SHOT RATE IMPROVEMENT STRIVE FOR THE NATIONAL IGNITION FACILITY (NIF)

MOD3O03

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Gordon Brunton
NIF Control Systems Lead

Lawrence Livermore National Laboratory

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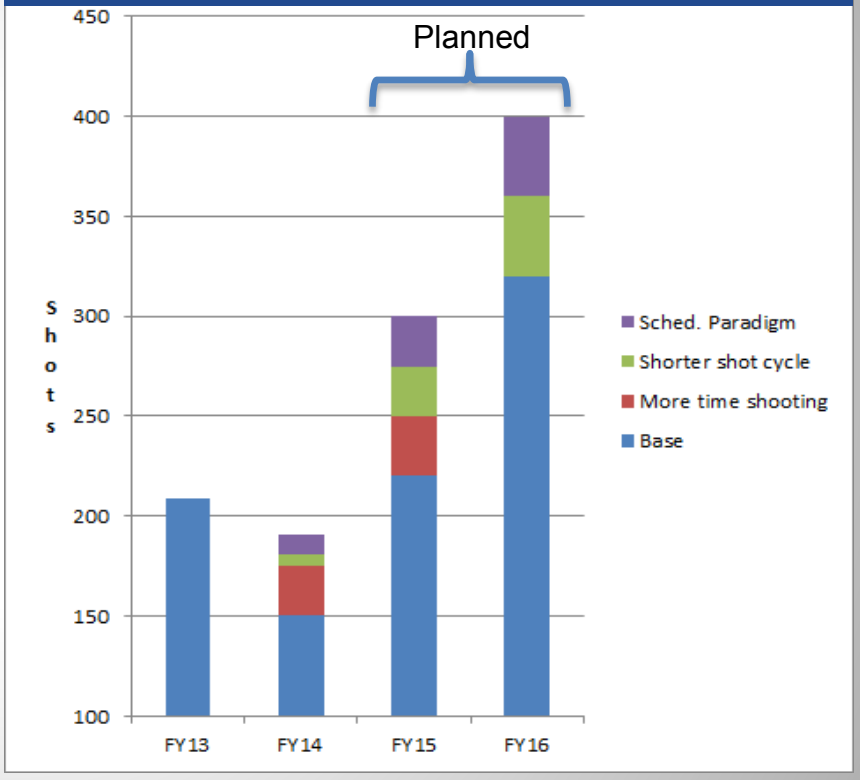
With NIF fully operational as a user facility focus now shifted to maximizing return of experimental data

- **Shot Rate Goals:**
  - FY15: 300 shots (>50% increase over FY14)
  - FY16: 400 shots
- **Primary Focus Areas:**
  - More shot time
  - Improved experiment scheduling
  - Reducing shot to shot durations

Focus Areas for Shot-Rate Improvement

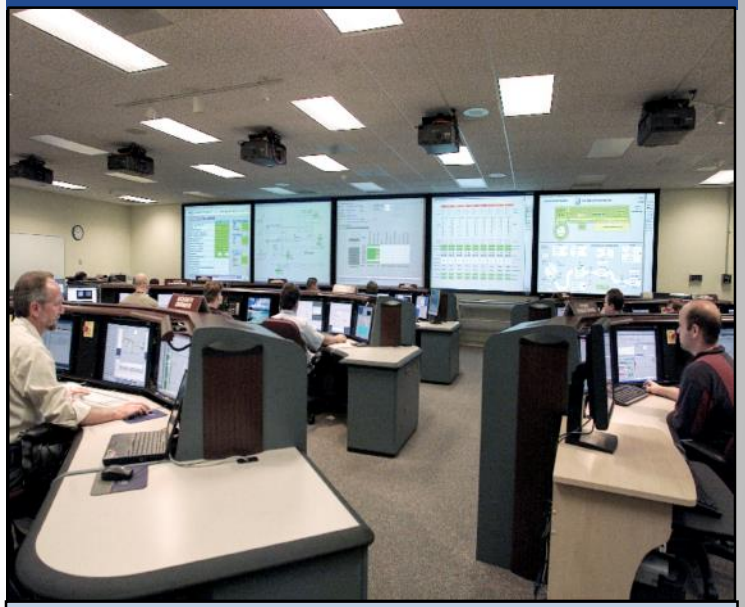


With changes already implemented to formalize 24/5 shot time and improved experiment scheduling focus shifted to reducing shot cycle durations

