

# National Ignition Facility (NIF) Sustainment Plan

Presented to:

NIF User Group

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Brianna Arth  
NIF Sustainment – Deputy Project Manager

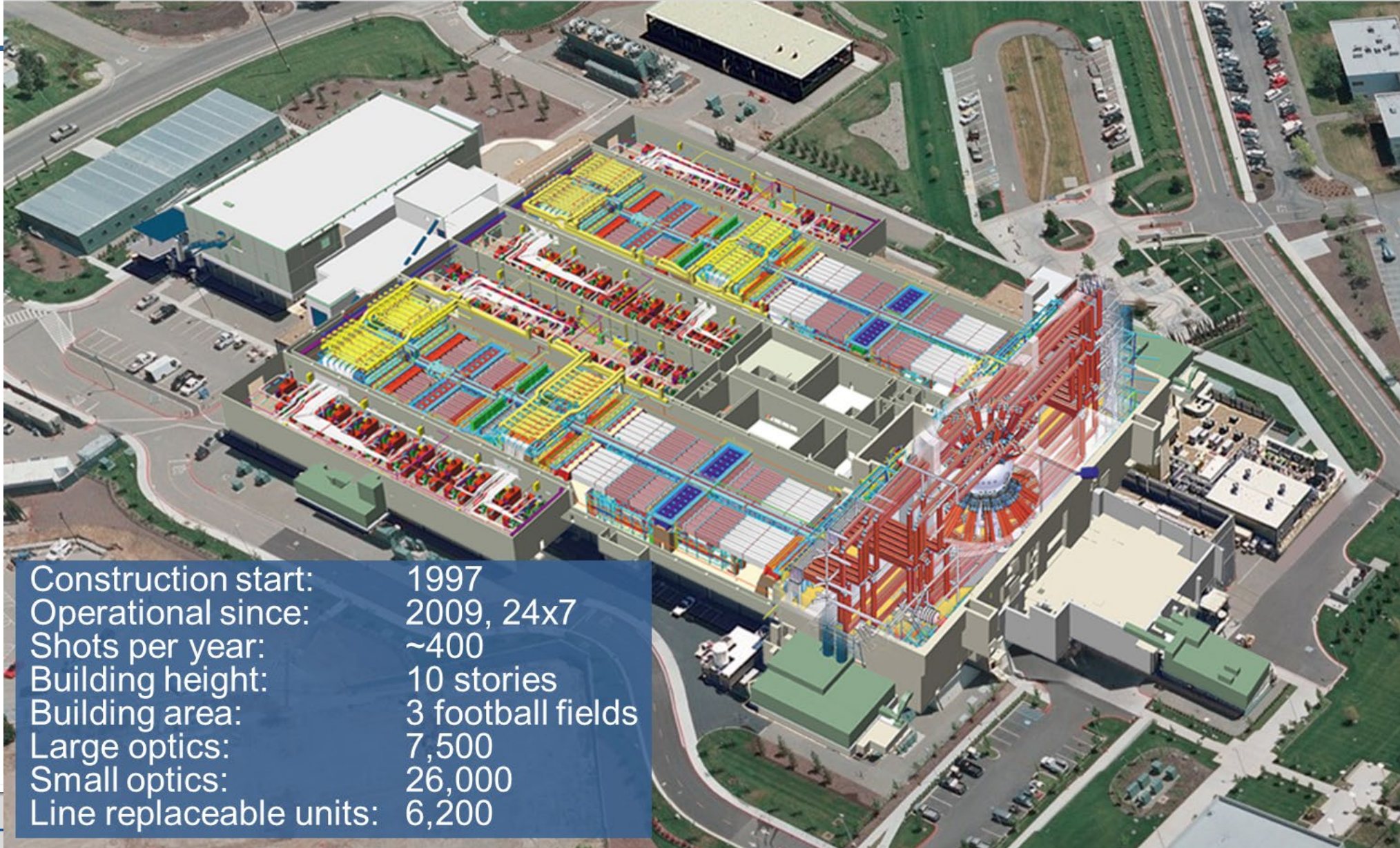


# Agenda

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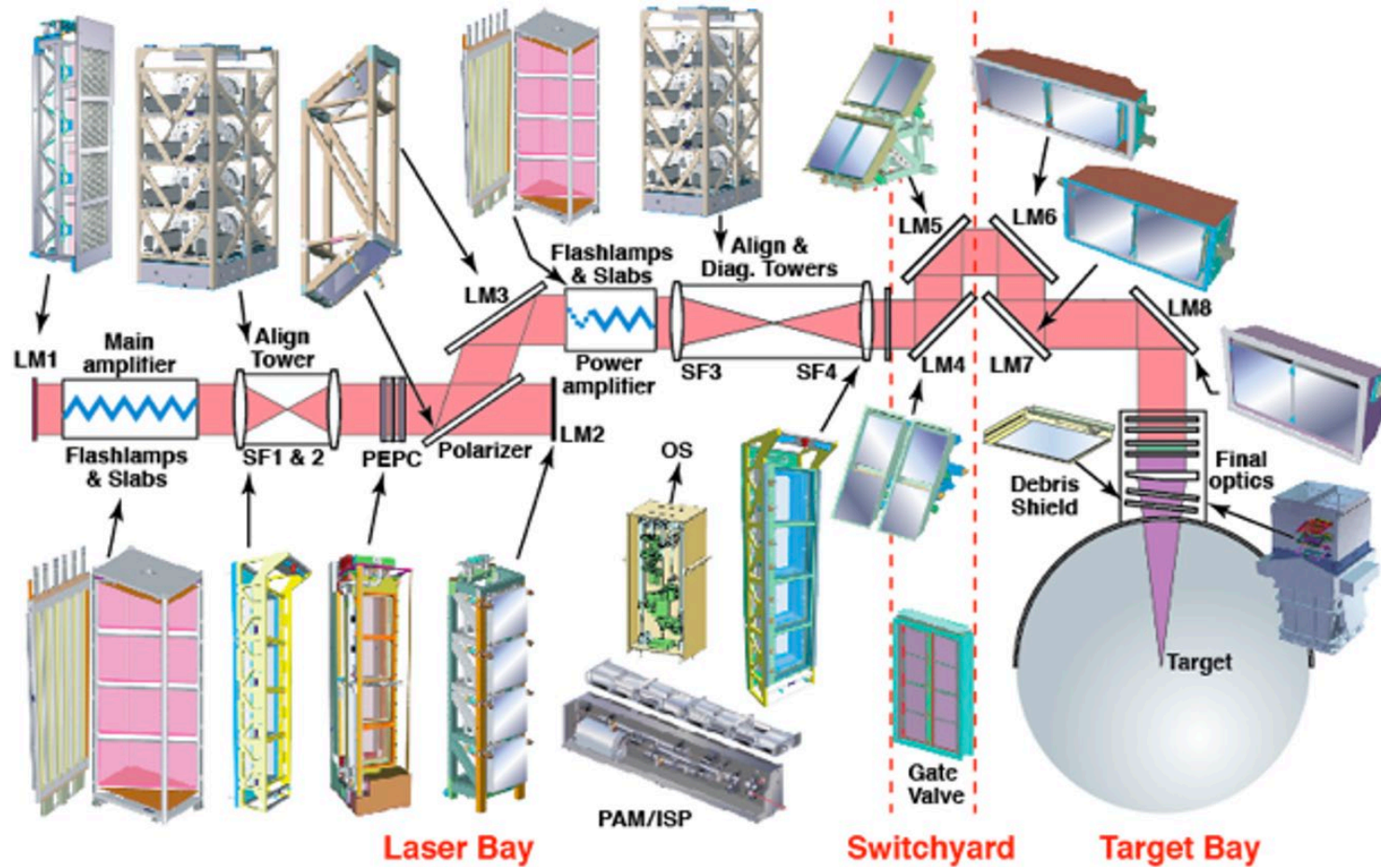
- Background on NIF Sustainment
- Sustainment Plan development and initiation
- Risk-based approach, example Blue Blockers and Integrated Optics Modules (IOMs)
- Execution strategy
  
