Lifecycle Management and Technology Modernization of a Legacy Control System

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Abstract *— This article shows a practical modernization of a legacy blender control system in a regulated pharmaceutical setting. The project replaced an Allen-Bradley SLC-500 with a CompactLogix 5380 (Studio 5000), migrated HMI/SCADA to FactoryTalk View SE on Windows Server 2022, and reused field wiring via 1492 conversion kits to limit disruption. A risk-based Computer System Validation (IQ/OQ, PQ as applicable) confirmed functional equivalence, data integrity (ALCOA+), and core cybersecurity controls. SCADA and historian paths were re-bound, backups were validated, and Quality authorized Return-to-Service within the planned window. Compared with complete replacement, the approach reduced capital cost, downtime, and retraining while improving supportability. The work documents method, results, and limits (e.g., targeted manual refactoring and legacy drive diagnostics) and offers a practical template for similar upgrades seeking GMP compliance, lifecycle support, and readiness for ISA-95/Industry 4.0 integration.*

Keywords *— CompactLogix, Industry 4.0, LCM, PLC Retrofit, SLC 500, Upgrading Legacy System.*

INTRODUCTION

For pharmaceutical companies, automated control systems' reliability and regulatory compliance are critical to maintaining product and data quality, equipment uptime, and reliable supply. Industries face a crucial challenge of modernizing legacy automation control systems in manufacturing facilities, where a substantial technological gap between existing legacy equipment and Industry 4.0 standards threatens operational efficiency, data integration, and long-term competitiveness. Replacing an entire automation control system is not always viable due to the substantial capital investment and extended implementation time required. Consequently, upgrading legacy systems often becomes a more attractive alternative, as it typically involves lower costs, reduced downtime, and minimal disruption to ongoing manufacturing operations while preserving the core system functionality and requiring little to no personnel retraining. Modernizing with the latest technologies also helps mitigate manufacturing reliability risks and cybersecurity risks, while ensuring long-term business continuity, sustained competitiveness, and alignment with Industry 4.0 requirements. Furthermore, it enables seamless integration across the different levels of the automation hierarchy, as defined by the ISA-95 standard—an international framework for connecting enterprise systems with industrial control systems [1].

Research Description

This research presents a practical case study on modernizing a legacy blender control system in a regulated pharmaceutical environment. This legacy system is an indispensable business-critical asset, since it is vital in achieving content uniformity for the final dosage form's overall quality and therapeutic efficacy. To protect confidentiality, proprietary configurations and other information are omitted; the discussion focuses on the modernization approach, validation outcomes, and lessons learned that are broadly applicable to similar facilities.

Currently, the manufacturing equipment is operated using a legacy Allen-Bradley SLC 500 (Small Logic Controller) PLC, which has been officially discontinued, making a technological upgrade imperative for maintaining long-term system reliability. It also has a Human-Machine Interface (HMI) runtime application hosted on Microsoft Windows Server 2012 R2, which has reached the end of its extended support lifecycle. Migration to a more current Microsoft Windows Server release is essential to ensure cybersecurity compliance and sustained IT support. As part of the control architecture, the system functions within a Supervisory Control and Data Acquisition (SCADA) environment, where the HMI serves as the operator interface for real-time monitoring, data visualization, and control of the blending process. Upgrading the underlying SCADA infrastructure will enhance system interoperability, data integrity, and integration with modern automation platforms aligned with Industry 4.0 standards.

This research aims to review literature, propose, and implement a comprehensive control system technology modernization approach for the legacy manufacturing equipment, including hardware and software upgrades aligned with current automation and lifecycle management best practices.

Research Objectives

This research aims to modernize a legacy control system within a pharmaceutical manufacturing company by addressing hardware obsolescence, software limitations, and compliance requirements. The key objectives for this research project are as follows:

- To improve equipment reliability, system performance, and long-term vendor support, the obsolete SLC 500 PLC is retrofitted with an Allen-Bradley CompactLogix controller.
- Migrate 100% of the legacy RSLogix 500 control logic to Studio 5000 Logix Designer, ensuring compatibility with Rockwell Automation's current standards and enabling future scalability.
- Upgrade the virtualization infrastructure and deploy the HMI runtime on Microsoft Windows Server 2022, ensuring alignment with internal IT governance and cybersecurity compliance standards.
- Implement and document lifecycle management (LCM) practices and complete computer system validation (CSV), in accordance with Good Manufacturing Practices (GMP) and internal quality systems and standard procedures.
- Achieve sustained operational continuity, regulatory readiness, and system maintainability by delivering a fully validated, supportable, documented control system upgrade.

