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ONGOING IMPROVEMENTS TO THE INSTRUMENTATION AND CONTROLS SYSTEM AT LANSCE*

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Abstract

Recent upgrades to the Instrumentation and Controls System at Los Alamos Neutron Science Center (LANSCE) have significantly improved its maintainability and performance. These changes were the first strategic steps towards a larger vision to standardize the hardware form factors and software methodologies. Upgrade efforts are being prioritized though a risk-based approach and funded at various levels. With a major recapitalization project finished in 2022 and modernization project scheduled to start possibly in 2025, current efforts focus on the continuation of upgrade efforts that started in the former time frame and will be finished in the latter. Planning and executing these upgrades are challenging, considering that some of the changes are architectural in nature; however, the functionality needs to be preserved while taking advantage of technology progressions. This is compounded by the fact that those upgrades can only be implemented during the annual 4-month outage. This paper will provide an overview of our vision, strategy, challenges, recent accomplishments, as well as future planned activities to transform our 50-year-old control system into a modern state-of-the-art design.

INTRODUCTION

Los Alamos Neutron Science Center (LANSCE) has been in operations for over 50 years. The multifunctional facility has grown over the years and has now five distinct state-of-the-art experimental facilities which provide the scientific community with intense sources of protons and neutrons, with the capability of performing experiments supporting civilian and national security research [1].

LANSCE was one of the first linear accelerators that had computerized control. Over the years some of the instrumentation & controls equipment (ICE) interfacing with a variety of beam line devices have been added and upgraded. As a result, the facility accumulated a wide variety of ICE hardware form factors and software methodologies that challenge the maintainability and longevity of the LANSCE Control System (LCS).

To address these concerns, a methodical and relatively well-funded upgrade effort between 2011 and 2022 focused on the replacement of the original 50-year-old RICE (Remote Instrumentation and Control Equipment) system. It was replaced with a modern customized control system in stages during each annual 4-month accelerator outage period. Despite the recent modernization success, the LCS still contains equipment up to 40+ years old and requires significant long-term investments beyond current base funding levels to upgrade it to current controls hardware and software technology maturation levels [2, 3].

Once that has been achieved, the focus should shift from upgrading obsolete and past-end of life equipment to active forward-looking life-cycle management. Accelerator instrumentation and control systems (from here on called simply “control system”) are modern information technology systems, and as such require constant investments. Risks associated with neglecting active lifecycle management increases the risk of disruption to operations, extended downtime, increase of system complexity which will increase maintenance cost, and loss of upgrade paths resulting in potentially costly greenfield recapitalization projects.

CONTROL SYSTEM DESCRIPTION

To understand the LCS upgrade and maintenance challenges, it helps to present some of the boundary conditions. First, we will describe the LCS size/complexity, and in the next section (Control System Group) we will discuss the number of people supporting it, their background, and funding levels.

The Accelerator Operations and Technology division – Instrument and Controls group (AOT-IC) is responsible for maintaining LCS which utilizes EPICS (Experimental Physics and Industrial Control System). Geographically, AOT-IC’s responsibilities include all ICE starting from the two Injectors through the nearly half-mile long accelerator, a proton storage ring, and the distribution lines to the experimental facilities including some target stations but not the experimental end stations.

Technically, AOT-IC is responsible for the computer-based system that gathers and analyzes industrial process and real-time data to monitor and control accelerator relevant equipment that deals with critical and time-sensitive information or events. This includes a distributed event-based timing system to trigger actions at different locations at the same time and in sequence with predefined time intervals, while synchronizing the local time at different locations with high precision and timestamping events at different locations to analyze what happened first.

In addition, the group is responsible for the LCS network star-like infrastructure including firewalls, core switches, distribution, and leaf switches as well as the CAT6 and fiber optics cable plant. Moreover, AOT-IC maintains its own server infrastructure. Finally, the group develops, deploys, and maintains all software application needs and custom services.

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It is worth mentioning that our group also maintains its own Electronic Computer Aided Design (ECAD) capability for high-speed, high-power, mixed-signal multilayer, and multi-stack circuit-board design using Mentor Graphics software for layout and simulation. In addition, 3D mechanical and electrical modelling using 3D SOLIDWORKS and SOLIDWORKS Electrical 3D supports the development of custom parts, prototypes, assemblies for fabrication plus advanced rendering and motion analysis capabilities as well as wiring and cable routing schemes used to provide verification of proper fit and length planning. This is complemented with our own 3D printing capability for rapid prototyping and cost-effective design optimization.