- Following talks highlight key Sustainment projects:
  - Amplifier Refurbishment
  - Injection Laser Portfolio Projects

NIF, the world's most energetic laser, concentrates energy from 192 laser beams into a few mm<sup>3</sup> in a few billionths of a second



Construction start:	1997
Operational since:	2009, 24x7
Shots per year:	~400
Building height:	10 stories
Building area:	3 football fields
Large optics:	7,500
Small optics:	26,000
Line replaceable units:	6,200

# The NIF line-replaceable-unit (LRU) 'optical building block' architecture was key to building and maintaining NIF



Each of the 6,000 LRUs house large optics that align and amplify each laser pulse as it travels 1,500 meters from origin to target

# Deferred maintenance and aging issues exist in both the NIF and support facilities



Many production and support facilities are from the 1970's era

# Demand for access to NIF's unique capabilities continues to grow

- NIF experiments provide data for the NNSA, Air Force, and Navy in the absence of underground testing
- Improves our understanding of weapons science:
  - Material properties including Pu aging studies at increased rate
  - Fundamental physical processes
- Recent achievement in ignition is fueling demand for increased experiments
  - Understanding sensitivities on the ignition cliff
  - Pushing performance to 10 MJ or higher
  - Developing and using robust platforms for new applications
- Workforce development

W80-4



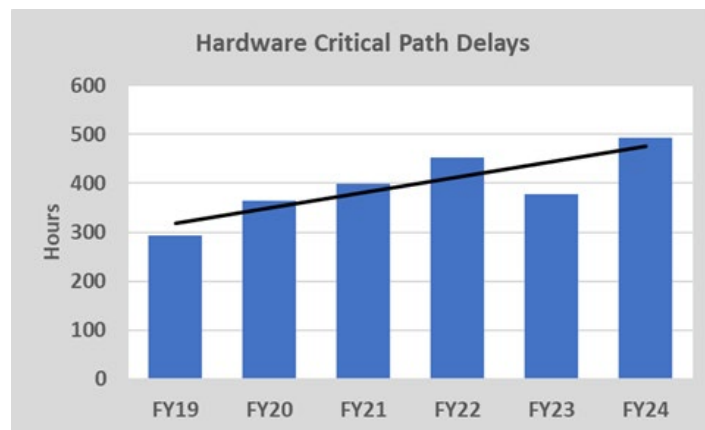
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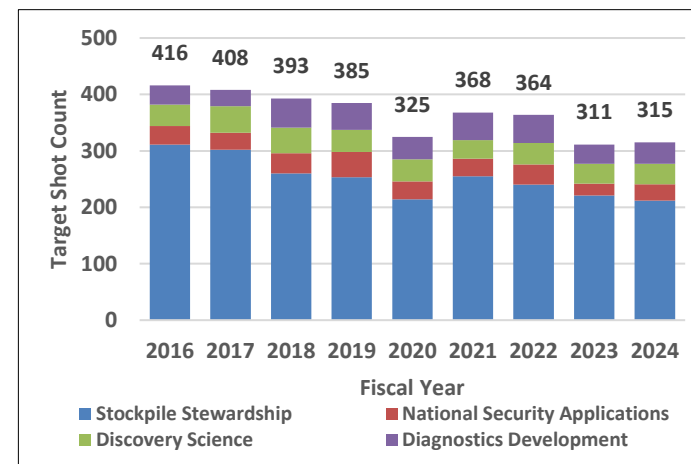
NIF is oversubscribed by >2x and HED, ICF and NSA program milestones are paced by NIF data rate

# Work scope for NIF's Sustainment Plan started in 2018 as a result of:

- Concerning indicators from on-going tracking of facility metrics
- Amplifier and final optic degradations motivated the urgent need to address
- Periodic inspections of the amplifiers and final optics show a continued degradation
- Degradations and declining output clearly supported need for action



Lost experimental time due to hardware failures is increasing

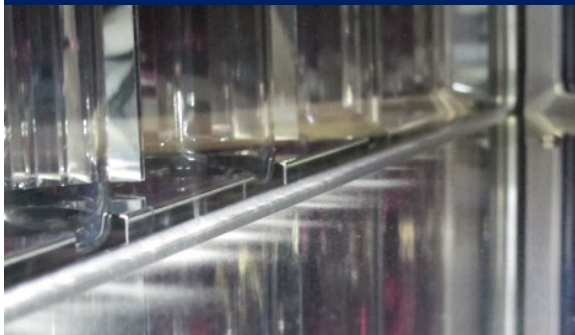


NIF's required precision drives many systems to performance limits; even minor degradations have significant impact on the laser

