Status of the National Ignition Facility (NIF) Integrated Computer Control and Information Systems

18th International Conference on Accelerator & Large Experimental Physics Control Systems (ICALEPCS)

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NIF Integrated Computer Control System (ICCS)

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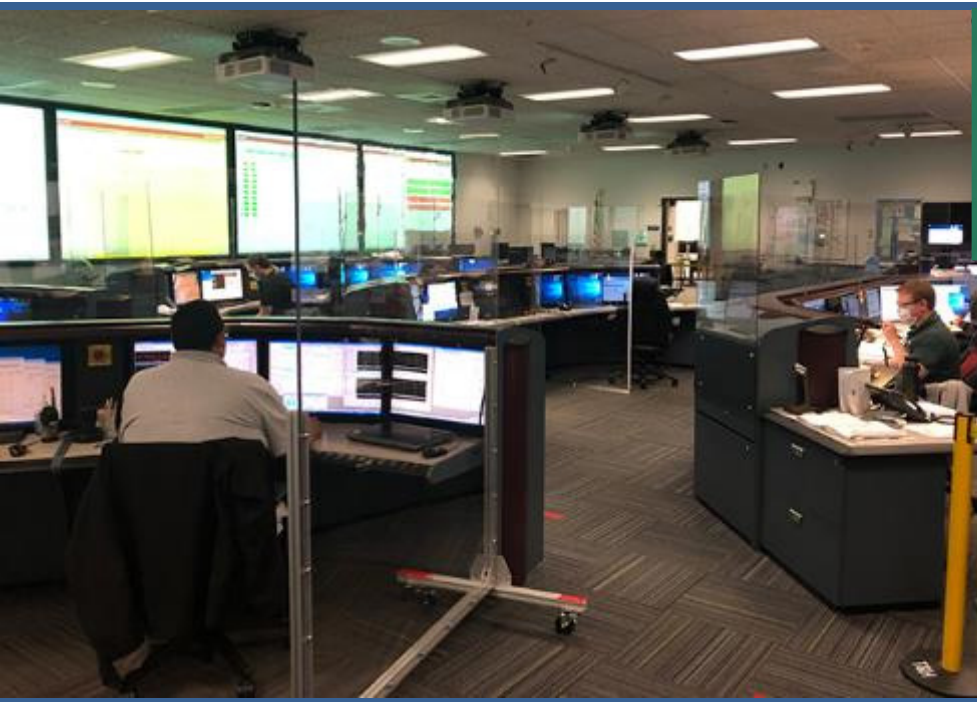
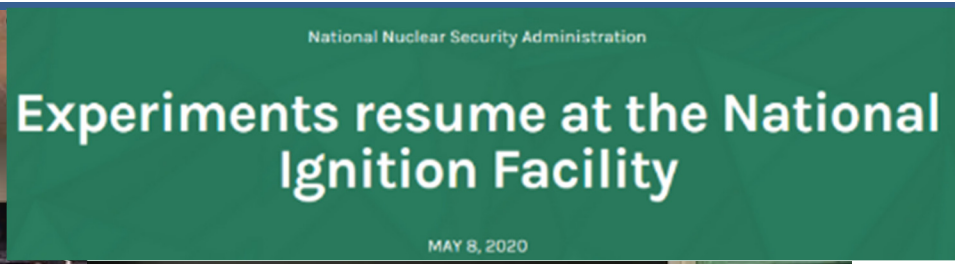
NIF in 2019-2021: Challenges, Priorities, Achievements

- **Maintaining 24x7 operations with minimal downtime during COVID-19**
- **On the path to Ignition: diagnosing, controlling, succeeding**
- **Prepare for the next 20 years of scientific discovery in HED (High Energy Density) and ICF (Inertial Confinement Fusions)**