Research Contributions

This research project delivers a practical case study on applying lifecycle management principles for industrial automation systems within the pharmaceutical sector, specifically addressing the challenges posed by legacy equipment operating on the obsolete SLC 500 family of controllers. It outlines a structured and systematic approach for upgrading such control systems, covering key aspects including hardware replacement, software and PLC/HMI programs migration, virtualization, and IT infrastructure modernization. The proposed upgrade enhances the manufacturing equipment reliability and data integrity while also addressing cybersecurity risks, ensuring alignment with current industry standards and regulatory requirements. Furthermore, this project supports the pharmaceutical companies' digital transformation goals by helping operations run smoothly and laying the groundwork for reliable, modern automation in the long term.

LITERATURE REVIEW

In a high-demand and highly regulated manufacturing landscape, industrial automation control systems are no longer support tools but the backbone of operational excellence. These systems orchestrate everything from field equipment coordination to data flow, acquisition, and quality assurance, ensuring that production runs efficiently, consistently, and complies with regulatory and industry standards. However, as automation technology advances, many manufacturing facilities face a growing dilemma: aging control systems that threaten reliability, cybersecurity, and long-term operation sustainability.

Legacy platforms such as outdated PLCs, HMIs, or DCS systems may lack vendor support, fall short of modern cybersecurity requirements, or be incompatible with Industry 4.0 initiatives. Yet, despite the clear need for modernization, manufacturers are requested to upgrade due to one critical concern: production downtime. Any interruption can lead to financial losses, product quality risks, or missed market demands.

This literature review explores current strategies, technologies, and methodologies to upgrade industrial automation systems while minimizing manufacturing line downtime. The literature review is broken into four parts that relate to different aspects of the work in this report:

- Life Cycle Management of Legacy Systems.
- Why Upgrade Industrial Automation Legacy Control Systems.
- Case Study of Strategic Industrial Control System Migration Approach.
- Solutions for Migrating from Legacy SLC500 to CompactLogix 5380.

This literature review section examines best practices, case studies, and innovative approaches to system migration to balance modernization efforts and operational continuity. Additionally, it focuses on facilities that still operate legacy systems, such as Rockwell’s SLC 500, which often lack essential cybersecurity features, compatibility with modern industrial protocols, and long-term vendor support. These limitations pose significant risks to reliability, compliance, and integration with Industry 4.0 technologies.

Life Cycle Management of Legacy Systems

While it is true that industrial control systems are often so robust that they can operate for decades, LCM remains critically important. Over time, hardware becomes obsolete, software loses support, and cybersecurity vulnerabilities increase. Without proper LCM as part of reliability and asset management programs, organizations potentially suffer unplanned downtime, regulatory non-compliance, and rising maintenance costs. Managing each phase of the system’s life from design and implementation to upgrades and retirement ensures long-term reliability, security, and operational continuity.

With the advent of Industry 4.0, the need for robust LCM practices has become even more pressing. Digital transformation initiatives such as predictive maintenance, real-time data analytics, and IIoT (Industrial Internet of Things) integration rely on modern, interoperable control systems. However, many facilities still operate legacy systems or outdated DCS platforms, which often lack cybersecurity features, compatibility with modern protocols and digital solutions, or vendor support (no support or high costs). Despite the obsolescence of these industrial automation control systems, these legacy systems are core to running manufacturing operations, and changes need to be planned carefully [2].

Why Upgrade Industrial Automation Legacy Control Systems

Upgrading legacy manufacturing control systems presents several challenges including: (1) substantial capital investments, (2) the operational risks associated to upgrade or retrofit failures, (3) downtime windows that can affect production and revenues, (4) compatibility issues and difficulties, (5) the need for manufacturer alignment (in case of Commercial Off-the Shell (COTS) or proprietary systems), and more. Furthermore, not all legacy systems are candidates for undergoing upgrades. Nevertheless, with the rapid technological advances, control system upgrades have resulted in increased efficiency and productivity for the plant. Literature review suggests that productivity can improve by reducing the time of delivering manufacturing products to market [2].