# Risk-based approach to identify deferred maintenance and aging issues that could lead to significant down-time over next 5 years

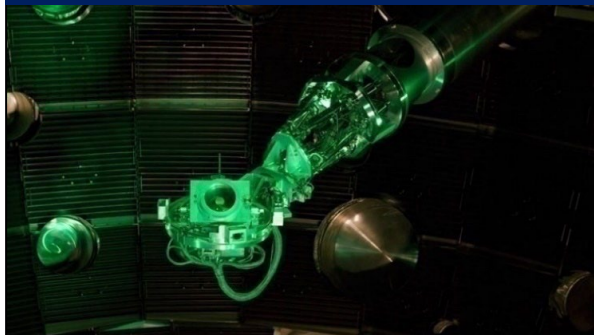
- Risks considered historical failure rates and supply chain availability for sparing

Deferred maint./Refurbishment



Amplifier/Optic Contamination

Obsolescence/Recapitalization



Final Optics Damage Inspection

Reliability/Efficiency



Target LRU

Sustainment Need	1-yr Risk	5-yr Risk
Mitigate Debris Induced Laser Damage	20	25
Chamber Entry Lift Controls Refurbishment	20	25
Optics Processing Equipment Refurbishment	15	25
High Fidelity Pulse Shaping	15	25
Chamber Imaging and Lighting	15	25
Optics Inspection System	15	25
Amplifier Refurbishment	12	25
Facility Control Systems Obsolescence	12	20
3w Power Sensors	10	20

NIF's Sustainment plan executes on the highest-risk deferred maintenance and aging across NIF systems and facilities



# The NIF Sustainment Plan was developed to address mid-lifetime degradations and obsolescence to support operations thru 2040s

- Execution plan optimized sequencing of independent activities to minimize experimental plan impacts while maximizing use of 'base' resources where possible
- Urgency of some scope increased due to recent high neutron yield levels
- Completion will sustain NIF over the next two decades, support higher neutron yield, restore shot rate to nominal levels, and enable an upgrade in laser energy



## Inertial Confinement Fusion (ICF) 10-Year Facility and Infrastructure Plan

Report to Congress  
September 2022

National Nuclear Security Administration  
United States Department of Energy  
Washington, DC 20585

FOA

# The Final Optics Assembly

Contains a number of optics to condition and focus the laser light into the target chamber

Vacuum window

Polarization rotator

Frequency conversion crystals

SHG  
2 $\omega$  CPP

THG

Wedge focus lens for color separation

Grating debris shield

Fused silica debris shield

Disposable debris shield

1 $\omega$  Beam

Integrated Optics Module (IOM)

