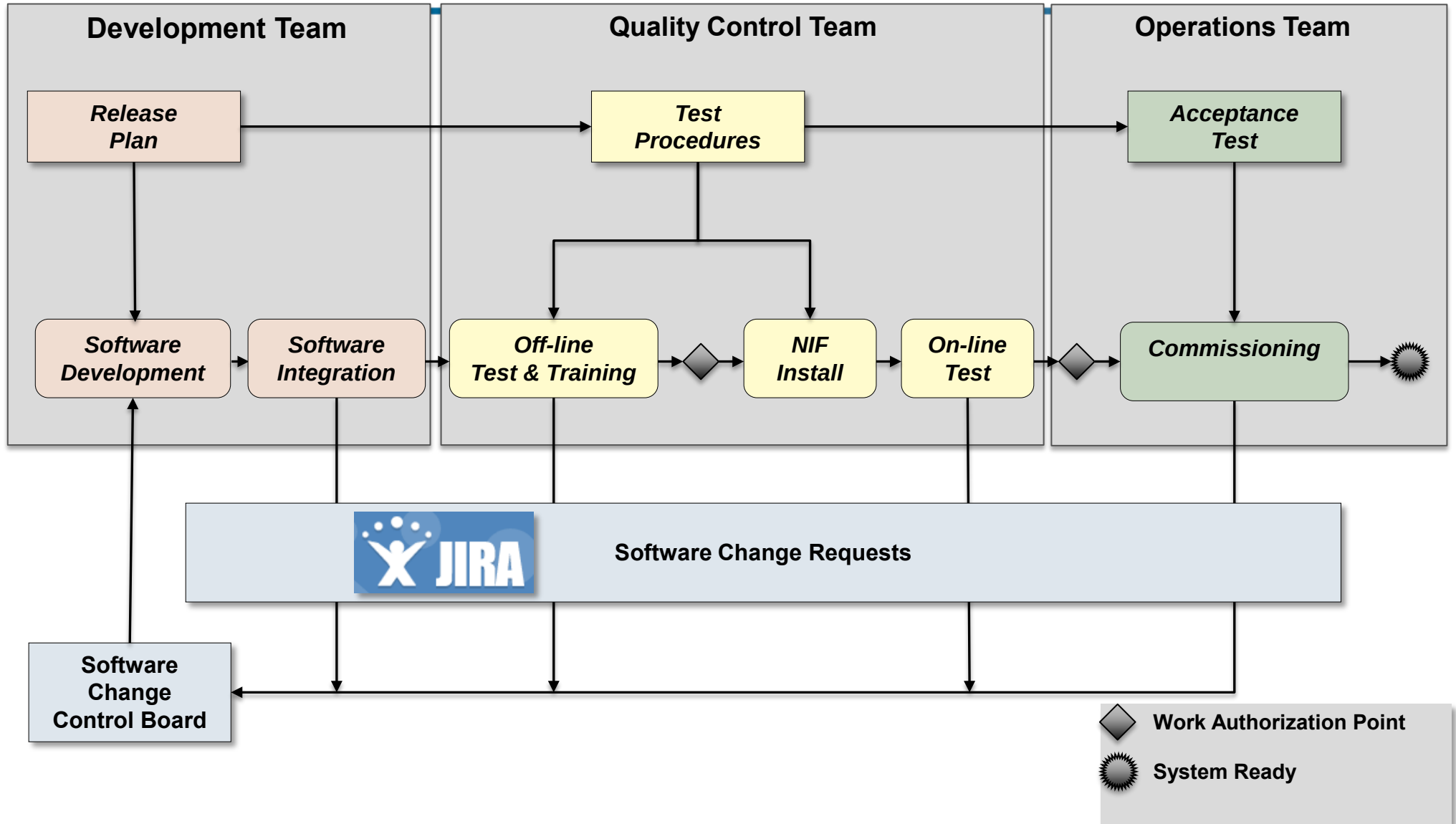
- **Programmable Logic Controllers (PLC) control**
 - 1000 i/o modules
 - 16K device points
- **Provide safety interlocks for**
 - Personnel and equipment protection
- **Control and monitor utilities**
 - Vacuum
 - Water
 - Argon
- **Tritium processing and shield doors**

Tritium Processing System



- **Robert Reed, “Personnel and Machine Protection Systems in The National Ignition Facility”, TUCOCA08**

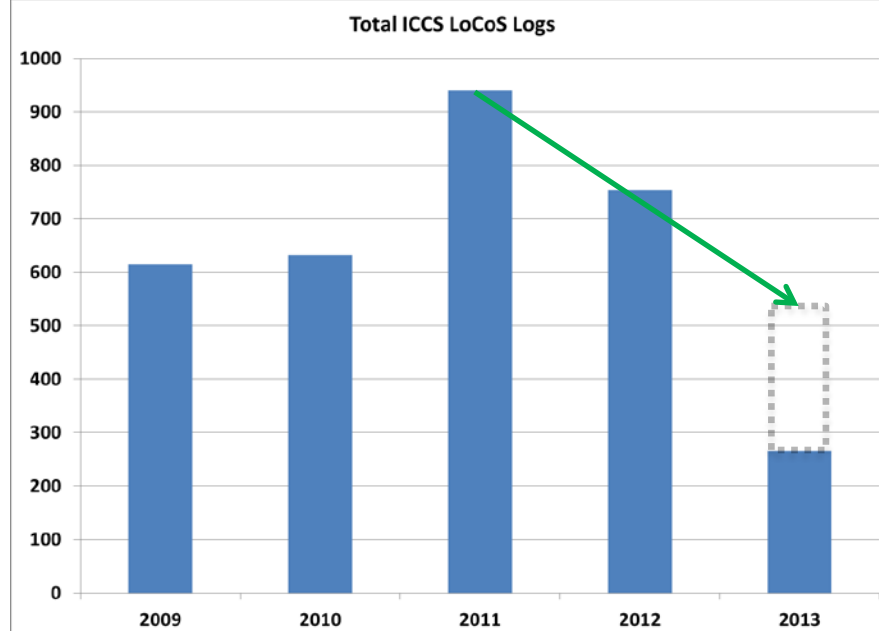
Rigorous quality controls at every development phase assure delivery of reliable software



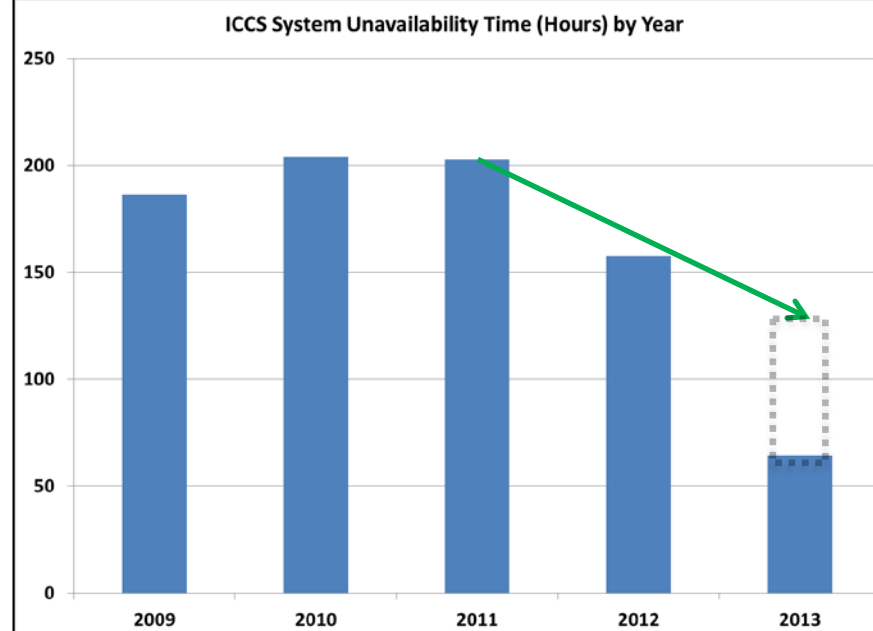
- John Fisher, "Utilizing JIRA for Large-Scale Software Development Management", TUCOBAB03