In other words, AOT-IC is a one-stop-shop for all instrumentation and controls hardware and software needs to operate and support the LANSCE accelerator. Table 1 below provides an overview of key numbers, providing a sense of size and complexity of LCS.

Table 1: LCS Size

Description	#	Description	#
Process Variables	~171k	AB PLCs	23
Network addressable Devices w/ IP address	~1500	Support Scripts	~883
Workstations providing LCS access	~101	Network Switches	~110
Operator Stations	8	Virtual Networks	4
NI cRIO IOCs	233	GUIs	~930
LLRF FPGA IOCS	34	Virtual Computers	44
TDAQ FPGA IOCs	62	Servers	22
BPPM FPGA IOCS	88	*VPX/cPCI standard*	

From an instrumentation and controls hardware prospective LCS consists of the following form factors: NIM-BIN, CAMAC, VME, and Allen Bradley PLCs, as well as our newer form factors like NI's cRIO, VPX, and cPCI. From the software perspective, the LCS supports the following real-time operating systems: RTEMS 4.x, VxWorks 5.x & 6.x, LinuxRT; other operating systems RHEL6, Solaris, Gentoo, RHEL7, Rocky 8, Windows, EPICS releases 3.14.x, 3.15.x and our own EPICS Data Access Release 3.15.x; programming languages; Java, Python, LabVIEW, as well as several scripting languages.

CONTROL SYSTEM GROUP

The AOT-IC group is led by a group leader and deputy group leader and consists of two teams (Hardware and Software) with each having their own team leader. As of this writing AOT-IC has 28 group members. Including the team leader, the Hardware Team consists of 14 members (3 technicians, 1 designer/drafter, 1 electronic computer-aided design technologist, 2 electrical/electronic technologists, and 6 engineers). The engineering staff's background includes electrical-, mechanical, and systems-engineering. Including the team leader the Software Team consists of 12 members with backgrounds in computer science, computer-, mechanical-, and systems engineering, as well as physics.

The maintenance and operational support of LCS provides most of the funding for the group. For Fiscal Year (FY) 2024 (October to September the following year), AOT-IC will receive for their efforts about $1.8M to purchase material and receive in addition funding for about 18.5 full time employees (FTEs) with about 1740 productive hours each, totaling 32,190 hours for the FY. Given that the group leader and half of the deputy group leader position is funded separately (out of overhead), this means that the group must seek and support other work that funds the remaining 8 FTEs, assuming the size of the group should stay at 28. In other words, about 27.7% of the groups time is spent supporting other funded accelerator (i.e., R&D activities, experimental facility work, …) and non-accelerator work.

It should be noted that even though 18.5 FTEs are funded by LCS M&O it has been our experience that the actual productive FTE levels are much lower. The reason is that extra-curricular institutional demands (training, meetings) and responsibilities (i.e., Chemical Inventory Coordinator, Designated Procurement Representative, Procurement Technical Representative, Mechanical Material Handling Coordinator, Worker Environment Safety and Security Team Representative, …, etc.), while justified and necessary, reduce our time to perform our technical M&O work. For planning purposes, we only consider about 67% of an FTE as technically productive, which reduces our M&O support to 12.4 FTEs.

Along these lines, it seems that for a long time every year our group must do the same or more work with funding that does not keep up with the cost of operations. It reduces our ability to keep up, with industry technology development pace falling behind technology maturation levels. While our funding situation may not be under our control, one aspect that is under our control is the skill level of our group members through targeted hiring and training, as well as our effort to improve our process-driven work (see later sections on Project Planning & Execution as well as Project Monitoring & Control). As such, our group provides ample training and certification opportunities to our group members which has resulted in a considerable list of certifications:

- **Fabrication and Assembly**
  - ETA International Fiber Optics Installer (FOI) Certification.
  - IPC/WHMA-A-620 Cable Assembly
  - IPC J-STD-001 Soldering
- **ECAD**
  - IPC 2221 Class 2 (Dedicated Service Electronic Products)
  - IPC Class 3 (High Reliability Electronics Products)
- **Software Development & Network Management**
  - Certification in Allen Bradley Logix 5000 Programmer/Maintainer
  - Certified LabVIEW Developer
  - Cisco Certified Network Associate