3 $\omega$  Beam

Target Chamber

lasers.llnl.gov

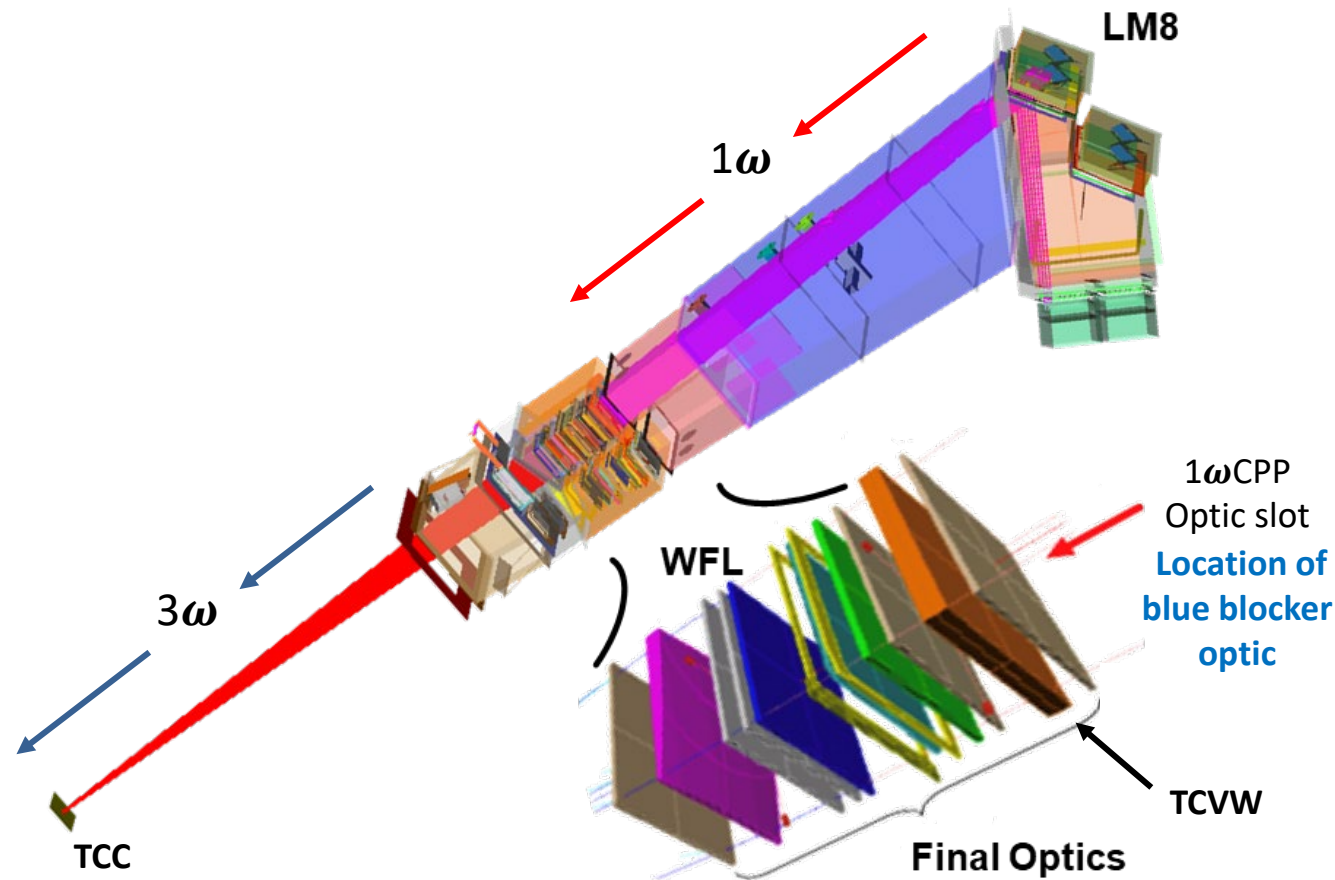
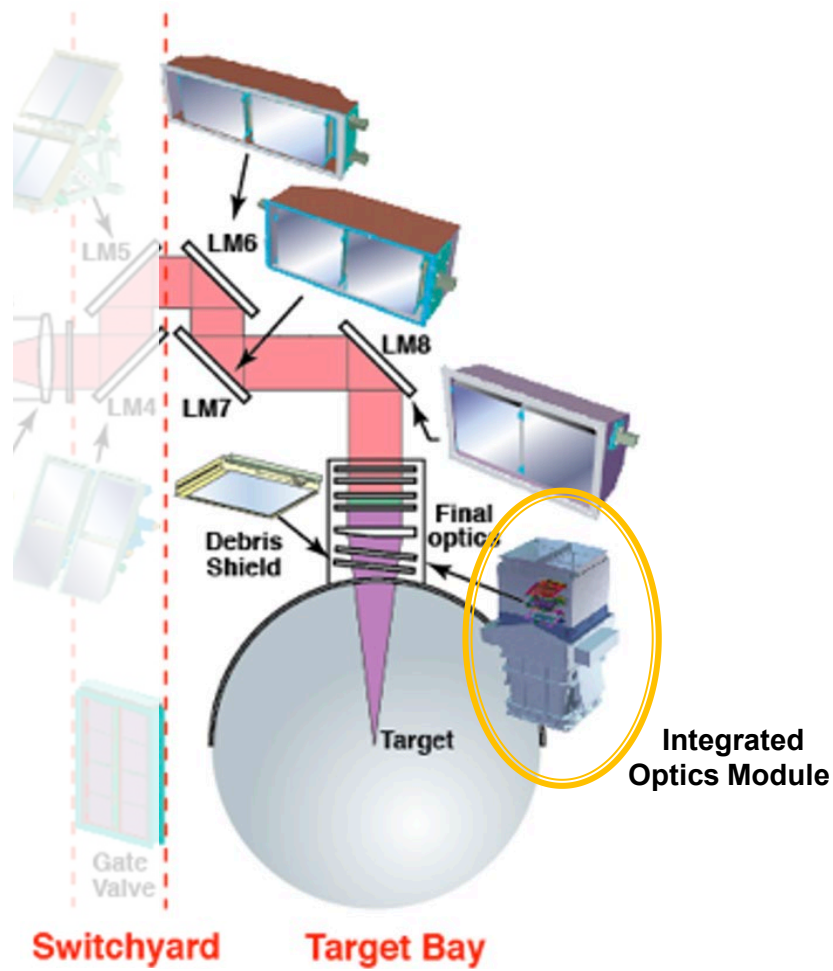


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NIF&PS

NNSA  
National Nuclear Security Administration

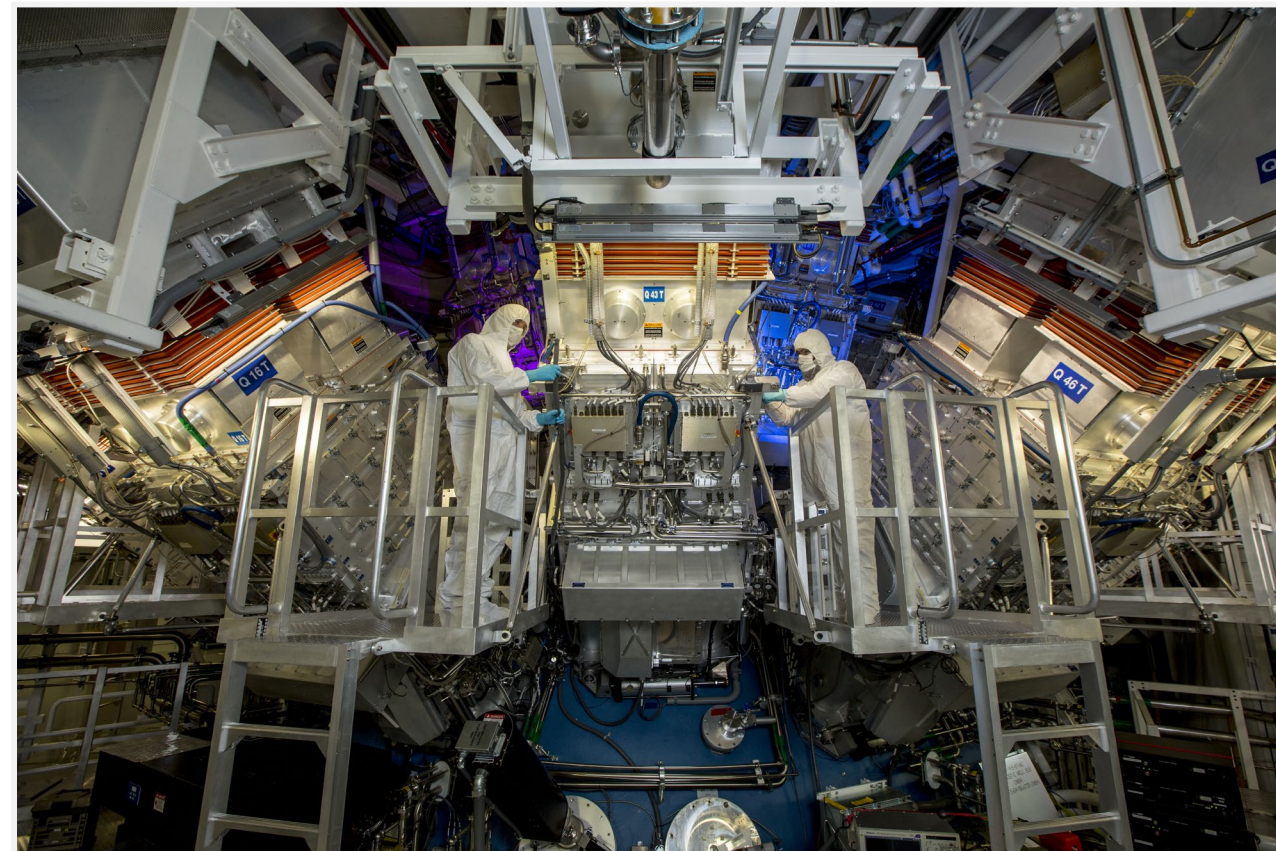
# The Final Optics Assembly: Integrated Optics Module (IOM) and Blue Blocker Optic