This aggressive quality program has made great strides in improving overall reliability and availability

Problem logs decreasing



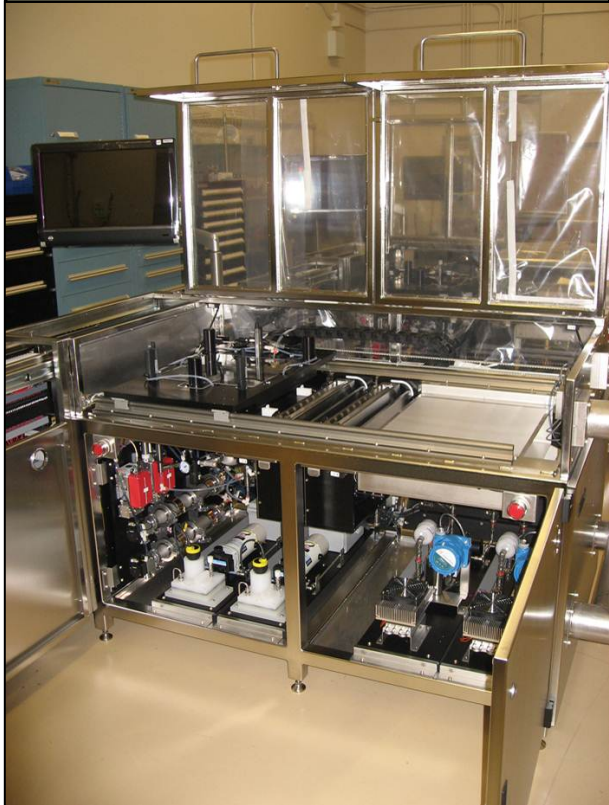
System availability increasing



- Russell Fleming, “Improving Control System Uptime and Reliability by Detecting and Reporting Failed Devices Quickly”, TUPPC129
- Eric Wilson, “Machine history visualization / predictive monitoring”, TUPPC128
- Mike Fedorov, “Application of Deep Packet Inspection and Data Viz tools”, THPPC086

A LabView-based software framework has been developed to support NIF's auxiliary production facilities

PhotoResist Meniscus Coater



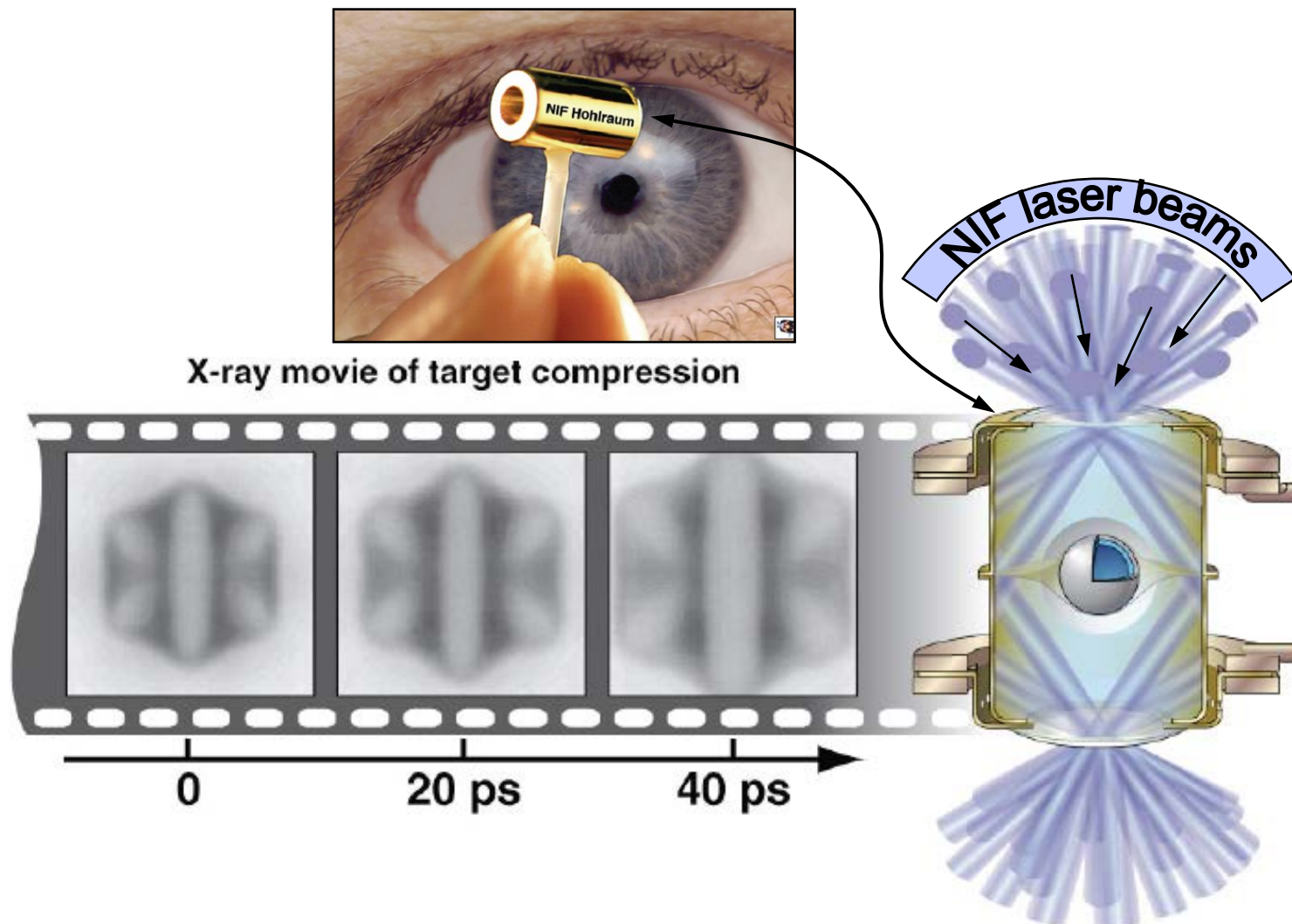
Capsule Fill Tube Assembly Mapping Station



- Deployed thus far to eight facilities
- 65% based on re-useable abstractions and components
- Recent systems cost significantly less effort