The NIF Control System is one of the world's largest operational scientific control systems

- 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

A large scale systems analysis and engineering effort was performed to identify where to best invest in controls enhancements to increase the NIF shot rate

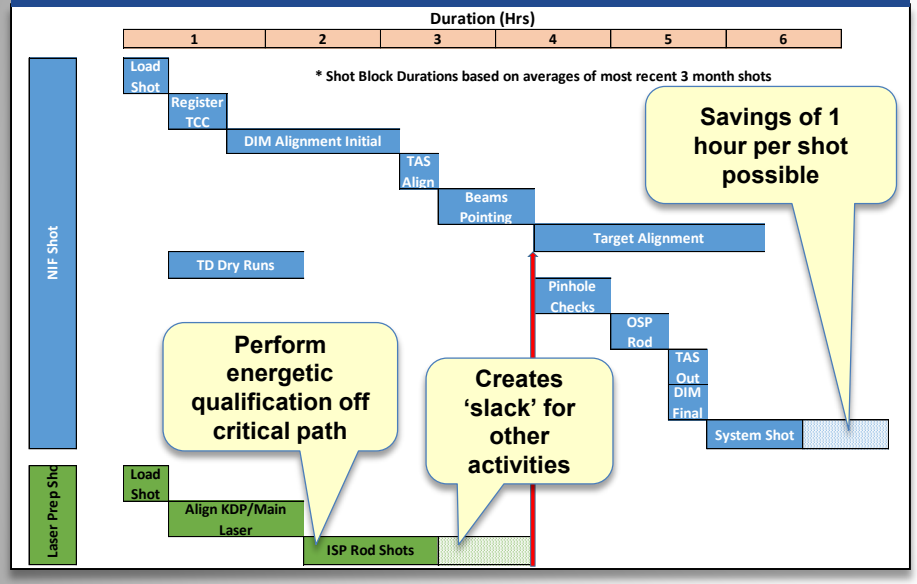
Several analysis approaches were used to identify the largest savings

- Years of shot cycle metrics analyzed to determine ‘normal’ critical paths
  - Shot cycles categorized by configuration complexity (i.e. warm simple, warm complex, cold and layered) due to high variance in execution times
- Shot cycle sequences analyzed to identify if ordering changes could reduce critical path durations (top down)
- Long duration shot cycle sequences analyzed in depth for optimization and/or elimination (bottom up)
  - Analysis considered both critical path and ‘close to’ critical path activities to ensure true return of investment was measured
- Improvement activities were prioritized based on assessed time savings and implementation effort

The following summarizes some of the key improvements chosen and results achieved

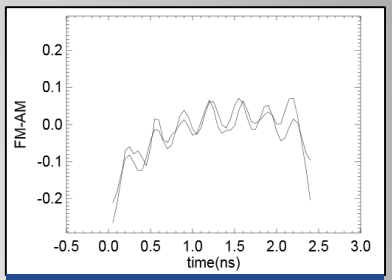
Performing alignment & energetics calibration in parallel with target area operations reduced shot cycle by 1 hour

New Parallel Shot Cycles



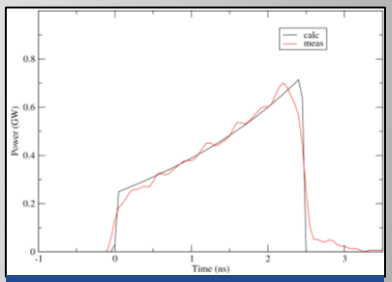
Other activities utilized 'Slack' Time

- **Amplitude modulation verification post experiment wavelength change**
  - Operational cost* = 120 * 2hrs per year



AM Modulation

- **Precision pulse shape calibration for high precision experiments**
  - Operational cost * = 150 * 3hrs per year



Pulse Shape

* Estimates based on historical shot metrics extrapolated forward to nominal goal rate of 400 shots per year

Utilizing new 'slack' time significantly reduced the number of independent calibration and verification shot cycles previously required