Refurbishment of the IOMs and insertion of the blue blocker optic reduces risk to NIF's machine safety

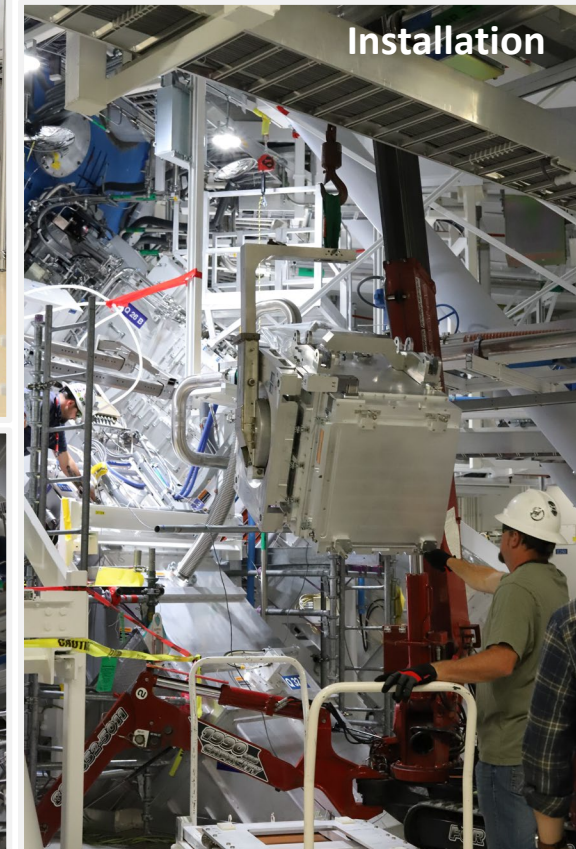
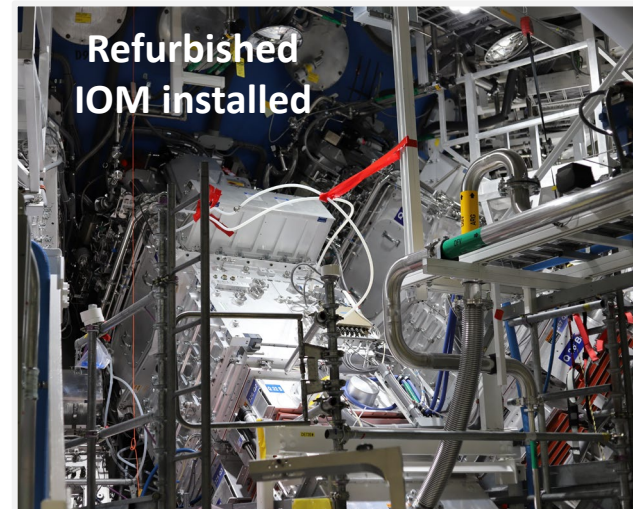
# Integrated Optics Module (IOM) Refurbishment

- There are 192 IOMs located around the NIF Target Chamber. Most have been in service for over 17 years!
- Each IOM undergoes operational alignment activities and requires routine optic exchanges.
  - Optic exchanges create opportunities for particles creating damage and debris
  - Operational alignment activities induce wear and tear in wheels, slides, etc. that are not easily addressed in situ.
  - A Target Chamber Vacuum Window (TCVW), which creates a boundary between the IOM optics and beam path argon environment, is a critical component to the refurbishment loop.