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- **Management**
  - Lean Six Sigma Yellow Belt
  - Management of Technology
  - Project Management Professional

MISSION

AOT-IC is a capability-based organization which focuses on the branch of engineering that studies the measurement and control of process variables, and the design and implementation of systems that incorporate them. Our mission is to understand and exploit instrumentation and controls capabilities for Los Alamos National Laboratory's (LANL) mission needs. As such, we provide complete engineering services for the selection, application and integration of measurement, control, analysis, process control, server, network, and data management systems for a wide variety of applications. We see ourselves within a larger eco-system at the Laboratory and collaborate with other AOT groups and other organizations at LANL. However, since our group would not exist without LANSCE, our primary focus is the maintenance and operational support of LCS.

VISION

Like many other organizations supporting older accelerator facilities, AOT-IC must carefully balance its annual material and labor resource investment between maintaining and supporting operations of the existing LCS and planning for its future. In that context, AOT-IC's vision for LCS seeks to outline what the future may look like and what values/criteria are guiding that journey. It starts with an assessment of where we are today and what risks and gaps need to be addressed. A relevant strategy is the step that gets the LCS from where it is today to where the vision wants it to be. Defining the mission (previous section), assessing where we are today, and establishing a vision for the future are critical elements before developing a strategy. As such, AOT-IC has cultivated a vision which is guided by 6 principal values/criteria:

1. Continue to develop a most qualified workforce.
   - Invest in developing a skilled and balanced workforce in support of the group's mission.
2. Conform to safety and regulatory requirements.
   - Ensure secure and safe operations of systems.
3. Reduce equipment failures and unplanned downtime.
   - Take proactive maintenance/upgrade steps to reduce system failures, address system obsolescence issues, and improve maintainability.
4. Optimize operational efficiency and performance.
   - Improve/upgrade systems that show operational inefficiencies or offer performance improvement opportunities.
5. Decrease operational & maintenance costs.
   - Streamline control hardware form factors and software methodologies with simplicity in mind.
6. Extend software and equipment lifespan.
   - Use a risk graded driven approach to maximize the return of investments for software and equipment.

Consequently, AOT-IC developed a LCS-specific vision and a strategy that incorporates these 6 values/criteria. At a very high level we believe values/criteria 3 to 5 can be best achieved by keeping LCS as simple as possible without compromising its ability to deliver on its functionality and performance required to support the LANSCE user facility program. To achieve that we have chosen to focus on reducing LCS's complexity and the variety of interfaces, hardware equipment and software tools used.

There are two platforms on which we standardize: 1) National Instrument's (NI) cRIO automation controller and 2) a distinctive 2-form factor system (VPX/cPCI crate) both supporting distinct capabilities. NI cRIO systems are used for 1a) slow controls/monitoring, and 1b) interceptive beam diagnostics. VPX/cPCI systems are used for non-interceptive diagnostics such as beam position and phase monitors & timed data acquisition which captures waveforms with real-time customizable timing and beam species triggering.

Standardization will improve our ability to leverage our research and development investments across a greater variety of applications through the reuse of new or existing technologies. It will also improve our efficiency, collect operational experience across a greater range of similar applications feeding back into our maintenance program, keep up better with our product lifecycle management, improve our economy of scale (cost) for purchases, and simplify our spare inventory management. In addition, it will reduce the training requirements for our controls group members and improve their flexibility to work across different LCS systems, among other things.

Like everything in life, objectives and boundary conditions may change in the future. Hence it is important to revisit/update our vision and strategy frequently - at least annually, given a typical annual fiscal cycle and the annual accelerator maintenance/run cycle.

In an environment where annual M&O budgets are often insufficient, managers have the challenging task to seek additional funding to update their control system. A developed vision and strategy deliver a documented justification for an increase of an annual M&O budget or additional one-time funding to address critical LCS deficiencies. As we will see later, as part of a Risk Management Plan, a risk register articulates specifically the possible impact on the control system if strategic activities are not being funded.