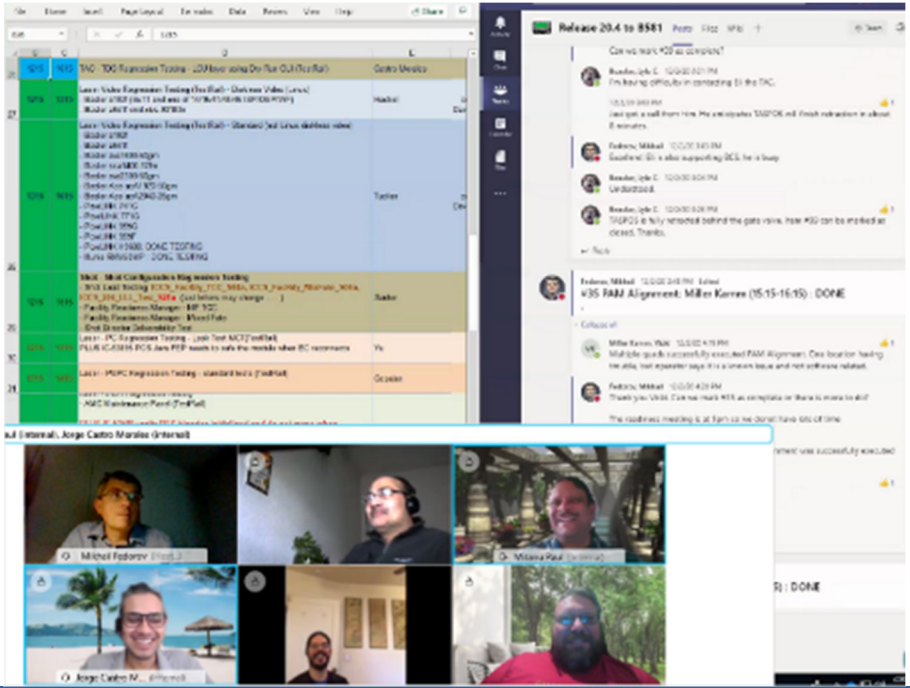
NIF Operations shutdown in April 2020 due to COVID-19 Shelter-In-Place order. Resumed in a month, to the praise from NNSA.





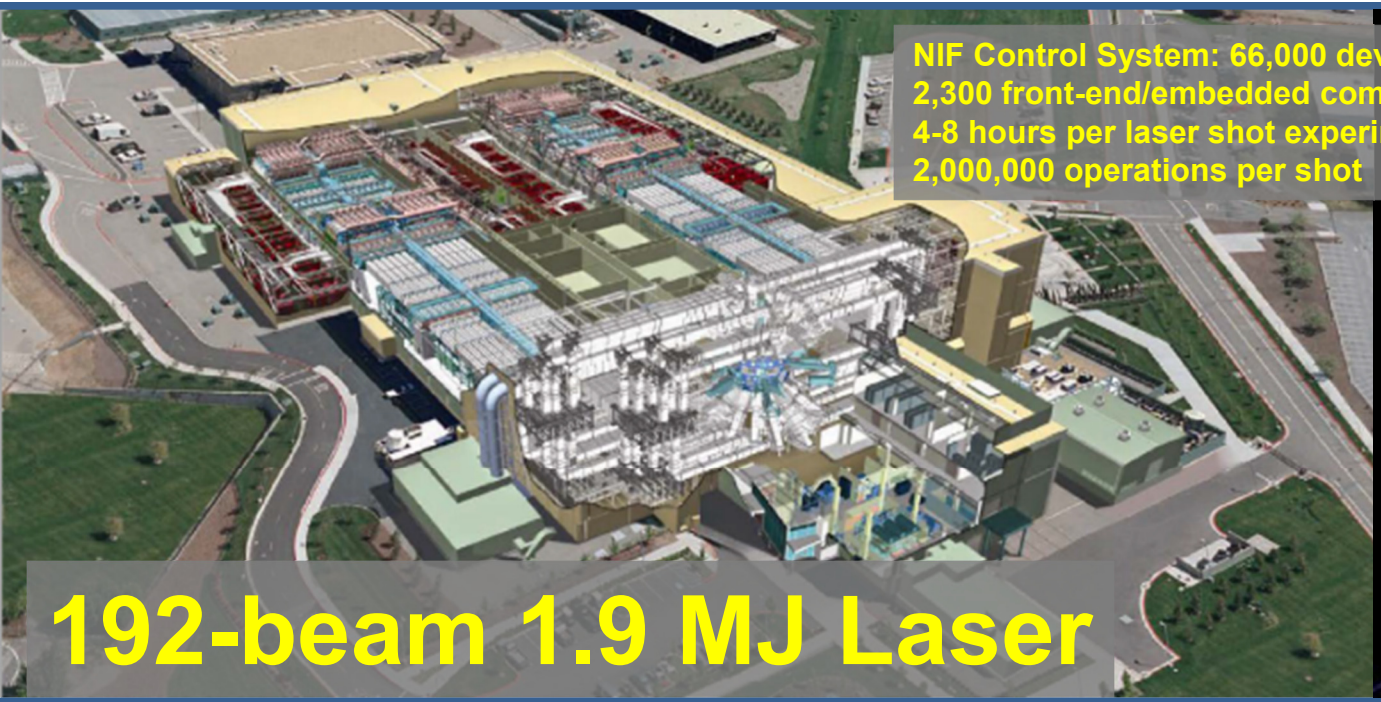
IT and Controls teams helped to secure NIF for minimal operations and resumption of experimental campaigns with new remote access, control and collaboration tools