# IOM Refurbishment – Progress to date

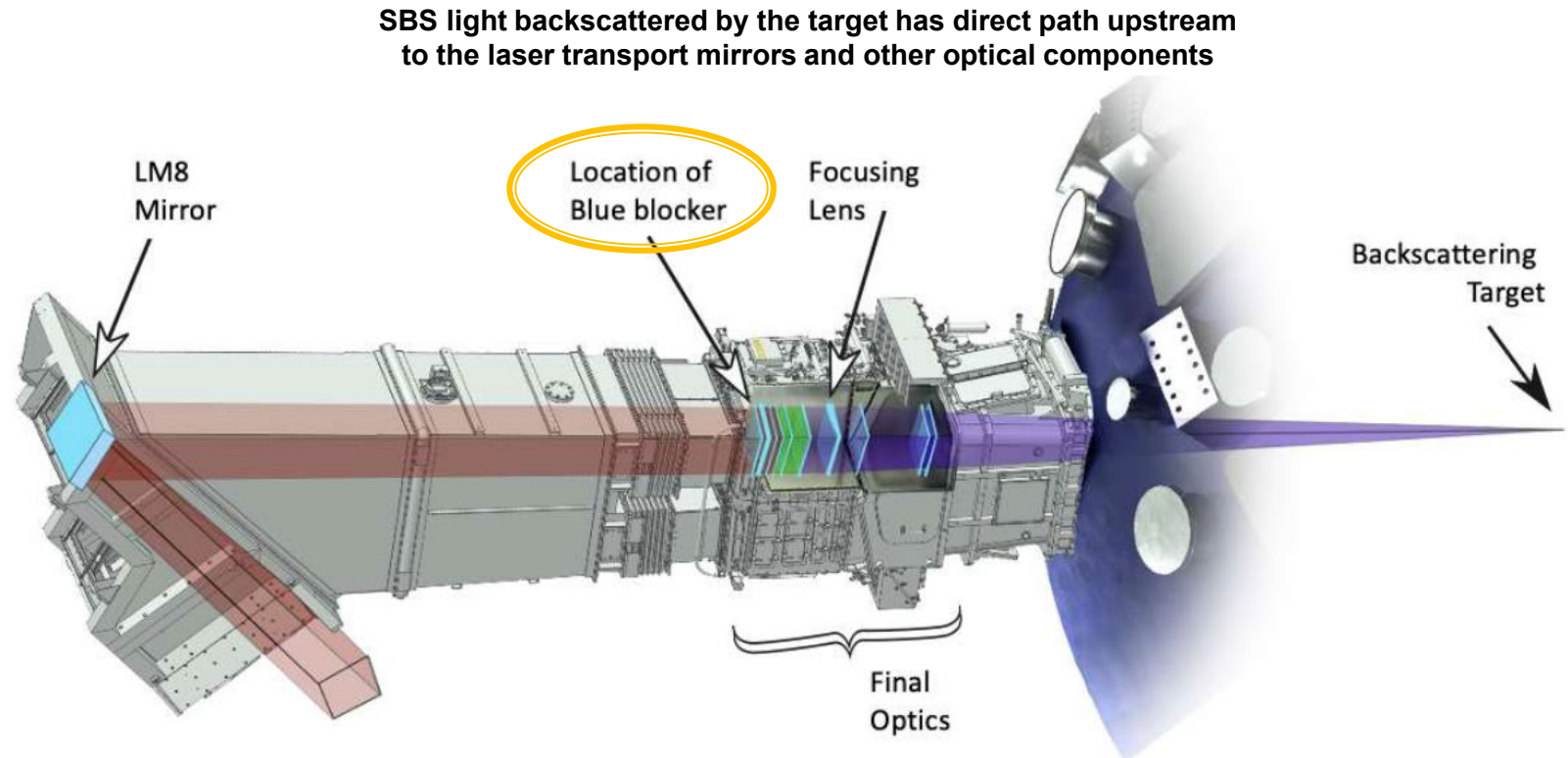
- Recommissioned the IOM Factory in 2024
  - Class 100 cleanroom, 2,400 sq ft
- IOM exchanges on NIF – 3/ 192 completed
  - Currently exchanged during planned maintenance periods
  - Ramping up for the ability to exchange IOMs on a weekend
- Engineering
  - Alteration of the  $1\omega$ CPP slot (located prior to the Target Chamber Vacuum Window) to accommodate the blue blocker optic



NIF Sustainment recommissions the IOM factory and refurbishes the IOMs on NIF

# Blue Blocker Optics

- The IOM converts  $1\omega$  laser light into  $3\omega$  light before hitting the target. This  $3\omega$  light can be backscattered up the optic beamline, known as Stimulated Brillouin Scattering (SBS).

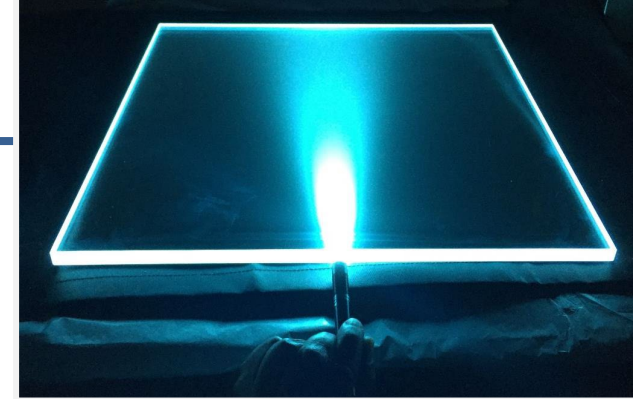


- SBS light is intensified after traversing IOM optics and can damage the large mirrors.
- Inserting a transmissive optic in the  $1\omega$  section that can block the  $3\omega$  light would mitigate this issue.

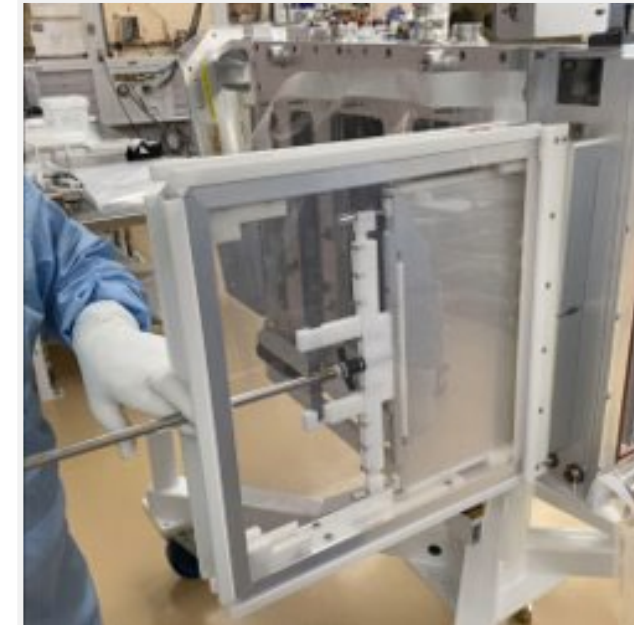
# Blue Blocker Optics

- Recent research and development efforts have found an optic doped with levels of Cerium can transmit  $1\omega$  laser light with near zero losses and then block the returning, reflected  $3\omega$  light.
- Placing this “blue blocker” optic in the unused  $1\omega$ CPP slot of the IOM provides protection to the upstream optical components and vastly reduces the amount of risk review and analysis that is built into each shot campaign.

A blue blocker optic seen emitting its characteristic blue fluorescence



Blue blocker optic insertion test within IOM Factory



NIF Sustainment funds the blue blocker optic purchasing and installation campaign to provide increased protection at current power levels and critical security against higher power levels in the future

# NIF Sustainment comprises ~60 independent activities at NIF and partner sites with funding support needs from both NA-10 and NA-90

## Injection Laser

- Beam-Based Blockers Replacement
- Multi-Pass Amplifier Replacement
- 3 $\omega$  Power Sensors Refurbishment
- High-Fidelity Pulse Shaping

## Amplifiers

- Debris Elimination & Refurbishment
- Pulsed Power Replacements
- Transport and Handling Equipment Repl.