Upgrading industrial automation control systems is critical for improving efficiency and staying current with technology, ensuring alignment with the latest cybersecurity standards. A 2024 Censys data found over 145,000 exposed Industrial Control Systems (ICS) services globally, with over 48,000 in the U.S. alone, where manufacturing cyber breaches originated from unsecured industrial control systems communication protocols. Also, 34% of C-More HMIs relate to the water and wastewater sector, while 23% are associated with agricultural processes [3].

Case Studies of Strategic Industrial Control System Migration Approaches

Ault's doctoral research (2021) provides a valuable reference point. His PhD Dissertation, "Modernizing Automation in Industrial Control/Cyber Physical Systems through the Systems Engineering Lifecycle", examines the large-scale migration of legacy PLC systems as part of obsolescence management. To illustrate the motivations and process, it documents an example of replacing an Allen-Bradley PLC-5 (1980s era) with a modern Logix controller. Ault identifies critical success factors: proactive planning for obsolescence, standardizing on a standard modern PLC platform across sites, and scheduling migrations during planned outages. The thesis notes that even for PLCs from the same manufacturer, program conversion software only provides a baseline – significant manual rework and testing are required to achieve a fully functional upgraded system. This source offers a comprehensive, high-level framework for PLC upgrade projects, emphasizing risk mitigation and systems engineering practices in commissioning new control systems. Ault based the PLC selection on a requirements-driven evaluation, using the systems engineering process to define functional needs, interoperability, scalability, and lifecycle support. He compared candidate PLC platforms against these criteria—such as vendor support, integration capabilities, and cybersecurity features—and selected the option that best aligned with the system's long-term operational and regulatory goals [4].

Ault proposes a framework rooted in model-based systems engineering (MBSE) and integrates the principles of lifecycle thinking to guide modernization efforts from planning through validation, which will be used in the following sections [4]. He emphasizes that if an automation subsystem cannot meet user/functional requirements, the system engineering V framework (where each stage on the left corresponds to a validation or verification stage on the right) could be repeated to upgrade a central automation subsystem.

The Core Components of the Framework are detailed as follows:

Requirements Definition

- Captures user needs, regulatory standards, safety criteria, and operational constraints.
- Includes functional and non-functional requirements (e.g., performance, scalability, cybersecurity).

System Architecture and Design

- Develops a modular, scalable control architecture.
- Incorporates interoperability and communication protocol decisions (e.g., Ethernet/IP, OPC UA).
- Selects hardware (e.g., CompactLogix) based on requirement matching.

Risk Management and Trade Studies

- Evaluates potential risks such as integration failures, data loss, or downtime.
- Uses trade-off analysis to justify controller and component selection based on performance, cost, and lifecycle support.

Implementation and Integration

- Involves hardware installation, I/O mapping, and program migration (e.g., RSLogix 500 to Studio 5000).

- Ensures backward compatibility and minimal disruption through staged deployment.
- Verification and Validation (V&V).
- Performs factory acceptance tests (FAT), site acceptance tests (SAT), and user acceptance tests (UAT).
- Ensures the system meets the initial requirements and compliance criteria.

Sustainment and Lifecycle Planning

- Includes documentation, training, and long-term maintenance strategies.
- Aligns with regulatory frameworks such as GMP 5 and ISA/IEC 62443 for validated and secure systems.

Another case study that demonstrates a practical approach to modernizing legacy systems is presented in the paper “Upgrading Legacy Automation Equipment to Achieve Industry 4.0 Compatibility”, published by IEEE [5]. This work addresses the challenge of upgrading legacy industrial automation equipment to meet the standards of Industry 4.0 by proposing a cost-effective and scalable solution that avoids complete equipment replacement. Instead, it enhances existing systems through web server integration within programmable logic controllers (PLCs) and IO-Link communication. The authors propose a hybrid upgrade method that retains most existing hardware and software while incorporating modern Industry 4.0 features. A case study involving a Pick and Place control system (using a pick, place, and storage point) illustrates the application of this method, introducing smart sensors and actuators with IO-Link to enable real-time diagnostics, remote monitoring, and efficient control. The system embeds a web server in the PLC to support remote visualization and control via HTML, CSS, JavaScript, Ajax, system parameterization, and alarm handling. Additionally, safety protocols are implemented to address potential cyber intrusions or system malfunctions.