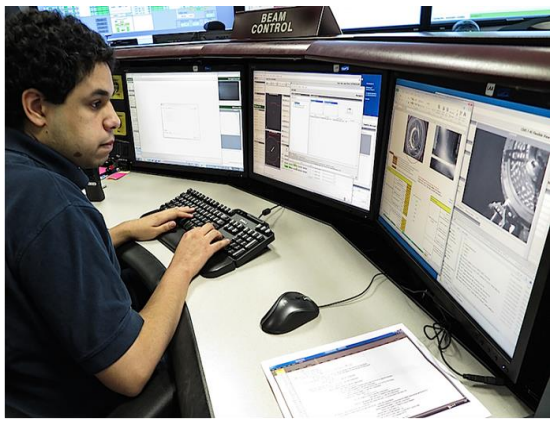
Target alignment process analyzed to automate some operations and minimize operator interactions

- Target Alignment Assistant Tool (TAAT) was developed to provide graphical scripted interface to guide operator through fine alignment process for NIF positioners
- Semi-automates manual alignment approach by removing opportunities for user input error
  - Data driven approach to allow ease of adaptability to novel target types
- Shot cycle savings of 30-60 minutes obtained

Operational savings using TAAT

	Manual Alignment Procedure				TAAT			
	# Measurements	# Moves	# Data Entries	# Move Choices	# Measurements	# Moves	# Data Entries	# Move Choices
Total	1413	130	83	26	763	34	0	0
Savings (%)					46%	74%	100%	100%

TAAT tool in-use

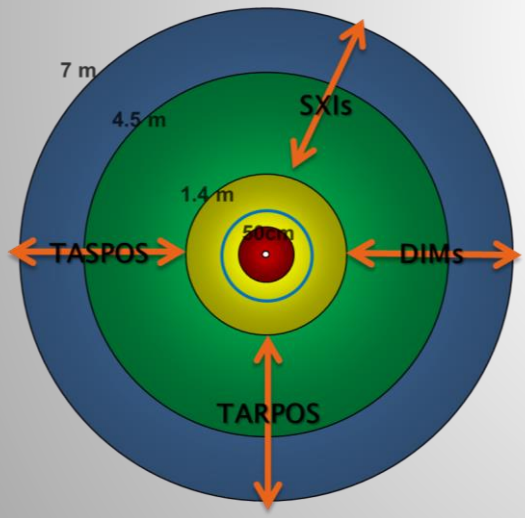


Use of TAAT for target alignment has significantly reduced the duration & variance of alignment times and is now under evaluation for diagnostic alignments

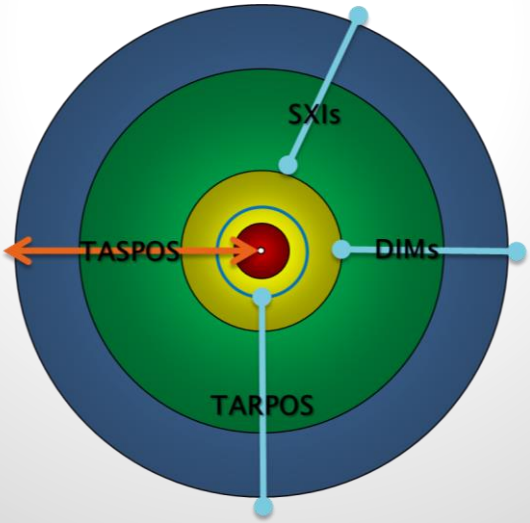
Target chamber positioner movement rules of engagement re-evaluated to reduce bottlenecks

- All target chamber positioner movements previously required 2 operators, for safety, which has caused delays due to staff availability and distraction
- New rules of engagement relax requirement to 1 operator for 90% of moves without compromising safety

