Sustaining the National Ignition Facility (NIF) Integrated Computer Control System (ICCS) Over Its Thirty Year Lifespan

ICALEPCS 2017

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NIF/ICCS will remain operational until at least Spring 2039

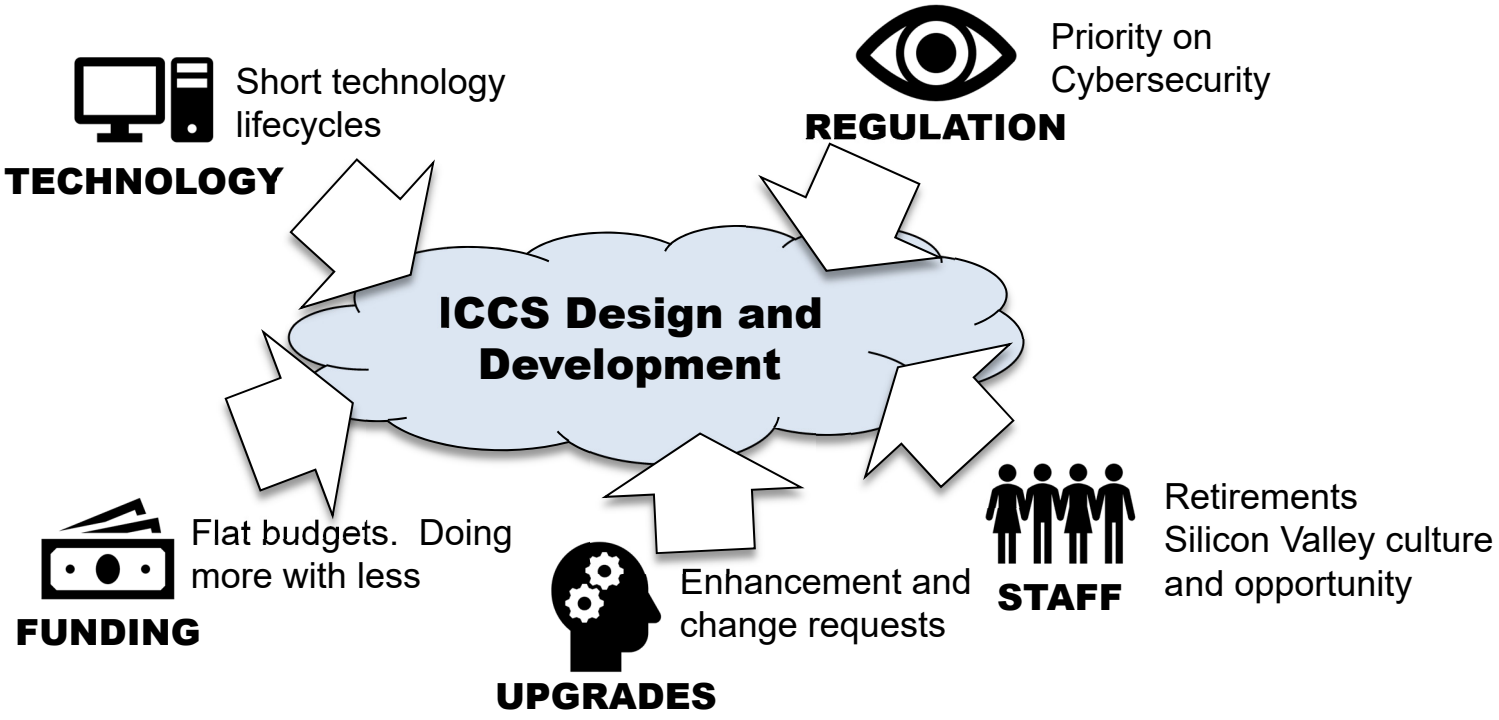
NIF was commissioned as an operational facility in 2009 with a 30 year planned lifespan