## Optics Processing

- Equipment Refurbishments

## Target Fabrication

*Separate LLNL facility*

- Equipment Replacements
- Data/ Processing Equipment Improvement
- General Atomics Equipment Repl.

## Facility and Infrastructure

*Facility wide effort*

- Additional clean room space
- Additional radiation handling space
- Clean Dry Air Compressors Replacements
- Electrical System Replacements
- Chiller Replacements
- Boiler Replacements
- ....

## Target Area

### Final Optics

- Final Optics Refurbishment
- Debris Induced Damage Mitigation
- Blue Blockers Damage Mitigation
- Optic Installation Platforms Repl.
- Phase Plate Exchange Improvement

### Alignment and Optics Inspection

- Optics Damage Inspection System Repl.
- Chamber Interior Viewing System Repl.
- Target Alignment System Repl.

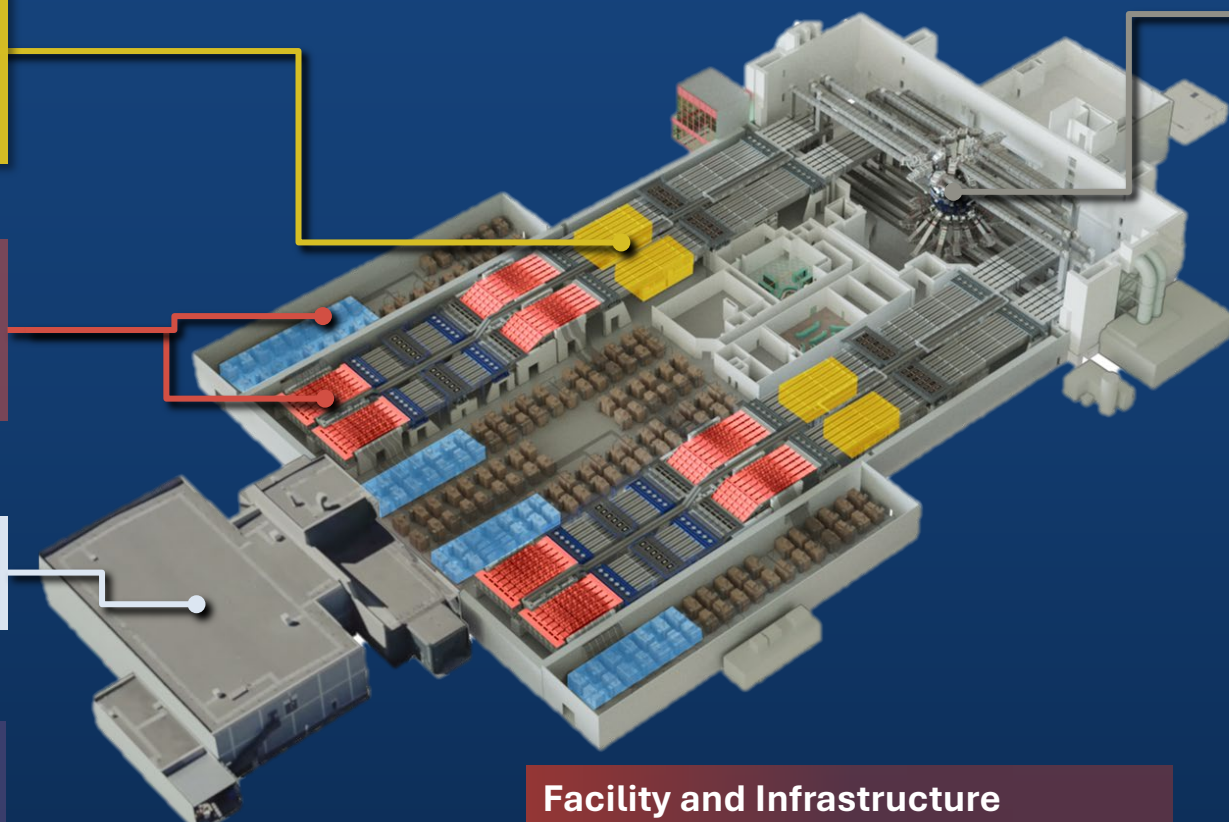
### Other

- Chamber Entry Lift Refurbishment
- Polar Diagnostic Insertion Replacement
- Target Line Replaceable Unit Improvement