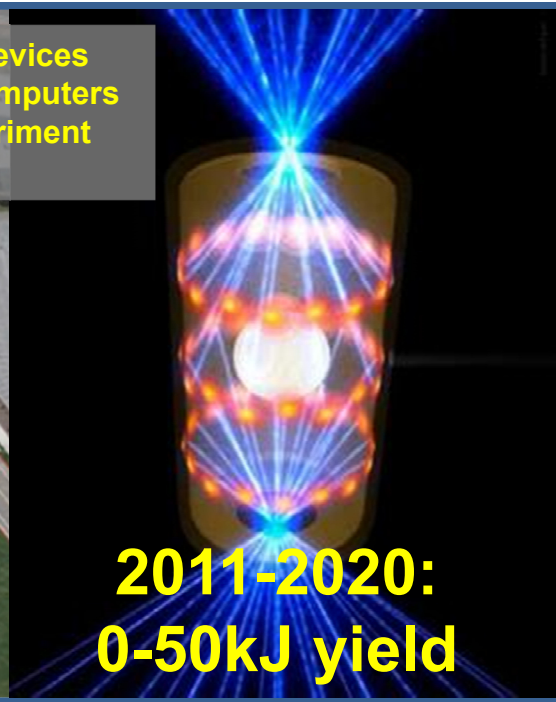
Change to all-remote 24x7 support and software delivery



Traditionally, software developers were joining NIF operators in the Control Room to test and troubleshoot our systems. With strict social distancing rules, we had to move out into cyberspace.

National Ignition Facility vs. Grand Challenge of Fusion Ignition



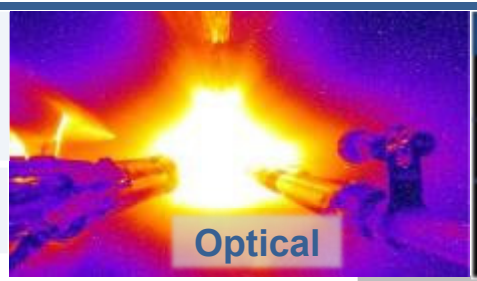


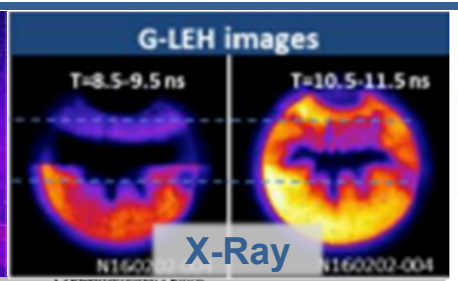
NIF, the world's largest and most energetic laser, is pursuing the goal of Ignition, when DT target produces more energy from fusion than laser drive input

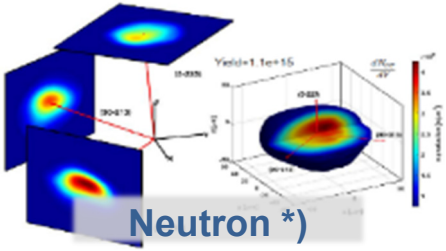
“Debugging” Ignition: extending control system to capture and measure target behavior in space, time and spectrum