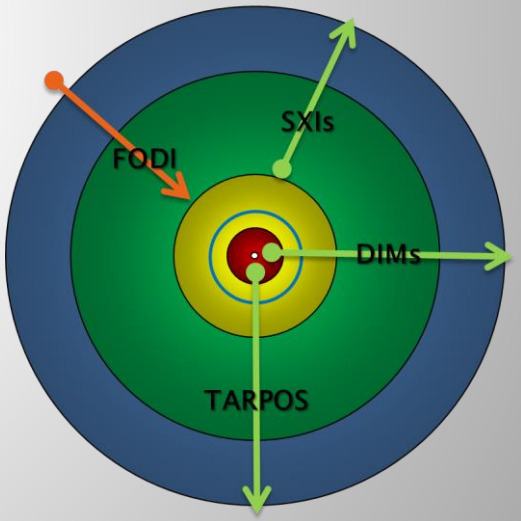
My Chamber Rule



Solo Positioner Rule



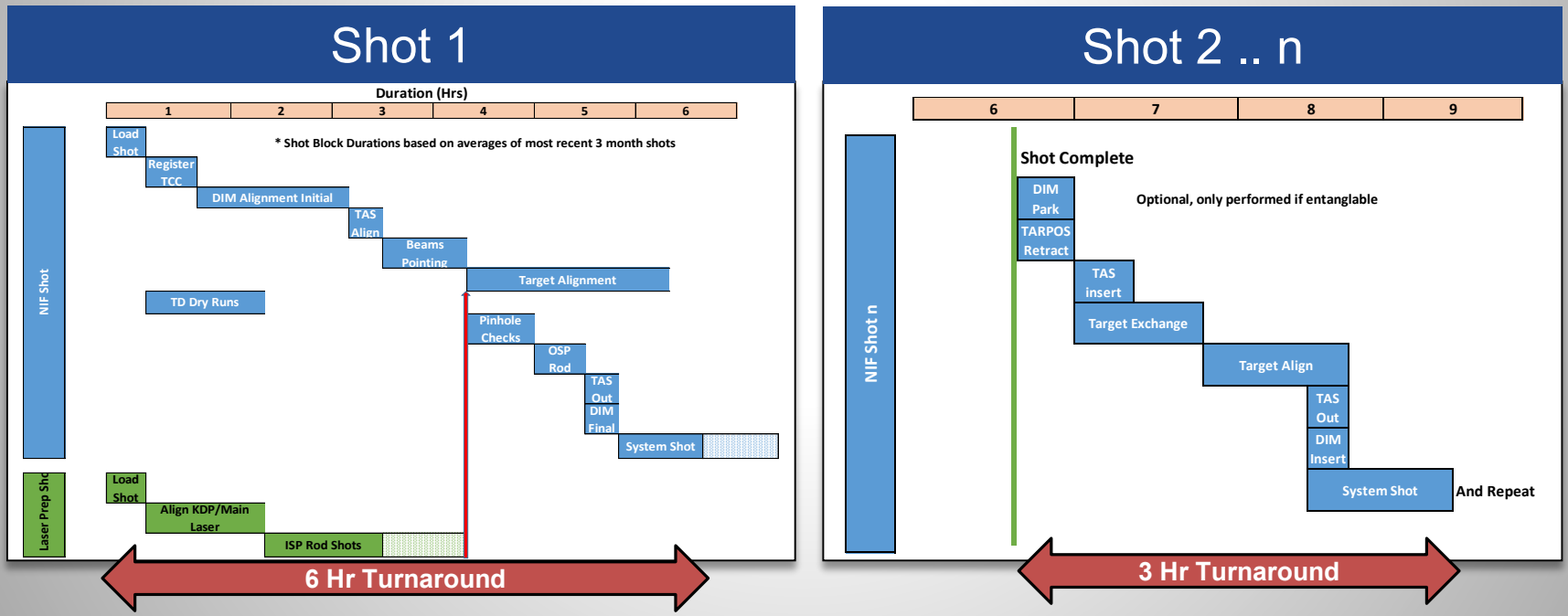
Retract Mode Rule



Alignment duration variances have significantly reduced with new rules without compromising safety while allowing greater operational flexibility

New ‘Gatling’ experiment type facilitates back-to-back target shots in the same shot cycle

- Avoids unnecessary laser preparation if shot configurations are similar
- Only target exchanges and diagnostic reconfigurations between shots
  - Can utilize interleaved positioners for further savings



The first series of ‘Gatling’ experiments are scheduled to be performed on NIF this fall and have the potential to significantly contribute to further shot rate improvements