## Controls and Data Systems

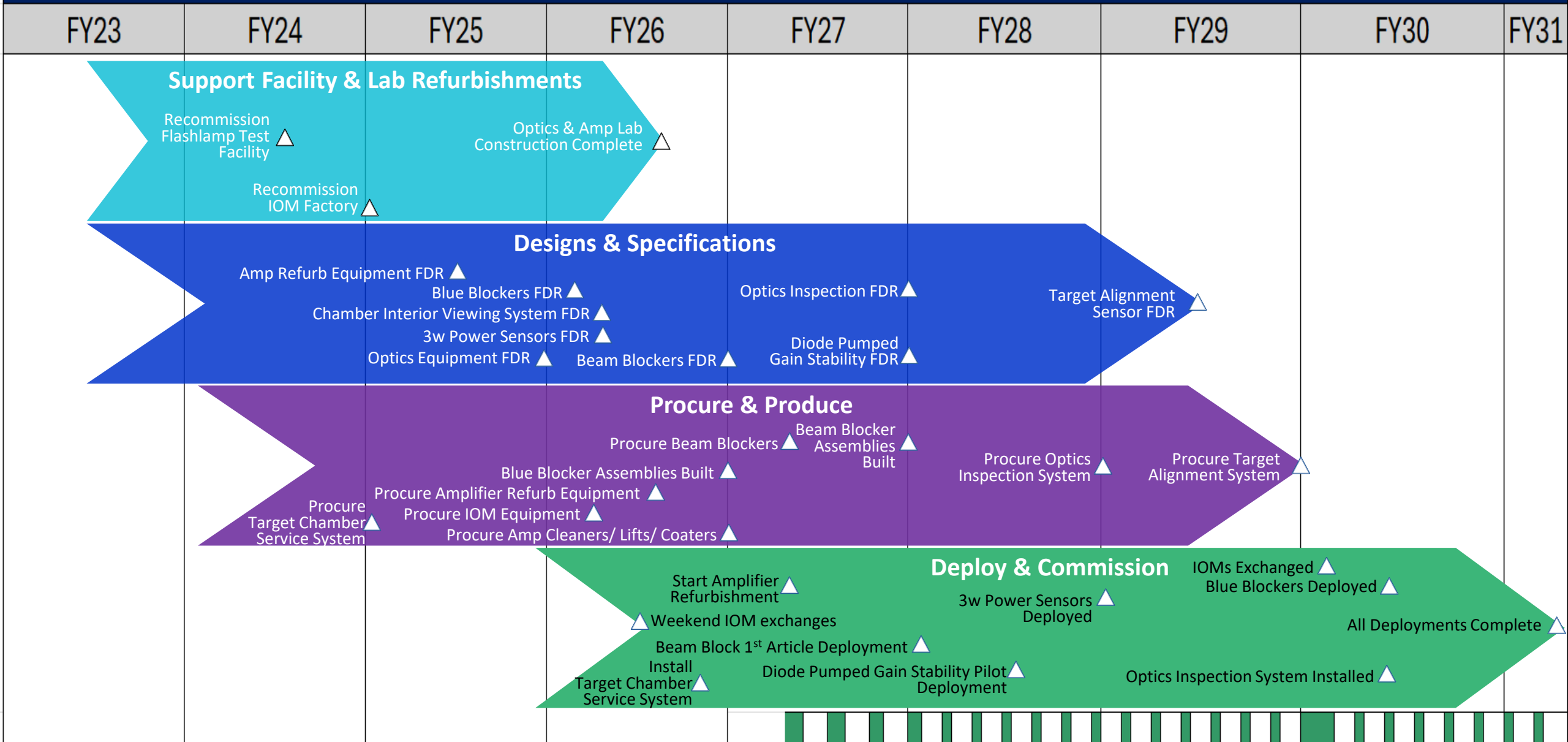
*Facility wide effort*

- Industrial Controls Replacements
- Facility Controls Replacements
- Embedded Controller Replacements
- Laser System Controls Replacements
- Alignment and Optics Inspection Controls
- Data Archive Replacement





# Sustainment Summary



NIF Increased Maintenance Periods

Extended Period

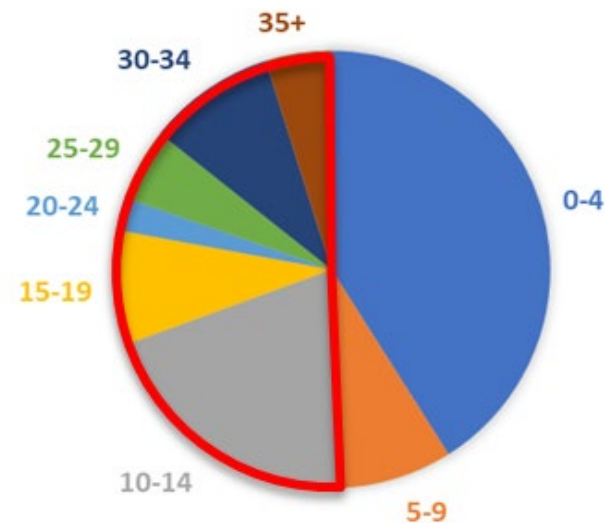
# Planned Approach for Increased Maintenance Time to Execute Sustainment Activities within NIF

- Several sustainment activities require increased maintenance time beyond the standard annual 6 weeks
- Original Sustainment Plan anticipated a 20% reduction in the experimental time in the final 2 years
- Refined plans made it clear that compressing into 2 years wasn't viable, so we've spread the same amount of increased maintenance time over the final 4 years, tentatively FY27-30 (funding level dependent)
- This refined plan anticipates a 10% impact in experimental programs over those 4 years, rather than 20% over 2 years. This approach is better for the experimental programs in the long run.

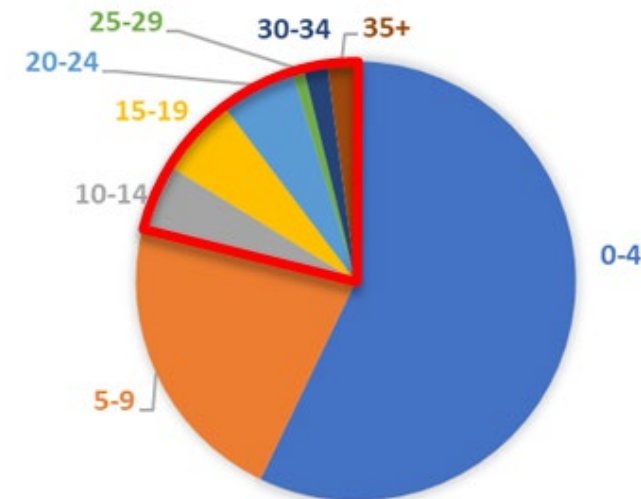
# Executing on Sustainment will restore skills to maintain NIF with the next generation workforce

- Our current workforce with greater than 10 years of service has reduced from 50% to 20% in past 6 years
- NIF sustainment provides an opportunity to re-train the workforce in the complex details of these critical NIF systems

YEARS OF SERVICE 2016



YEARS OF SERVICE 2022



# Sustainment is also for our staff

- Sustainment is for our future NIF teams
- Retirements + attrition have reduced the remaining workforce that built NIF
- We are taking a project approach to the sustainment projects
  - Defining projects with budgets and schedules
  - Utilizing budgetary and scheduling tools
  - Writing Project Execution Plans (PEPs) which define how the project will be run including WBS, budget, change control processes
  - This provides an opportunity for the project leaders to learn and use a formal process with project management and system engineering
- Integrated Product Teams (IPTs) are being revived to create forums for systems engineering discussions and decisions

# Key Take Aways

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- Without Sustainment, NIF would be unable to deliver the data needed to support the stockpile stewardship program and experimental campaigns at the rate currently required
- Sustainment prioritizes risk management of key systems that face performance degradation at NIF's current and planned operating levels – for example NIF's final optics
- Creates significant opportunity to train the next generation of workforce in engineering and scientific systems
- Sustainment efforts are entering their third year and are making significant progress in addressing the most critical areas.
- Completion of Sustainment restores NIF to its original operating and performance levels and readies it for higher yield capabilities



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