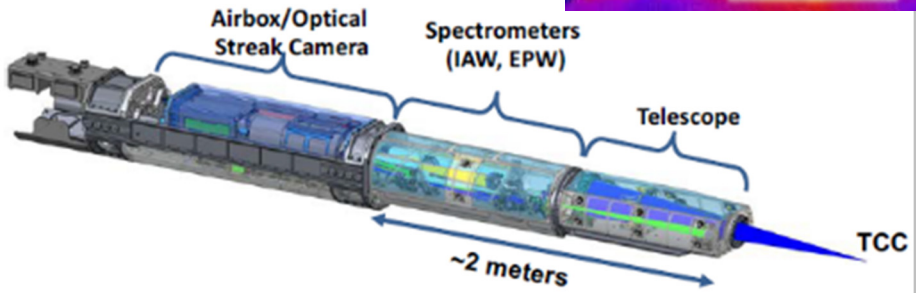
87 software-controlled diagnostic instruments, combining over 600 peripherals of 55 types (cameras, oscilloscopes, alignment, etc)

API-rich devices corresponding to 50,000 elementary control points

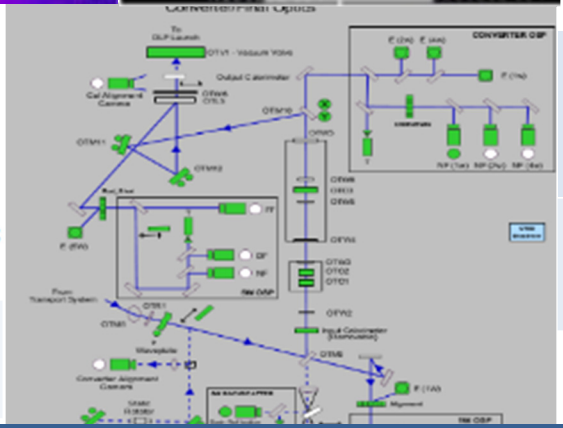








Optical Thompson Scattering (OTS): new instrument controls and automatic alignment for deep-UV (210nm) laser “plasma probe”: 400 devices, 3 new device types, 20 alignment loops



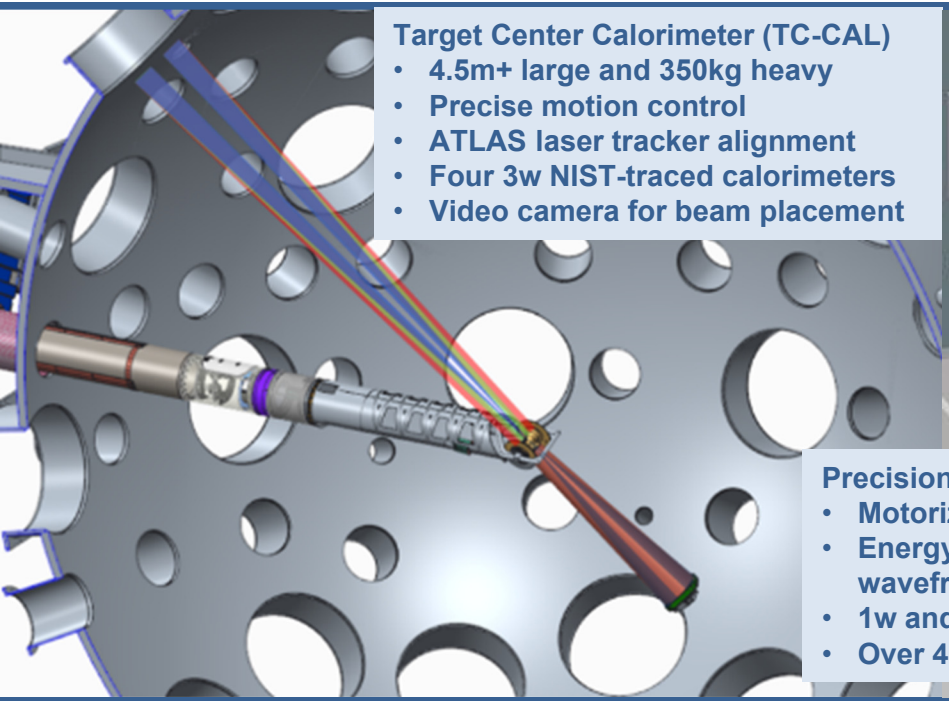
MOPV021 A.Barnes Upgrading the National Ignition Facility's (NIF) Integrated Computer Control System to Support Optical Thompson Scattering (OTS) Diagnostic

WEAL01 A.Awwal Image Processing Alignment Algorithms for the Optical Thomson Scattering Laser at the National Ignition Facility