DEVIDE & CONQUER THOUGH SUBJECT DOMAINS

Many of the older accelerator facilities have control systems that have grown over time in size and complexity making it often difficult, even for long serving members of a controls group, to comprehend and evaluate the entire system that the group is responsible for. Retirement, employee turnover, and changes in leadership may compound this issue. However, to develop a strategy towards a vision one needs to understand the entire scope of the controls system and assess its current state.

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The question then becomes how to capture these systems with their longevity in mind. One could sort them based on their geographical location (i.e., low energy transport, drift tube linac, …), based on their type of application (i.e., quadrupole power supplies, vacuum ion pumps, wire scanners), or one could sort them by hardware form factors (i.e., microTCA, VME, cRIO, …). Each of these approaches provide advantages and disadvantages.

We offer a different approach which introduces the concept of a subject domain or capability. The term subject domain has been used in software engineering. Formally it represents the target subject of a specific area of responsibility, whether narrowly or broadly defined. We expand this term to the hardware area of responsibility of our control system.

The advantages, as we see it, are that these subject domains provide longevity within our control system. While the underlying software technology and hardware form factors may change over time, traditionally certain domains or capability persists. This makes developing a vision and strategy for these subject domains more meaningful and long lasting. A positive side effect is that it allows to track over time its progression and consolidation in these subject domains. It is of course important that these subject domains vision and strategies fit into the larger concept of the six values/criteria as outlined in the previous section.

In the following we describe these subject domains specific to LANSCE which align with our software and hardware team structure and the team's area of responsibility.

Software Team - Subject Domains

- **Control System Network:** switches, firewalls, network cables (i.e. fiber, CAT6).
- **File Server System Administration:** software packages and server operating systems.
- **Control System Platforms:** IOC operating system, board support packages.
- **IOC Application Software:** Industrial I/O, instrumentation including data acquisition and motion ctrl.
- **Graphical User Interfaces:** EPICS edm,Tcl/TK, Java.
- **Archive and Alarms:** CA-Flux, EPICS Appliance,
- **Utilities**: Central Control Room Log, other EPICS extension, non graphical user interfaces.
- **DevOps**: Revision Controls, Application development environments, EPICS releases, integration, and improvements.

Hardware Team - Subject Domains

- **Timing System:** Master Timer, Distributed Timing IOCs, fiber optics cabling, pulsed timing.
- **High Speed Data Acquisition:** real-time, triggered/synchronized, waveforms.
- **Industrial I/O:** control and slower monitor functions**.**
- **Motion Control:** actuators.
- **Signal Conditioning/Level Conversion:** COTS (TCs, RTDs), cPCI, Custom-no back plane (MTD, synchronizers).
- **Visual Systems:** Hi-rad & network cameras.

We acknowledge that there are possible interfaces/overlaps within and among the hardware and software subject domains. Other accelerator facilities may choose a different subject domain classification. Given the complexity of our control system and considering the pros and cons of the other alternatives to categorize it, we believe this is the best option for us.

SUBJECT DOMAIN ASSESSMENT & STRATEGY

The control system as whole is only as reliable as its systems in each of the individual subject domains. Even though different domains will have different impacts on the availability of the control system (i.e., network is going down vs operating system on servers is three versions behind the most current release), for their longevity it is important that all subject domains maintain their functionality and keep up with their technology maturation.

For each subject domain we envision a Strategic Lead (SL). That person is not necessarily a system expert (even though they might become one), but is responsible for assessing the current state, creating a vision, and strategy for the subject domain. The SL does so by leading the effort and utilizing people with subject domain knowledge and reports to the team leaders and group management. Defacto (s)he is the spokesperson advocating for the subject domain. SLs may rotate in an out of these positions at an appropriate interval but ideally stay on for at least a year, in line with the review cycle of the subject domains, thus providing leadership and career development opportunities for our group members.

The SLs will assess each subject domain's current state using established criteria and associated scores (1, 2, or 3)) to determine the most critical systems based on Safety, Security, Environment, and the ability to support the LANSCE's Mission. The latter considers Reliability, Availability, Maintainability (RAM).