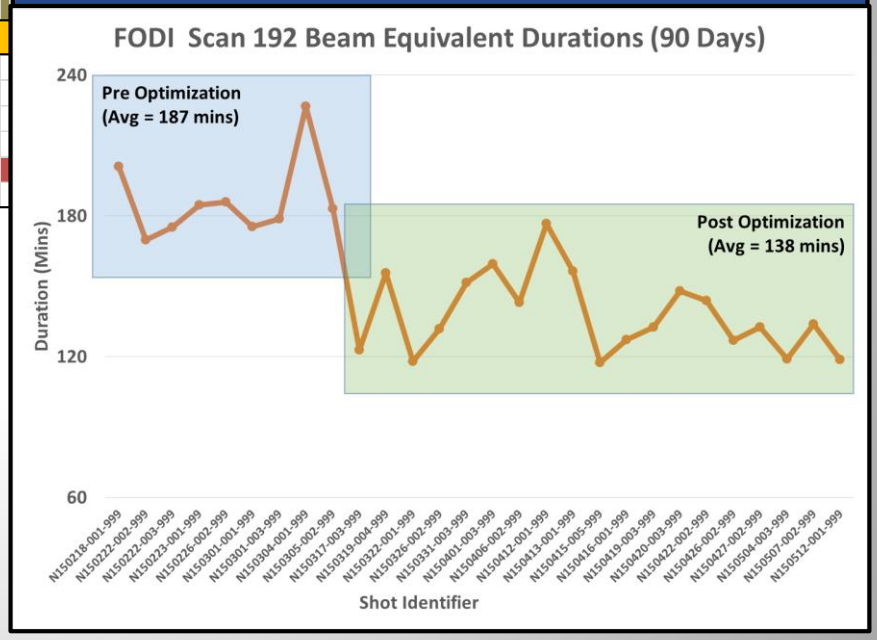
Sequencing of optics inspection (FODI) analyzed and optimized to minimize shot to shot turnaround

FODI Steps w/ Proposed Optimizations

	Duration per beamline (seconds)	Savings per beamline (seconds)	Duration (Seconds)
Present FODI acquisition			
Laser OFF	65	0%	
Laser Switch to Beamline			
Focus Motor to Position (Brake Off & Brake On)			
Laser On			
Capture and Archive Image			
Image Capture Complete			
With acquisition script optimizations			
Laser OFF	50	23%	
Laser Switch to Beamline			
Focus Motor to Position (Brake Off & Brake On)			
Laser On			
Capture and Archive Image			
Image Capture Complete			
With 'Deferred Braking' optimization			
Laser OFF	40	38%	
Laser Switch to Beamline			
Focus Motor to Position (Deferred Braking)			
Laser On			
Capture and Archive Image			
Image Capture Complete			
Overall savings			
Laser OFF	38	42%	
Laser Switch to Beamline			
Focus Motor to Position (Deferred Braking)			
Laser On			
Capture and Archive Image			
Image Capture Complete			

FODI Inspections performed 2-4 times per week between shots
- Savings = ~110 Hrs per year