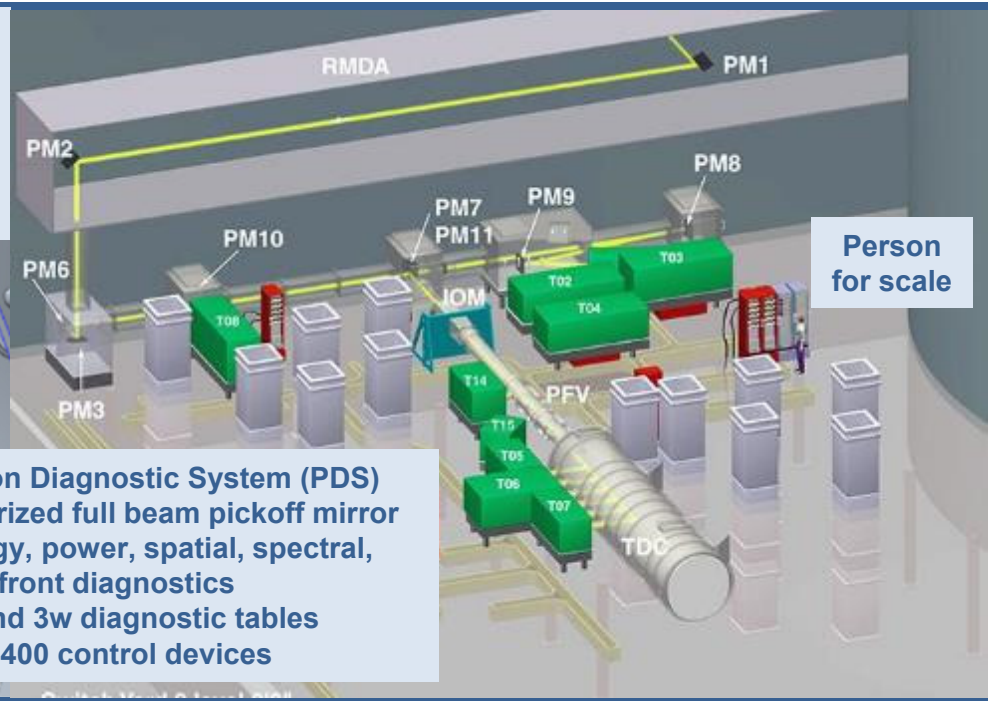
*) PL Volegov, SH Batha, DN Fittinghoff, CR Danly… 2021

Depending on the experimental goals, the control system commands 4-24 target diagnostic instruments through the steps of setup, alignment, dry-runs, picosecond-timed laser shot and data collection

“Debugging” the light which compresses the target – new instrumentation to characterize laser beams energy and quality



Target Center Calorimeter (TC-CAL)
- 4.5m+ large and 350kg heavy
- Precise motion control
- ATLAS laser tracker alignment
- Four 3w NIST-traced calorimeters
- Video camera for beam placement

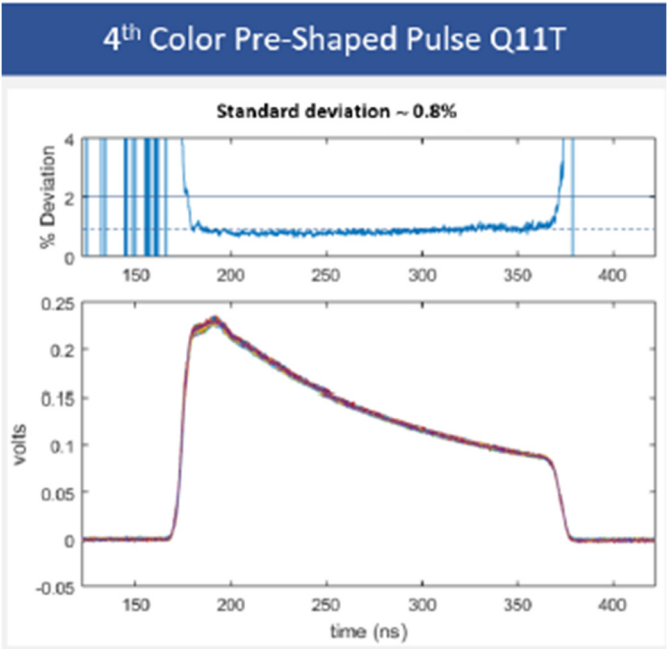


Person for scale

Precision Diagnostic System (PDS)
- Motorized full beam pickoff mirror
- Energy, power, spatial, spectral, wavefront diagnostics
- 1w and 3w diagnostic tables
- Over 400 control devices