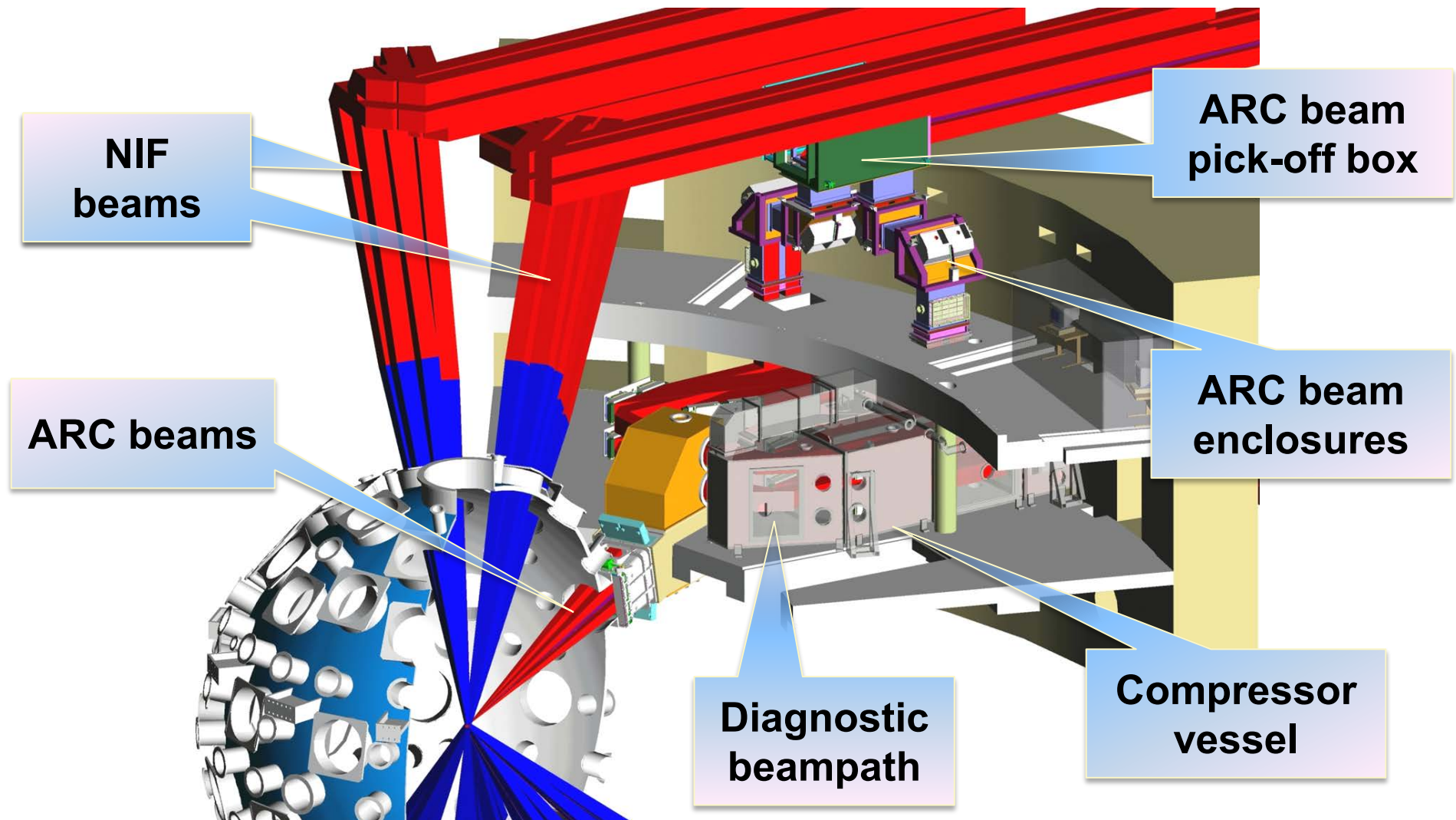
- Michael Flegel, "Designing and Implementing LabVIEW Solutions for Re-Use", TUCOCB06

The Advanced Radiographic Capability (ARC) is one of the primary focus areas for Controls in FY13 and FY14



ARC will provide a dynamic x-ray radiography of ICF implosions, a core requirement of NIF

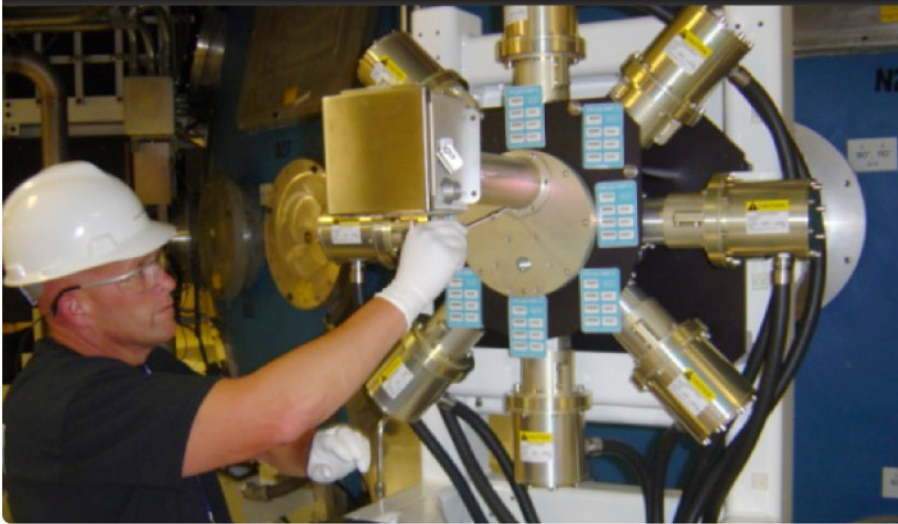
ARC will utilize up to a quad of NIF beams in the target bay for short-pulse use on target



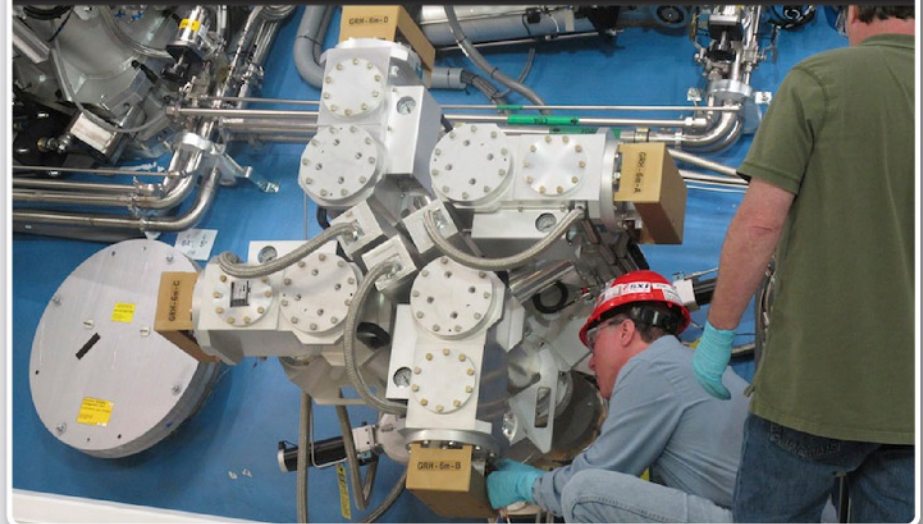
- Gordon Brunton, "The Advanced Radiographic Capability, a Major Upgrade of the Computer Controls for the NIF", MOCOBAB04
- Randy Roberts, "Image Analysis for Alignment of the ARC Diagnostic Path", THPPC085