- **Reliability:** Is the probability of zero failures over a defined time interval (or mission). Often expressed as Mean Time Between Failures (MTTF) - time passed before a system fails under the condition of a constant failure. I.e. (MTBF is 7,500 hours)
- **Availability:** Is the percentage of time a system is considered ready to use when tasked. I.e., system has an availability of 99.56%
- **Maintainability:** Is defined as the probability of performing a successful repair action within a given time. In other words, maintainability measures the ease and speed with which a system can be restored to operational status after a failure occurs.

While Reliability, Availability, Maintainability each can be mathematically calculated, we as an organization do not collect the data to calculate them. However, we do calculate Availability but only based on whether it causes beam downtime. This does not include for example a wire

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scanner's unavailability, since wire scanners are usually used for tuning and are not necessarily required for beam production/delivery. Having said that, our organization is in the process of rolling out an Asset Management initiative that will give us quantitively the information we need to calculate RAM and reduce our dependency on qualitative subject domain expert opinions.

After the assessment the SL identifies for each subject domain deficiencies that could impact impact/impacts the functionality, performance, and longevity of the control system. The deficiencies are the difference between our vision for that subject domain is and its current state. With that information at hand, we develop a strategy for each subject to make our vision a reality. This usually results in four possible outcomes:

- **Maintenance:** Making smaller modifications to minor software problems, updating software application packages, correcting, and keeping equipment in good condition through small repairs, replacing failing components with the same type, etc.
- **Recapitalization:** Reversing years of decapitalization by replacing degraded *equipment* with reliable, well-functioning equipment. The purpose of recapitalization is not to enhance functionality, but it may be a side benefit.
- **Modernization:** Replacing *systems* with more modern systems, to improve reliability, reduce risk and operating/maintenance costs, with an eye to ensuring needed functionality for potential future upgrades.
- **Upgrade:** Increasing the functionality of the accelerator. Likely to include recapitalization of some decapitalized parts and modernization of others.

For other accelerator facilities, this distinction may not matter; however, for LANSCE, as a Department of Energy (DOE) - National Nuclear Security Administration (NNSA) facility, it often matters since it may determine the funding source for that scope of work. Maintenance activities, however, are usually paid out of the annual M&O budget that is provided to our group on a FY basis. We consider Recapitalization, Modernization, and Upgrades as projects. Not like maintenance that is usually going on continuously, projects have a start and end date, using for the complexity an appropriate level of project management (initiation, planning, execution, monitoring and control and project closure) usually requiring a larger amount of money that may not be covered by M&O.

RISK MANAGEMENT PLAN

Each of the subject domain deficiencies can be considered a risk, but we did not explicitly identify the likelihood of occurrence and the impact on our control system availability. Often it is assumed that a risk assessment and a risk management plan are synonymous; they're not. A risk management plan documents the whole process and addresses the following:

- **Plan Risk Management:** Define how to conduct risk management activities.
- **Identify Risk:** Determine and document the characterizes of risk which may affect the activities.
- **Perform Qualitative Analysis:** Prioritize risk for further analysis or action by accessing their probability of occurrence and impact.
- **Perform Quantitative Analysis:** Analyze the effect of identified risk on overall objectives.
- **Plan Risk Response:** Develop options & actions to enhance opportunities & reduce threats to objectives.
- **Monitor and Control:** Implement risk response plans, track identified risk, monitor residual risk, identify new risk, and evaluate risk process effectiveness.

The risk management plan deals with risks which are possible events that could or will impact eventually the availability of our LCS in a positive (an opportunity) or negative (a threat) way. The risks are cataloged in a risk register which is a spreadsheet that includes detailed information about risk identification, risk evaluation, and risk mitigation including financial information [4].

Since the risk register is very detailed, and therefore more labor intensive to maintain, we submit to it only those risks (subject domain deficiencies) that have ranked high in the subject domain assessment. Hence the assessment acts as a filter to the risk management plan letting us focus on the most critical aspects in a subject domain across all software and hardware subject domains.

RISK RESPONSE

Our risk register is frequently being updated and used as our primary prioritizing tool to determine what needs to be addressed in a proactive manner – before it becomes a catastrophic issue and needs immediate attention. Currently, we have over 70 major risks identified/described, each receiving a primary risk category (technical, funding, schedule, and/or scope), followed by a risk analysis based on a well-defined likelihood of occurrence & impact (mission impact of experimental facilities, beam downtime, and safety/environment/security) criteria. It is followed by a risk response planning process in which the technical readiness level is determined, as well as the material cost and labor time requirements to develop and install/deploy an upgrade solution associated with the risk. Any resulting maintenance or project work is then evaluated based on the ability to complete the work during a certain period.