- ICCS coding started in the mid-1990s
  - Control system code has grown to over 3.5M lines
  - Much of that same code base is still in active use within NIF
  - Hardware has been used for 1000s of laser shots since operations commenced
- Multiple large influences are resulting in voluntary and involuntary control system updates
  - Demand from various programs for new capabilities
  - End-of-life for original software languages, hardware components, operating systems, and compilers
  - Operational need for high reliability, availability, and maintainability

Process and design changes are allowing us to manage this necessary volume of change

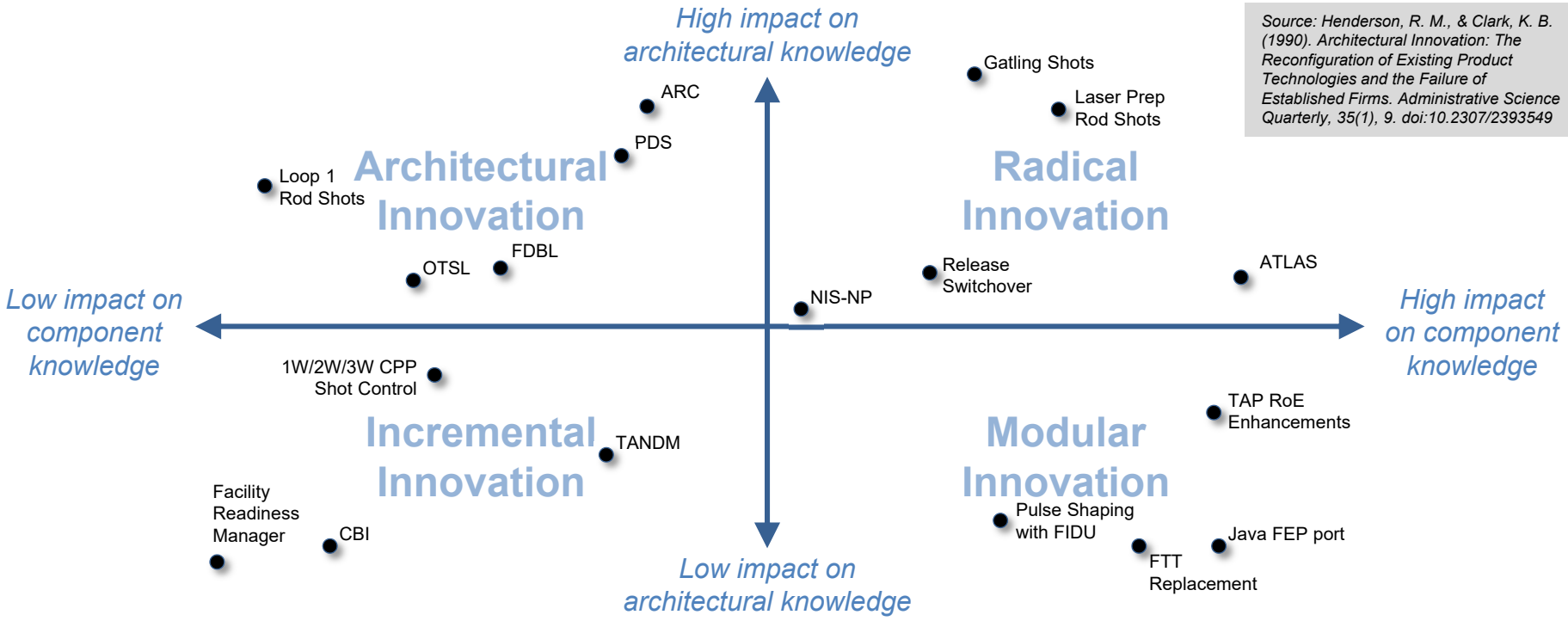
Influences on our design and development processes

Significant effort in managing project priorities with limited staff



Development processes need to accommodate loss of experienced and knowledgeable developers