A diverse suite of 50 Diagnostics have been deployed to the NIF to measure experimental target phenomena

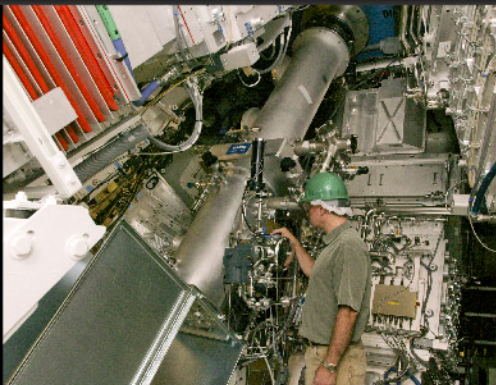
Hot Electron diagnostic



Gamma Reaction History diagnostic

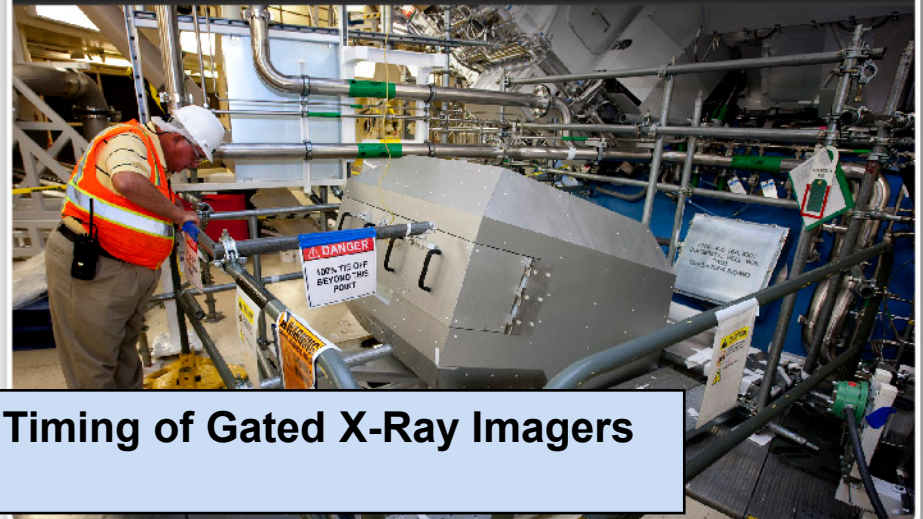


Dante 1

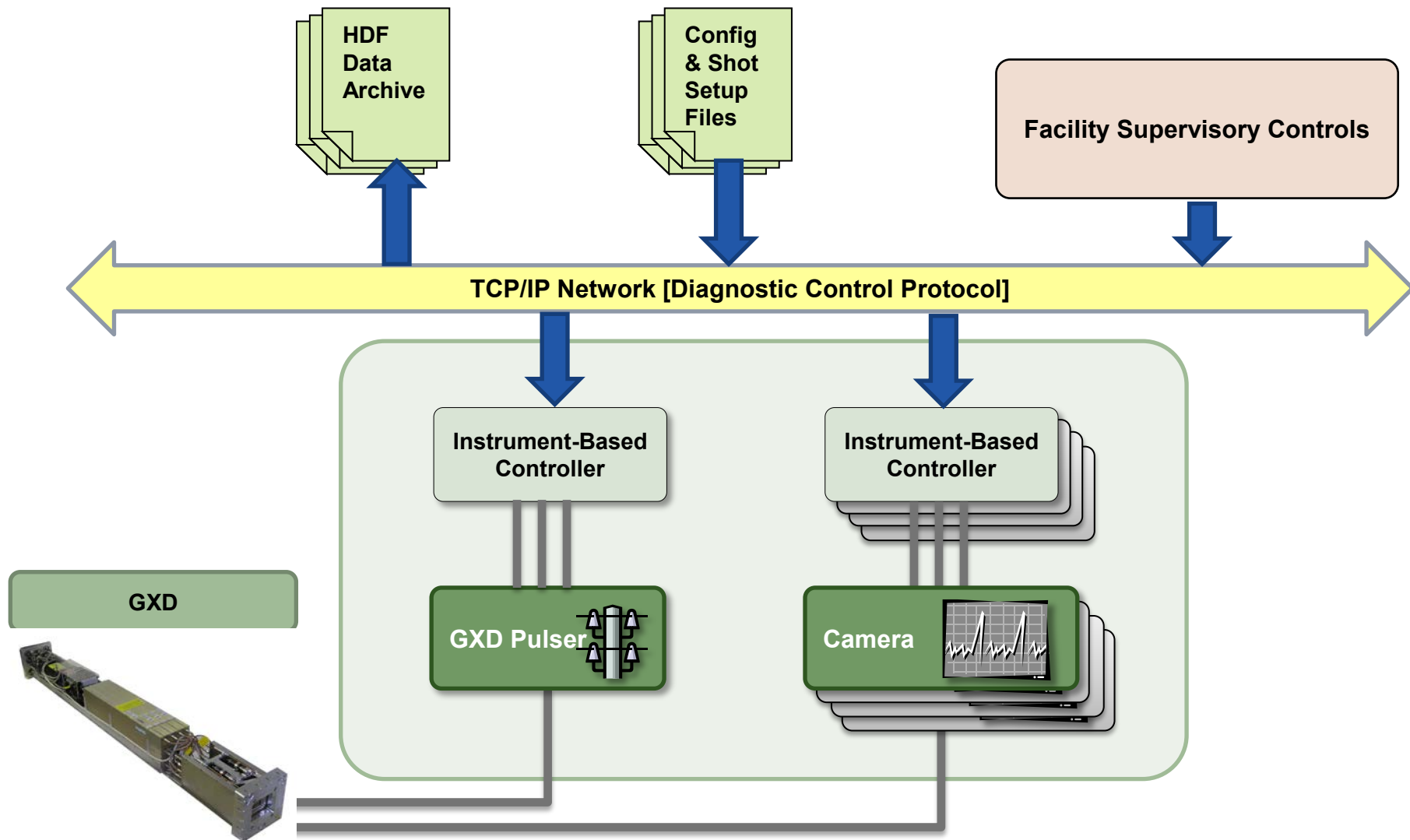


- Steven Glenn, “High-Precision Timing of Gated X-Ray Imagers at the NIF”, THCOCA03