Since operations support, maintenance, and project work may occur concurrently – they are all in need of labor resources coming from the same labor pool - there is a constant struggle between acute tactical support vs needed maintenance, as well as strategic project activities towards our subject domain vision. In general, we prioritize our labor resources as follows:

1. **Operations Support:** addressing acute issues that negatively impact LANSCE operations and user program.
2. **Strategic Project Support:** executing subject domain projects to bring them to current technology maturation levels.

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3. **Current Technology Level Maintenance Activities:** maintenance on systems that mostly use more modern or current technology.
4. **Obsolete Technology Level Maintenance Activities:** maintenance on obsolete systems that are being in the queue of being replaced.

It may be surprising to some that we value strategic project support higher than some of our maintenance activities. One reason is that decades of deferred upgrades have created an enormous backlog of projects to update systems to modern/current technology maturation levels. After weighing our options, we deliberately delay/omit maintenance on our current/older systems to make strategic investments for our future. Unfortunately, we must make that decision since our labor/funding shortage does not allow us to do all that should be done.

Until the control system if fully caught up to modern/current technologies, we feel we are forced to minimize the chance of catastrophic failures of our older systems that need replacement. It should be noted that most of the older systems have lost their ability to follow a migration path to newer versions since they have been neglected for too long. This results in many cases to starting over from scratch with the possible exception of existing field wiring.

PROJECT PLANNING & EXECUTION

With the risk register having information about risk level, scope, technology maturity level, full time employee level needs for pre-deployment efforts, and deployment, we are in the position to strategize about project prioritization, sequencing, possible project start and end date (duration), needed level of labor effort, as well as possible additional funding needs. Planning also includes needed employee skill set & level as well as consideration as to how it would benefit employee career growth opportunities. AOT-IC management and team leaders then evaluate the conflicting constraints, labor and material resource needs and determines which projects are being pursued.

In the past, project execution in our group suffered from the lack of leadership, accountability, and efficiency due to some degree of stove-piping between the different teams, leaving us often with the feeling that more could have been accomplished. In response to this suboptimal approach, we are assigning to each project a Person-In-Charge (PIC) and supporting staff creating a mini project management environment. We manage it accordingly in a graded fashion (based on complexity) with requirements & design reviews, as well as frequent status/progress reporting meetings during the planning and execution phase.

PROJECT MONITORING & CONTROL

During the planning/preparation phase (~June - December) we hold monthly group wide update meetings where the PIC presents a one-page status update slide: Overall Status (met with team, responsibilities determined /assigned, interfaces determined, requirements determined, requirements review held, design developed, design review held, bill of material determined, material purchase placed), Latest Accomplishments, Immediate Critical issues that need Attention, Major Outage Risk/Concerns, and Next Steps.

At the end of preparation phase (November/December) each PIC will also give a presentation to relevant stakeholders, addressing the following topics a) Work Scope/Outage Task b) PIC of outage activity + who supports it as well as information about System(s) and Location(s), c) What will change - What will we do (Hardware & Software) including c1) Interfaces to and support need from other groups c2) Current status of outage task preparation, c3) Potential issues and risk mitigation strategy, if any, and d) Summary including benefits to the facility and potential future work. This facilitates the communication with the organization and should ensure that everyone is aware of the panned work. At this point the PIC has also developed a detailed Gantt Chart for the Long Maintenance Outage which will be integrated into a wider outage plan.

During the Long Maintenance Outage (execution phase), we hold bi-weekly status update meetings where the PIC discusses the following based on a one-page status update slide: Safety Issues, Overall Status (how far ahead or behind schedule), current work being executed/work locations, required coordination within our group or others, Risk/Concerns & Possible Mitigation efforts, as well as Next Steps.

Overall, this planning, execution, monitoring, and control approach has been very successful. We believe that the reason for the success may be linked to the projectized approach where a small project team led by a project manager (PIC) are focused for a very specific period (~10 month) on delivering a product that has measured positive impact on the control system/accelerator facility. The projects and their scope change usually from year-to-year and the project teams are newly formed each year providing opportunities to our employees to lead them and work with different team members.