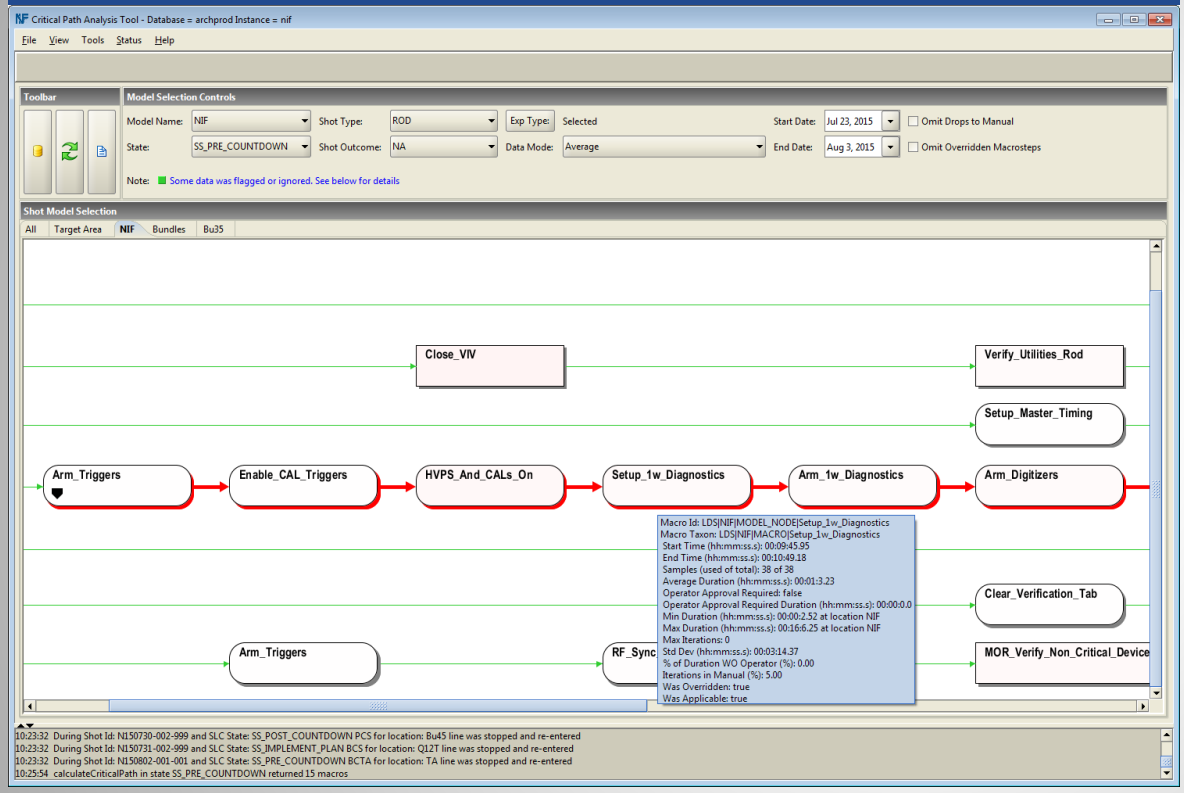
Optimization Results



With limited archiving in this area, optimization analysis made significant use of Splunk™ log parsing ability to identify optimization strategies and evaluate return on investment

To assist with measuring efficiency improvements a critical path analysis tool (CPAT) has been developed

Critical Path Analysis Tool (CPAT)

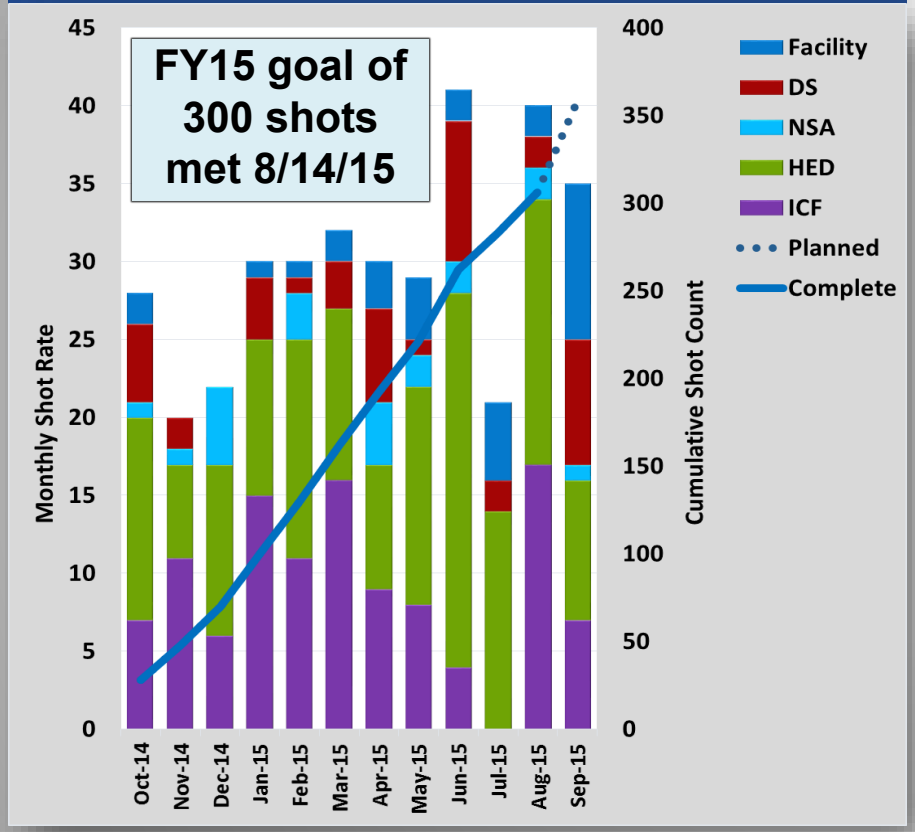


- Analyzes historical shot cycle metrics
- Visualizes critical path of shot cycle(s)
- Provides metrics on shot execution including long operations, averages and standard deviation
- Rapidly identifies ‘slack’ time on non-critical path blocks