Magnetic Recoil Spectrometer

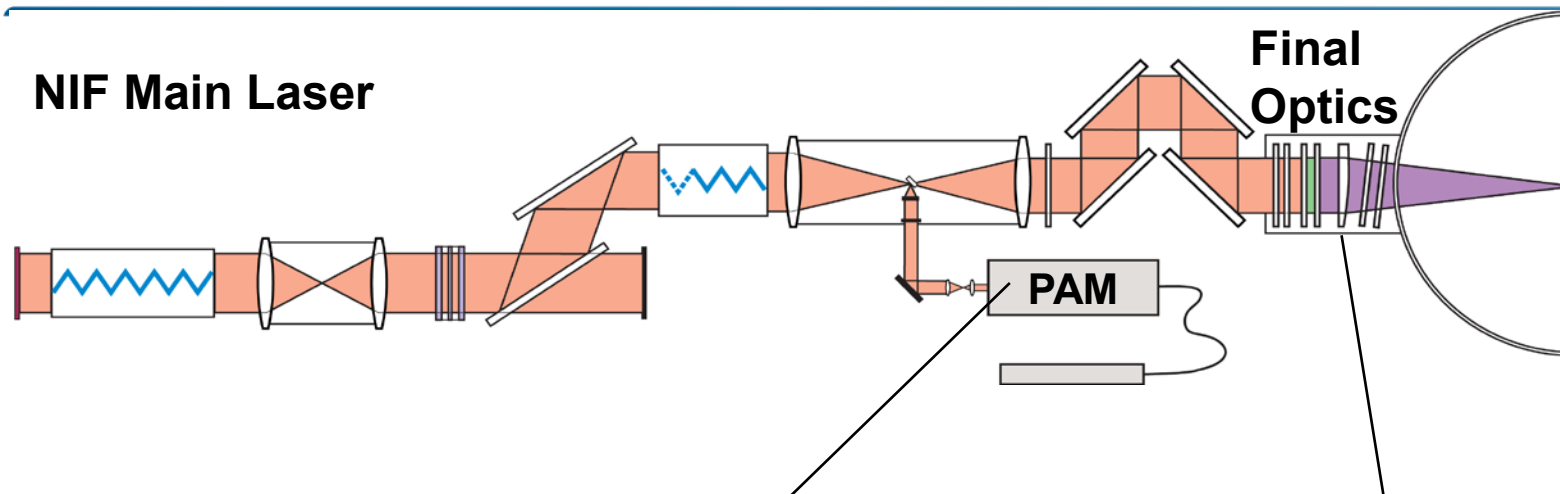


Instrument-based Diagnostic Controller software and hardware provides flexibility needed to accommodate diverse diagnostics



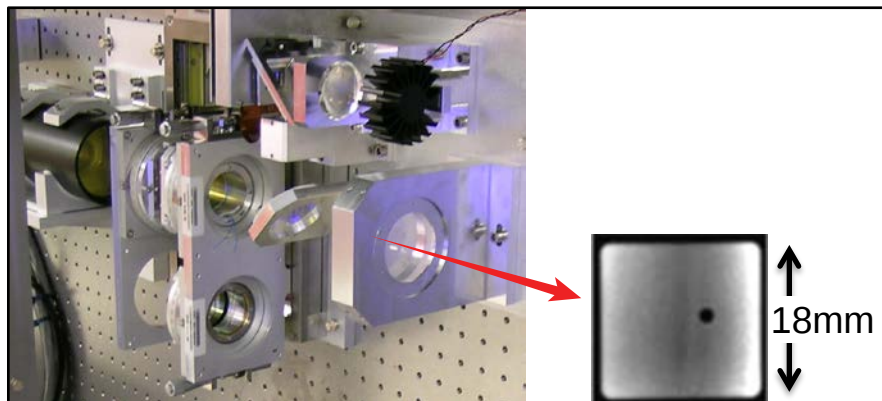
- Jarom Nelson, “NIF Dilation X-ray Imager (DIXI) Diagnostic Instrumentation and Control System”, TUPPC073

Programmable spatial shapers reduce energy on optics through beam shaping and transmission blocking

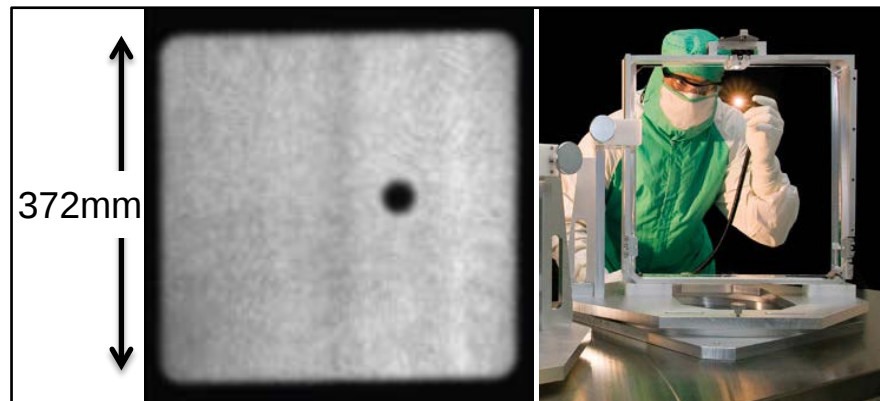


The PSS creates blockers at $1/20^{\text{th}}$ scale at RP0 in the PAM

The blockers shadow flaws on the Final Optics from high fluence



**Programmable
Spatial Shaper**



**Wedged
Focus Lens**

- Barry Fishler, "Rapid Software Prototyping into Large Scale Controls Systems", MOPPC038

Image Analysis and Machine Learning are used to locate hotspots for flaws that require blocking