New instruments allow to measure with improved accuracy parameters of 3w ultraviolet light delivered onto the target, tune-up the laser and update calibrations for better energy balance

From debugging to enhancing – better control of the laser pulse shape and adding laser wavelength “colors”



Modernization of the 15-years old MOR, Master Oscillator Room

Independent wavelength generation for Outer 50° cone, 4 colors total

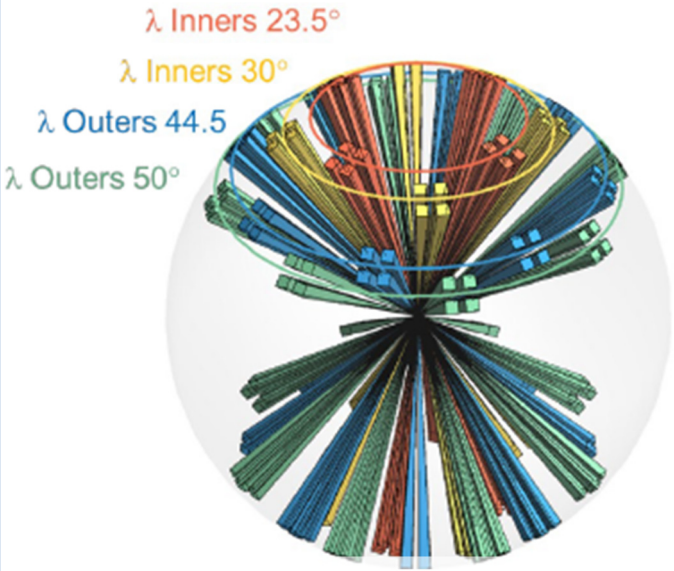
Pre-Shaped Pulse Generation PSPG for 3x better shot-to-shot stability

Enhancements to continue 2021-22: HiFiPS project

- new pulse shaping hardware
- new low-level software controls
- new pulse shaping algorithm
- 4X better short-term stability