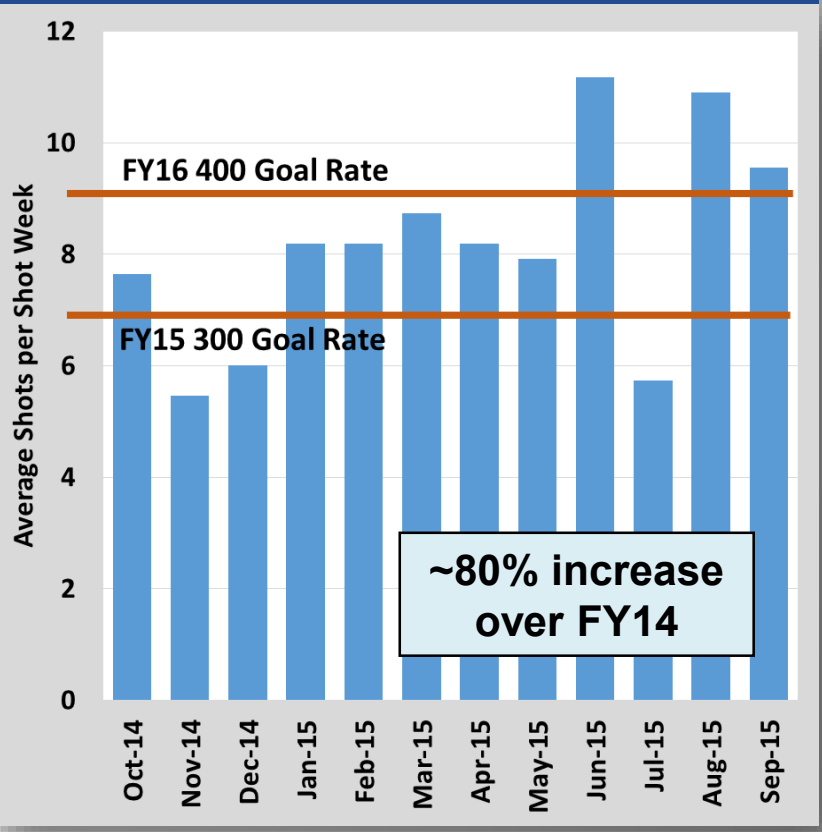
CPAT already used to identify 5 minute saving from sub-optimal rod shot sequencing.
NIF performs ~1300 rod shots per year (108 operational hours).
These savings equate to ~11 additional shots per year

The results of the shot cycle schedule and controls enhancements have resulted in significant improvements

FY15 Target Shots



FY15 Weekly Shot Rate



The shot rate process improvements resulted in meeting the FY15 300 shot rate goal >1 month earlier than planned

Future Work

- **Advanced Tracking Laser Alignment System (ATLAS)**
  - Laser Tracker based diagnostic package alignment
  - Replaces need for opposed port imaging systems
  - Decouples diagnostic alignment from use of Target Alignment System (TAS) thus removing diagnostic alignments from the shot cycle critical path

FARO Laser Tracker

- **Target And Diagnostic Manipulators (TANDM)**
  - Addition of 2 new target/diagnostic positioners
  - Allows additional diagnostics and allows Cryo positioner to be layering without impacting shot schedule
  - Requires ATLAS as no opposing port alignment system (OPAS) being implemented for alignment

Summary

- Historical metrics were critical to process improvement
  - Invaluable in accurately analyzing optimization approaches and measuring success
- Both top down and bottoms up analysis approach identified improvements
  - Top down typically yielded the most gains (i.e. big picture)
- Return on investment important to accurately capture
  - Aids in defining need for change and prioritizing order of deployment
- Reliability, Availability & Maintainability (RAM) also important to analyze
  - With parallel execution the slowest cog governs speed of overall system
- System optimizations often best left until system is completed
  - However imposed system constraints should be considered throughout design to ensure optimization potentials are not being inhibited

NIF shot rate has made significant gains during FY15 and optimizations implemented have positioned us well for meeting FY16 goals and beyond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