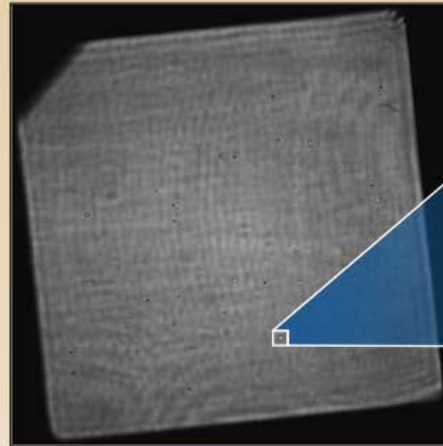
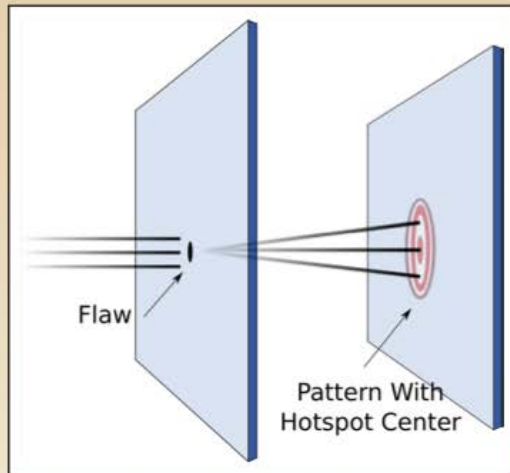
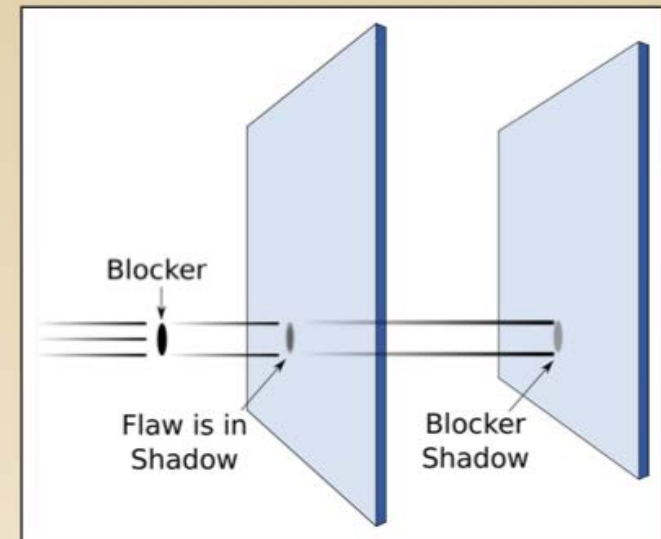
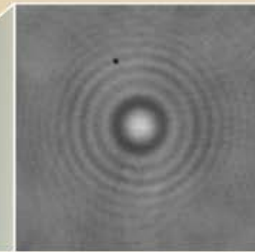
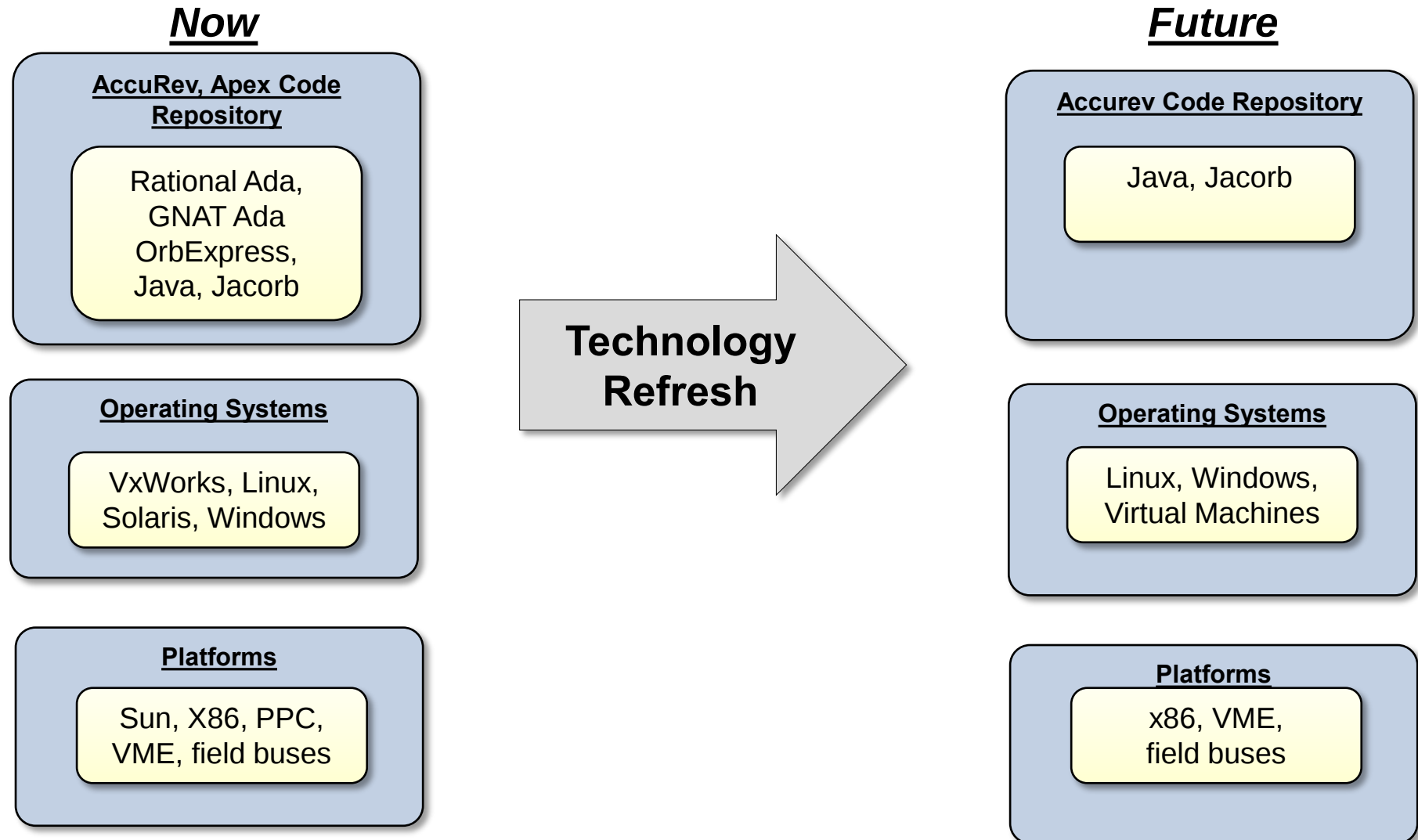


Image of a Wedge-Focus Lens (WFL), showing evidence of a flaw on an upstream optic



- Laura Kegelmeyer, “Optimizing Blocker Usage on NIF Using Image Analysis and Machine Learning”, THMIB04

Consolidation of compute platforms and software languages is an active project focus for the Controls team



- Mark Miller, "Building a Maintenance and Refresh Strategy to Address Controls Hardware Diversity for the NIF Computer Control System", MOCOBAB07

Shot Planning Tools serve to coordinate teams and maximize facility availability for experiments

Planning Tools help teams ask:

- When is the experiment needed?
- What is needed from the facility?
- What supplies are needed from the factories?
- What replacements are predicted?
- When is maintenance scheduled?
- How will the laser operate under certain conditions?

Daily Operations Planning Meeting



- Kathleen McCandless, “The Role Of Data Driven Models In Optimizing the Operation of the NIF”, THCOCB02

Setup Tools enable the users to configure the facility for an experiment... and to verify that it is correct

Shot Setup Tools provide:

- All shot details (laser, target, diagnostics, facility) using pre-defined templates
- A “Rules Engine” to enforce operating envelope
- Electronic reports and approvals
- Comparison of Requested to Actual configuration
- Over 20,000 setup items

Dante has over 500 setup parameters



- Doug Speck, “Data-Driven Campaign Management at the NIF”, FRCOAAB0

Configuration Tools maintain a historical record of millions of parts installed on NIF

Configuration Tools answer:

- Where is a part or assembly installed?
- When was it installed?
- What is its calibration?
- What is its maintenance plan?
- What is its exposure to laser fluence?
- “Seating Charts” show current state
- Integrated Work Orders track parts
- Drawings are under strict document control

Operations staff performing maintenance on target positioner



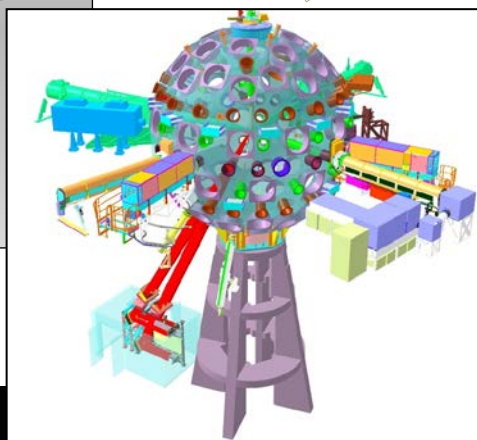
- Darwin Dobson, “Managing a Product called NIF”, MOPPC090

Automated Analysis Tools provide scientists with analyzed experimental results within 30 minutes