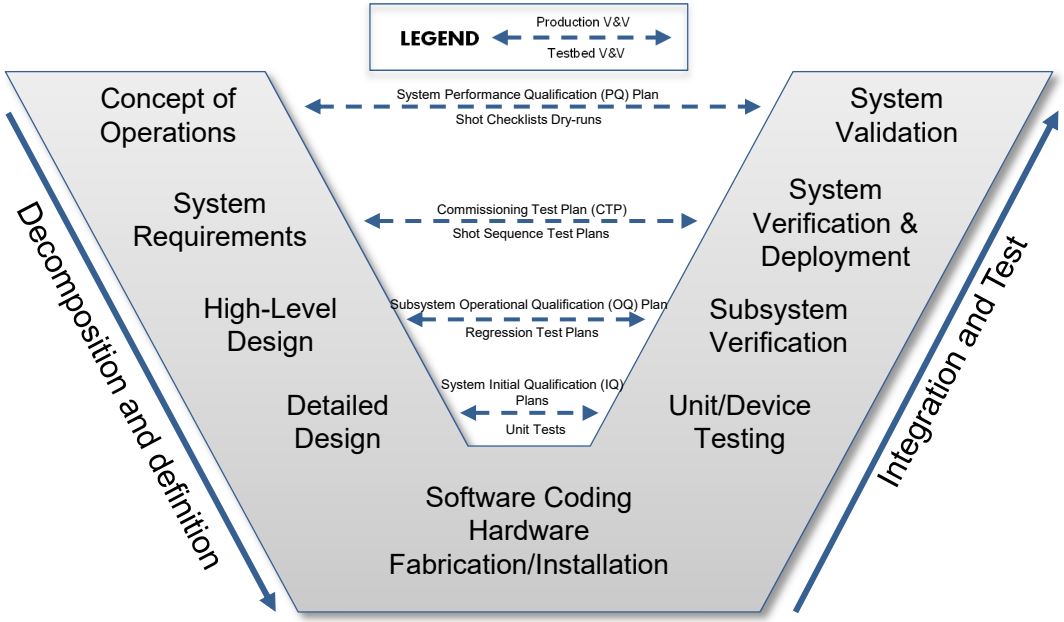
ICCS is undergoing significant architectural and component upgrades while NIF operates as a user facility



Source: Henderson, R. M., & Clark, K. B. (1990). Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms. Administrative Science Quarterly, 35(1), 9. doi:10.2307/2393549

Separate strategies are required to address both architectural and component level changes while ensuring high RAM

Investment in specific areas of the V-model were necessary for long term sustainability



- Design documents and test plans fell out of date as they were not intrinsically updated in development process
- Could not rely on subject matter expert retention
- As the number of software capabilities grew, manual testing could not sustain quality

Lessons learned from initial Ada to Java porting attempts quickly identified areas for improvement in quality processes

Mandatory automated testing institutionalized as pre-cursor for Java porting effort

Provides direct comparison of Ada vs Java results, including performance

- Too many test cases to qualify software in testbed solely through manual testing
- Schedule relief provided for porting milestones to focus on test frameworks and test case development
  - Substantial improvement on our ability to successfully deliver on those milestones
- Test case annotations:
  - "fast" for inclusion in continuous integration environment, and "slow" tests for running on-demand (e.g., by developer during coding)
  - Emulation, real hardware, or both
- Long term benefits:
  - Immediate qualification on component level changes, including hardware
  - Test cases documents expected system behavior to facility more rapid staff onboarding