FlexCM project

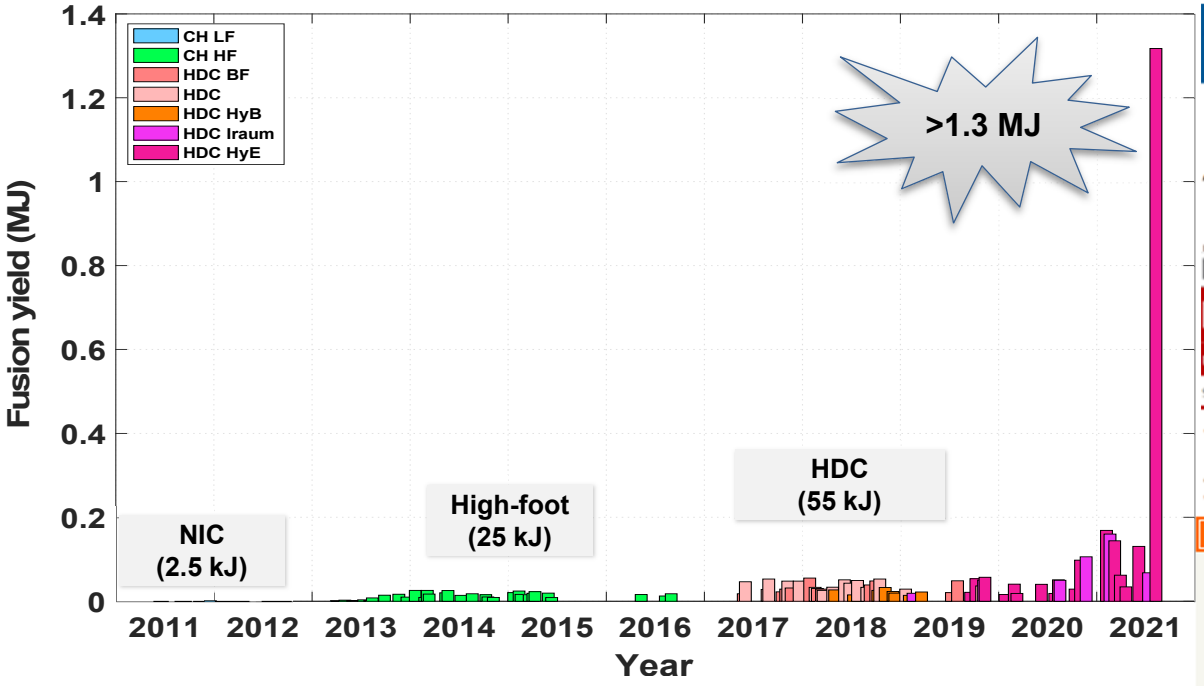
- custom map of colors to cones



Di Nicola, J. M., et al. The National Ignition Facility Laser Performance Status, 2021.

Better control of the laser pulse shape will improve energy control in the experiments and repeatability of the measurements

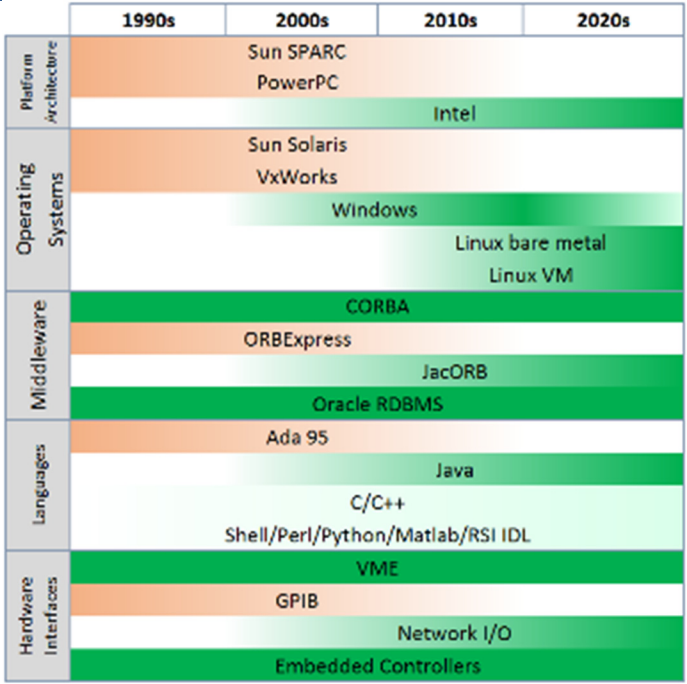
NIF shot on August 8, 2021, produced 1.3 MJ of fusion energy output, 8X over previous records



This latest experiment culminates a series of record-setting shots of 2020-21, breaking both the 100 kJ and 1 MJ barriers within a year

Failures of aging hardware as well as obsolescence of computing platforms call for a broad technology refresh effort

- **By 2020, NIF software team has completed migration from Ada95 to Java, from PowerPC VxWorks to Intel Linux, all without stopping 24x7 facility operations**
- **Current focus for 2020-2021 is to migrate Video acquisition systems from proprietary Windows software to Linux, open source, diskless**
- **Next: replace Embedded Controllers, a mix of VxWorks/PC104-like systems with a modern small factor platform**
- **Development of control system architectures for new mid-to-large laser projects for NIF & Photon Science (NIF&PS) Directorate of LLNL**



MOAR02 V.Gopalan Modernizing Digital Video Systems at the National Ignition Facility (NIF): Success Stories, Open Challenges and Future Directions

MOBL05 B.Davis Photon Science Controls: A Flexible and Distributed LabVIEW Framework for Laser Systems

Future Control System enhancements are part of large-scale sustainment plan to be executed over the next 5 years, necessary to extend NIF scientific discovery into the 2030s

Conclusion and Future Work

- **Unexpected challenge of COVID-19 has been mitigated by adapting to "New Normal" with more health protections, social distancing and remote work**
- **NIF achieved new exciting results on our 10+ years quest toward fusion ignition**
- **Increased neutron yields add urgency to already planned sustainability efforts, including renovation of the Control Systems**
- **NIF entered a new experimental regime, requiring a new generation of high precision, time-resolved diagnostics, such as Magnetic Recoil Spectrometer (MRSt)**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