- **Flexible Data Driven Analysis allows:**
 - Customized analysis flow for each diagnostic
 - Structured input data for each analysis
 - Straight-forward mapping of analysis results to data archive
- **These tools enable:**
 - Algorithm updates that support diagnostic and experimental changes
 - Aid in maintenance of accurate calibration

Diagnostics:

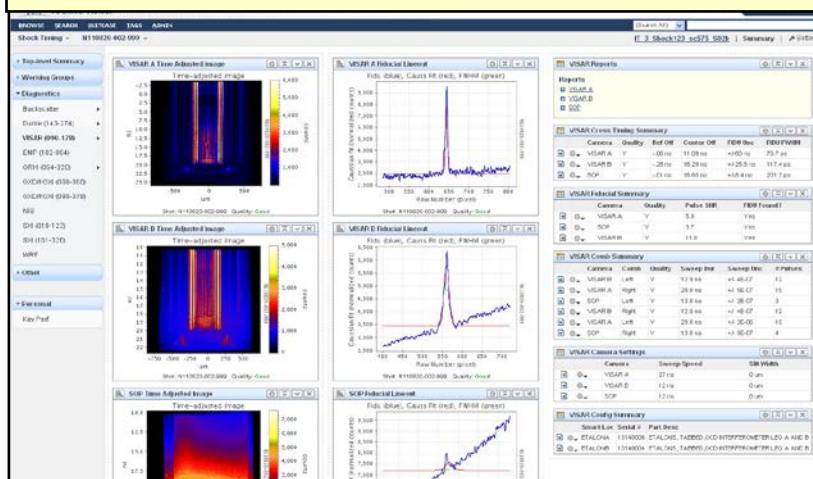
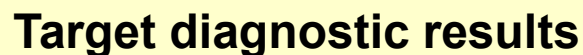
- NTOF: Neutron Time of Flight
- NIS: Neutron Imaging
- Dante: X-ray Temperature
- Gated/Streaked X-ray Imagers
- Static X-ray Imagers
- NBI/FABS: Backscatter
- SPBT: Bang Time
- GRH: Gamma Reaction
- FFLEX: Electron Preheat
- VISAR: Shock Timing



Analysis Results

- Allan Casey & Rita Bettenhausen, “Flexible Data Driven Experimental Data Analysis at NIF”, TUPPC072
- Judith Liebman, “Understanding NIF Experimental Results: NIF Target Diagnostic Automated Analysis Operations and Calibrations”, WECOA05

- ## Shot vs. simulations



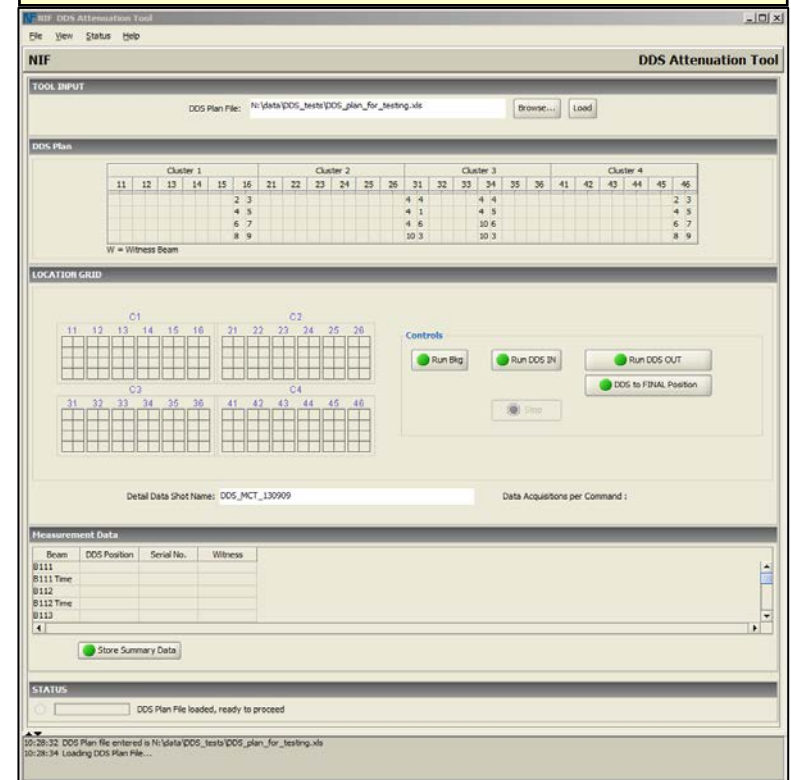
- **Matt Hutton, “Visualization of Experimental Data at the NIF”, TUPPC126**
- **Scott Reisdorf, “Rapid Development Using Web 2.0 Technologies”, THCOAB05**

Over 60 scripted Maintenance and Commissioning tools (MCTs) have been developed to assist operators in performing repetitive and tedious operator functions

Automatic Disposable Debris Shield (ADDS) Attenuation tool:

- Processes configuration file specifying debris shields to measure
- Positions the ADDS for measurements
- Executes alignment commands to analyze images in ADDS IN/OUT positions
- Retrieves data, performs calculations, and outputs data in user friendly format
- Performed in parallel on 192 beams for efficiency

Automated Disposable Debris Shield Attenuation Tool GUI



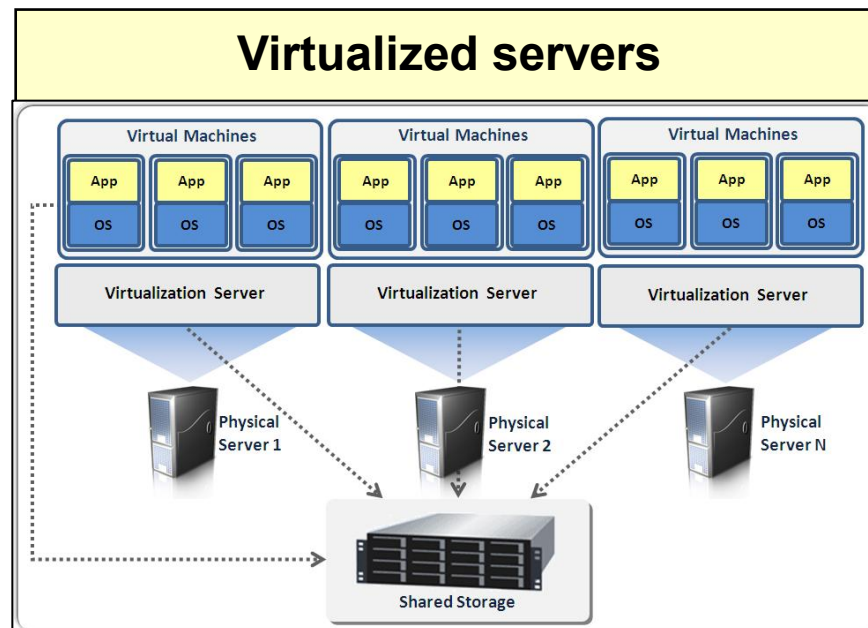
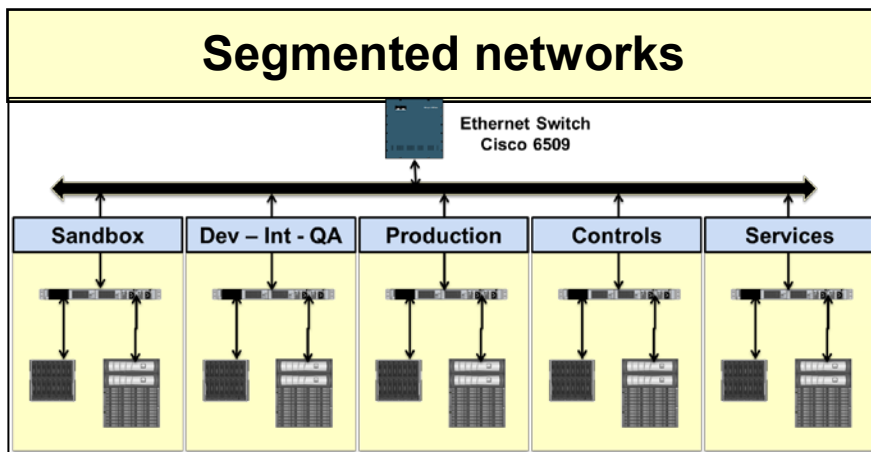
- Vicki Miller-Kamm, “Software Tool Leverages Existing Image Analysis Results to Provide In-Situ Transmission of the NIF Disposable Debris Shields”, THPPC083