		Ada		Java	
	Test Case	Status	Time (s)	Status	Time (s)
Common					
	checkEmulationStatus	PASS	3.002	PASS	2.999
	checkHealthStatus	PASS	3.003	PASS	3.004
	checkInterfaces	PASS	3.009	PASS	3.421
MotorBasicsTest					
	checkSettings	PASS	3.031	PASS	3.422
	getComponentStatus	PASS	3.033	PASS	3.011
	isMovingWhileBusy	PASS	7.433	PASS	9.012
	motorNotMovingWhileIdle	PASS	3.006	PASS	3.002
	setBacklash	PASS	3.017	PASS	3.011
	setInvalidHighBacklashFails	PASS	3.011	PASS	3.001
	setInvalidLowBacklashFails	PASS	3.021	PASS	3.022
MotorFindLimitTest					
	findLimitWhenMotorStoppedFails	PASS	7.269	PASS	15.180
	findLimitWhileBusyFails	PASS	6.587	PASS	8.104
	findLimitWithInvalidKeyFails	PASS	3.067	PASS	3.062
	findLimitWithValidKeySucceeds	PASS	28.230	PASS	30.734
	findNegativeLimitSucceeds	PASS	34.215	PASS	36.725
	findNegativeLimitWhenAtNegativeLimitSucceeds	PASS	15.614	PASS	20.240
	findPositiveLimitSucceeds	PASS	20.602	PASS	22.357
	findPositiveLimitWhenAtPositiveLimitSucceeds	PASS	15.619	PASS	20.202

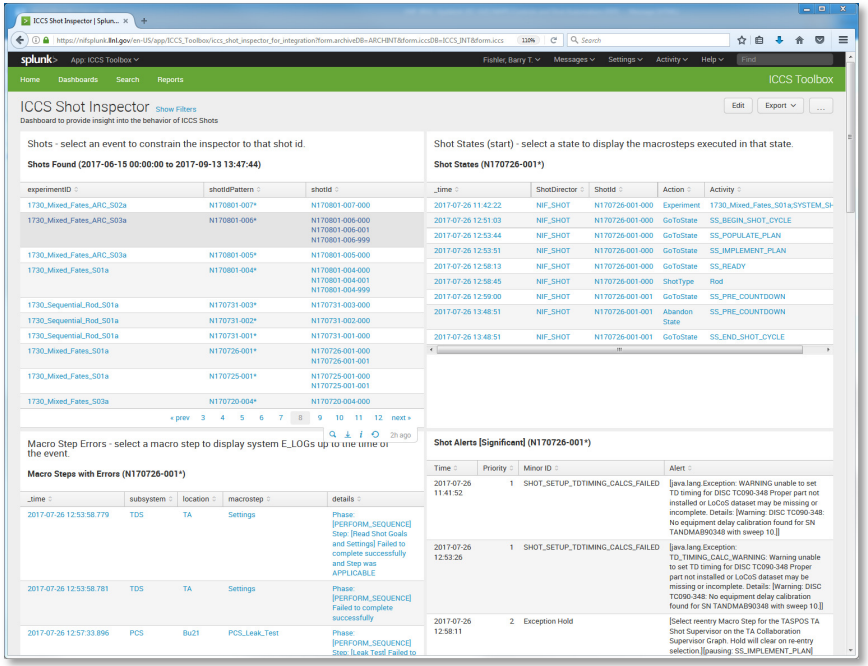
Sample test results for early run of Java motor

Manual testing, especially in the form of exploratory testing, is still a necessity for testing components