The LANSCE accelerator facility follows an annual operating schedule which at a high level has three major periods:

- January to April - Long Maintenance Outage: maintenance and improvement projects are being executed with the accelerator being shut off for the entire time.
- April to mid-June – Accelerator Startup: From the injectors to the experimental facilities the accelerator is being turned on and tuned in a geographically step-by-step fashion.
- Mid-June to December – Production to Experimental Areas: beam is being delivered to the experimental areas based on the annual operating schedule only interrupted by an ion source recycle (nominal 2½ -days-replacing consumables and (re)tuning) and machine interventions studies (24-48 hours available for accelerator teams to study accelerator specific questions or test equipment with beam).

Usually, the controls group management team and team leaders start planning for the following years' Long Maintenance Outage (January-May) projects in March –

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April the year before. New outage projects are then rolled-out/kicked-off in the June time frame. Giving each team about 7 months to prepare the outage projects as much as they can so that the long maintenance outage itself (January - April) is only used to deploy, test and commission (without and with beam) the systems. The project cycle concludes with a lesson learned session just before we roll-out the new projects for the following year.

Testing newly to be deployed systems prior to the Long Maintenance Outage/during the Production to Experimental Areas is of great value. In the past we often wouldn't get to it since we would only test a finished production ready system. To take advantage of testing our system in a production like environment we introduced the concept of Minimum Viable Product (MVP) - a version of the production system that enables a full turn through the Build-Measure-Learn loop with a minimum amount of effort and least amount of development time. Using this approach has greatly increased our ability to collect feedback on the technical side but also from the stakeholder side, giving us the opportunity to preemptively address any issues prior to the deployment during the Long Maintenance Outage. This reduces the risk for schedule delays during Accelerator Startup due to untested system issues.

ONGOING IMPROVEMENTS

Following our methodical approach, we are actively working on our 2024 projects. The scope is set to continue our effort to replace obsolete and past end-of-life equipment, some of which was custom-made. It further aims to streamline our hardware form factors and advance the majority of the LCS computerized equipment to the same up-2-date technology maturity level using our 2 hardware de-facto standards for most of our equipment. Furthermore, the projects will help improve the performance, functionality, and longevity of our control system:

- Emittance and Harp Instrumentation: upgrading from our NIM-Bin & custom system to our new QAC/DAC standard NI cRIO platform.
- Chopper Control Pattern Generator: upgrading from our CAMAC & custom system to our three commercial-of-the-shelf Berkley - Nucleonics Model 685-8C arbitrary waveform generators, custom RF Gate Synchronizer, and custom patch panel.
- Proton Storage Ring - Beam Position Instrumentation: upgrading from our custom system to our new standard VPX/cPCI platform [5]
- Low Energy Beam Transport – digital Low Level Resonance Frequency – Buncher Control: upgrading from our custom system to our new standard NI cRIO platform [paper reference?]
- Isotope Production Facility PLCs: preparing for an PLC to NI cRIO based upgrade.
- Network Addressable Devices: upgrading from analog/digital interface to Ethernet enabled devices as they are being replaced.
- Network Switches Upgrade: upgrading our obsolete network switches from different brands to an all-CISCO system.
- Core Switch Upgrade: upgrading our obsolete network core switches to a fail-safe/redundant CISCO system.
- Virtual Input Output Controller migration to Virtual Machines: moving softIOCs to a virtual machine (Hypervisor Dell r750) and subdividing them as needed to manageable sizes.
- Server Service Migration to Rocky 8: migration of Linux services to the new operating system.
- Deployment and Migration to modern EPICS Extensions: upgrading to EPICS Archiver Appliance from LANSCE CAFlux, DSRP, Alarms application.
- Object Oriented Industrial I/O implementation: refactoring LabVIEW code to and LabVIEW object-oriented architecture to improve reuse & maintainability.
- Tcl/TK to EDM/Python Operator Screens: upgrading our Tcl/Tk based operator interface screen to a more maintainable software solution.
- EPICS 3.15 Consolidation: upgrading all EPICS IOCs to the 3.15 version.

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