New web and iPad applications help operations in efficiently managing and executing checklists



- Scott Reisdorf, “NIF Electronic Operations: Improving Productivity with iPad Application Development”, THCOAAB07

An IT infrastructure consisting of 2,500 servers, 400 network devices and 700 TBs of storage provides the foundation for NIF's control and information systems



- Tim Frazier, "Evolution of IT Infrastructure for Fusion Control Systems", THCOBA04

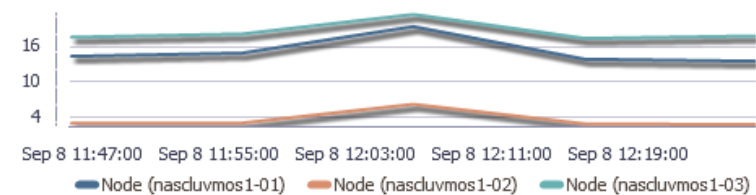
Common storage platforms and continuous monitoring using OEM and Splunk have also been deployed

Common storage

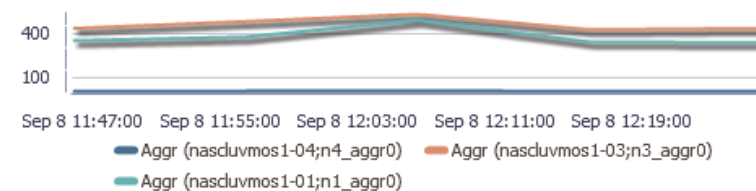


Continuous monitoring

Top 3 Nodes By CPU Utilization (%)

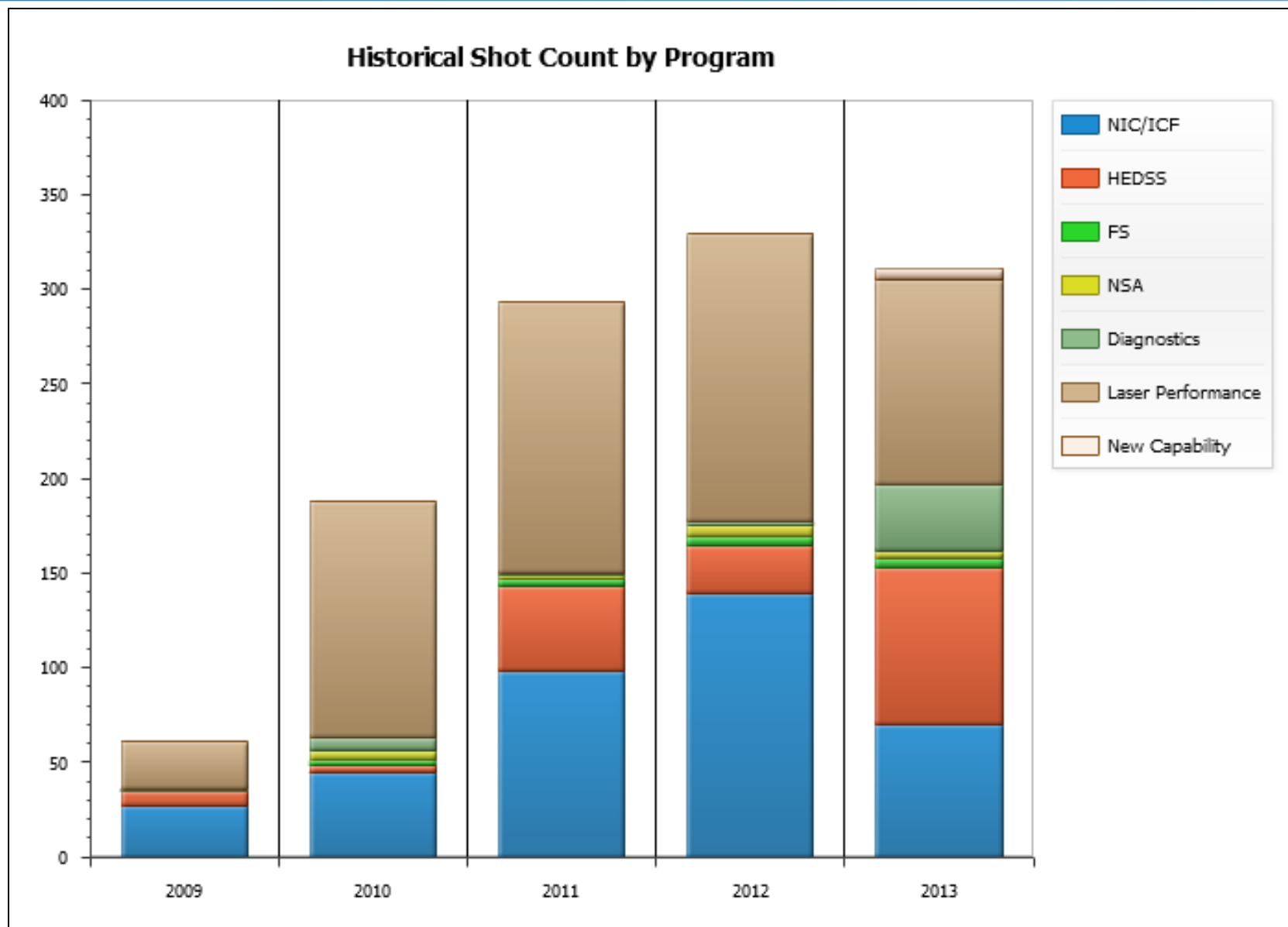


Top 3 Aggregates By Throughput (Blocks/Sec)



- Phil Adams, “Data Driven Center at the National Ignition Facility”, TUPPC033
- John Fisher, “Monitoring of the NIF Control System”, THPPC082

NIF has fired approximately 1,200 shots since project completion (May 2009)



NIF missions

Ensuring National Security



Advancing Frontier Science



Enabling Clean Energy



Building Future Generations of Scientists



We have consistently delivered safe, secure and reliable enterprise solutions to meet NIF's missions

NIF