End-to-end automated shots in an emulated NIF environment

Used for frequent verification of shot cycle integrity

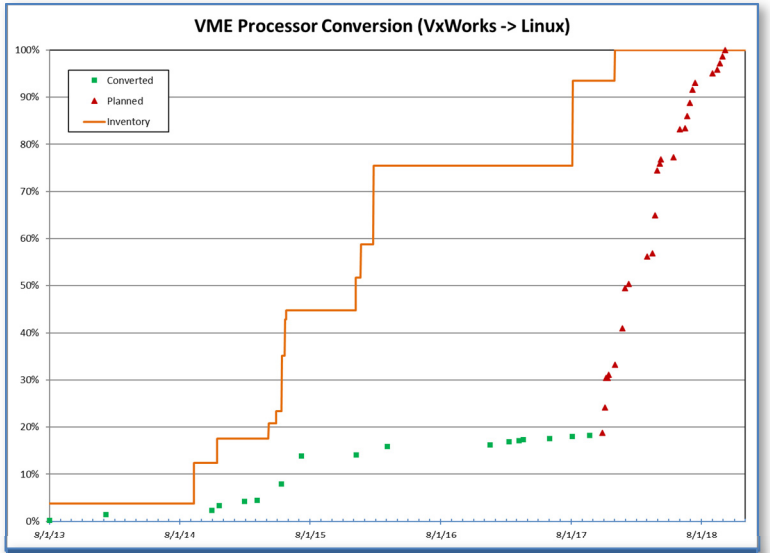
- Developed the Automated Shot Tester (AST) engine to run series of end-to-end NIF shot sequences
- Allows coverage of the significantly expanded value of experimental test variations
  - Manual testing could no longer effectively cover all of the variations
- Test cases includes NIF reconfiguration activities, experiment updates mid-shot, and off-normal events
- Test cases are run after-hours
- Focused manual shot testing by developers and testers offline is still required to look deep into subsystem behavior



Future enhancements includes measurement of performance impact for critical path analysis, and inclusion of AST in our continuous integration environment

Simplification of our build environment through Java porting

- Porting effort has been challenging, but necessary for maintaining ICCS in the long term
- Interpreted language reduces compilation for specific operating systems
- Virtualized Linux and Windows for supervisory systems, and some FEPs
- VME based Single Board Computers (SBC) running customizable Linux Gentoo distribution



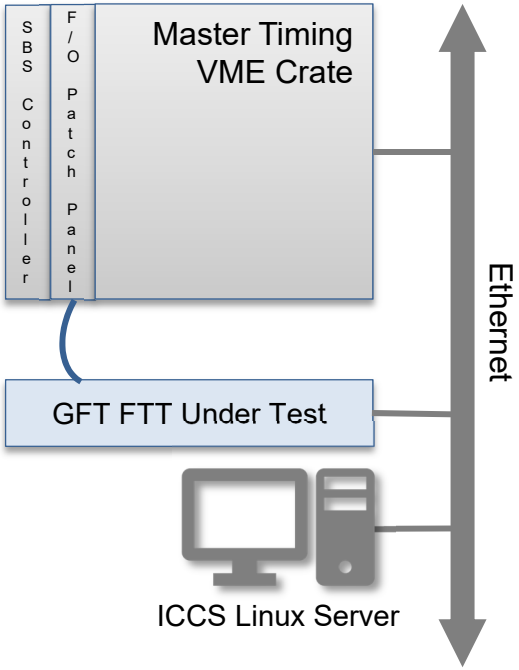
Spike in VME conversion rate represents code complete for >90% of device types

SBC procurements performed in bulk to minimize manufacturer changes.

Replacement of original timing hardware from 1990s

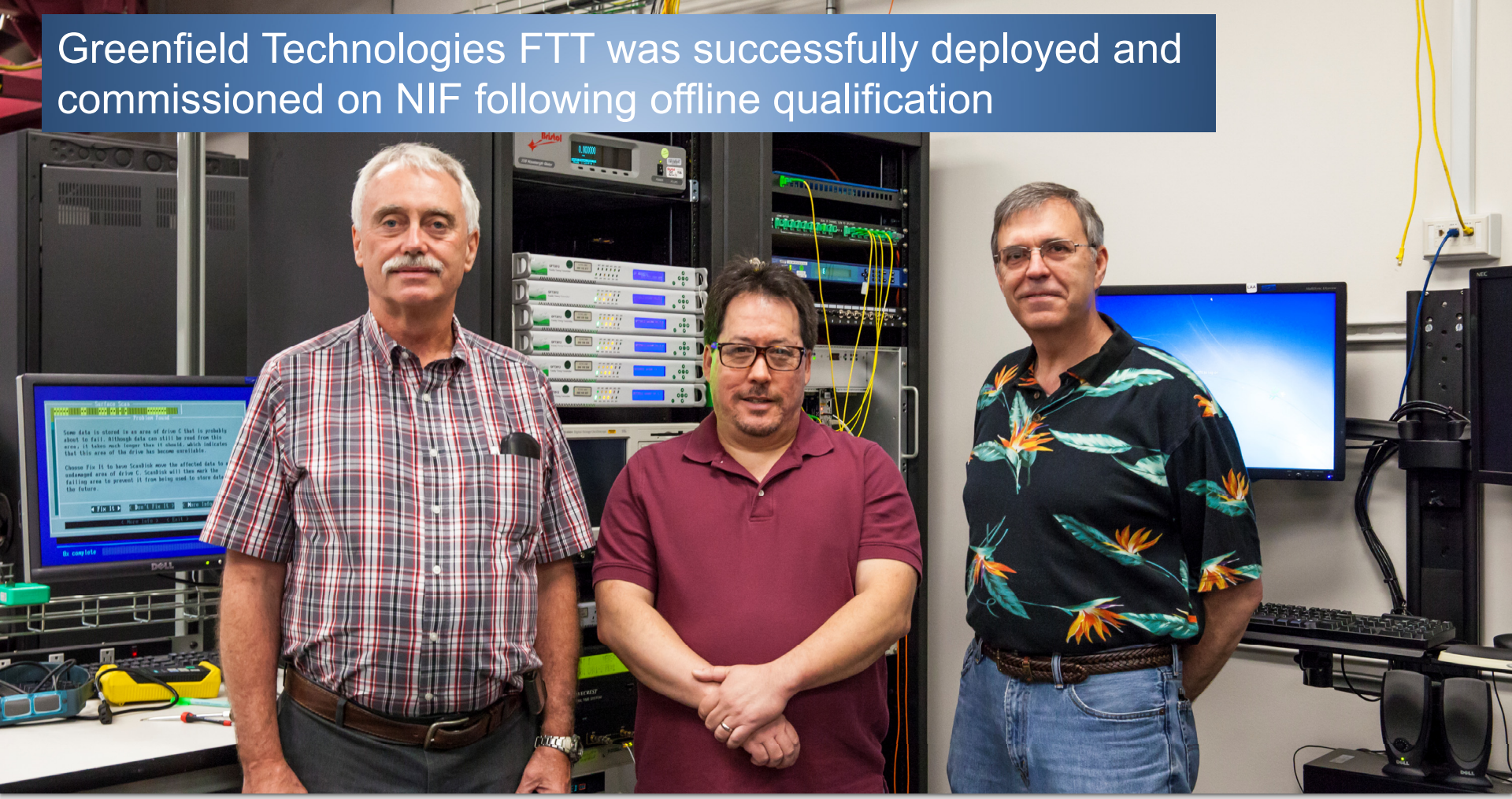
Delivered ICCS test platform for vendor qualification on new Facility Timing Transmitter

- Custom Facility Timing Transmitter hardware was long past end-of-life
- Manufacturer had been bought and resold multiple times. No engagement from new company without $$$
- High risk in source code held in escrow. Many updates had been applied to production FTT firmware
- Loss of timing SME due to retirement
- Greenfield Technology contracted to build drop-in FTT replacement
- Shipped “ICCS In-a-box” complete with automated test suite to factory acceptance testing of new system



Automated test suite provided the interface control requirements in the absence of formal documentation

Greenfield Technologies FTT was successfully deployed and commissioned on NIF following offline qualification



Conclusions

- Modernization is a necessity for sustaining ICCS over the next 20 years
- Cannot rely on retention of SMEs
- Automated testing used to document requirements and behavior of components
  - Supports component changes and onboarding of new employees
- Automated testing required for systems undergoing significant architectural changes
- Flexibility in platforms while simplifying runtime and compile time environments