Solutions for Migrating from Legacy SLC500 to CompactLogix 5380

The SLC 500 (Small Logic Controller) is a family of programmable logic controllers (PLCs) developed by Allen-Bradley, a Rockwell Automation brand, in the late 1980s. It features a modular, rack-based architecture designed for mid-range industrial automation. However, the SLC 500 platform has been phased out due to constraints in memory, processing power, communication protocols, and the lack of modern security features.

Rockwell Automation offers CompactLogix-based migration solutions to address these limitations that allow for a seamless upgrade path. These solutions include conversion kits, prewired adapters, and I/O interface modules that enable users to retain existing field wiring while migrating to the CompactLogix 5380 platform. Introduced in 2016 as part of the Logix 5000 family, the CompactLogix 5380 controllers feature high-speed processing, native Ethernet/IP support, enhanced diagnostics, and embedded cybersecurity features, fully aligning with Industry 4.0 requirements.

The following section highlights the main differences between the SLC 500 and CompactLogix controller families [6]:

Table 1

Comparison Table: SLC 500 vs. CompactLogix 5380

Feature	SLC 500	CompactLogix 5380
Introduction	Late 1980s	~2016
Status	Discontinued (as of ~2021)	Actively supported
Programming Software	RS Logix 500	Studio 5000 Logix Designer
Addressing	File-based (e.g., N7:0, B3:0/0)	Tag-based
I/O Support	1746 local rack I/O only	5069 Compact I/O, EtherNet/IP remote I/O
Networking	DH-485, DH+, RS-232, limited Ethernet	Full EtherNet/IP, safety, and motion integration.
Memory/ Processing	Limited (~8K – 64K max)	Up to 10MB user memory, 1ms task rates.
Security	No native security features	Role-based access, digital signature, encryption.

Motion Control	Not supported	Integrated motion over EtherNet/IP
Safety Integration	Not supported	GuardLogix 5380S supports SIL2/SIL3 safety.
Diagnostics & AOI	Basic	Advanced diagnostics, Add-On Instructions (AOI)
Lifecycle Support	End of Life (EOL)	Active, with long-term roadmap.

Following the hybrid upgrade approach—which preserves most of the existing hardware and software while integrating modern Industry 4.0 capabilities—the Rockwell Automation publication "Migration Solutions: SLC™ 500 to CompactLogix™ 5380 Control System" outlines how the CompactLogix I/O system facilitates migration through pre-designed I/O conversion modules. These modules eliminate the need for extensive rewiring, significantly simplifying the migration process and reducing implementation costs and system downtime. These plug-and-play solutions retain the original terminal blocks and wiring, using a conversion base that maps signals from the legacy I/O to the new system. It uses a chassis adapter plate to mount the latest modules in the old chassis space [7].

According to Tim Leo, Rockwell's Product Manager, successfully migrating to CompactLogix requires translating file-based logic from RSLogix 500 into tag-based architecture in Studio 5000 [8]. Their guidance outlines cautiously using tools like Rockwell's PLC Code Conversion tool, which only provides partial conversion support. Instead, they recommend a manual logic rewrite for better maintainability and scalability [8]. The selection of the CompactLogix controller is based on the required memory capacity and I/Os needed to support the solution.

METHODOLOGY

This section outlines the structured methodology that will be followed to achieve the research objectives previously defined. The methodology is based on a system engineering and computer system lifecycle management approach, incorporating practical steps for retrofitting obsolete control hardware, migrating legacy software, upgrading IT infrastructure, and validating the new system in compliance with Good Manufacturing Practices (GMP).

The selected methodology consists of a step-by-step project execution and validation plan aligned with industry best practices for automation, computer system upgrades, and regulatory compliance in pharmaceutical manufacturing.

METHODOLOGY APPROACH

The proposed methodology includes the following six sequential phases:

Phase 1: Assessment and Planning

- Conduct a detailed assessment of the existing control system, including I/O mapping, ladder logic structure, and hardware configuration.
- Evaluate the virtualization environment hosting the HMI application.
- Identify and document gaps in cybersecurity, compliance, and hardware support.
- Define user and functional requirements and specifications impacted by the proposed LCM.
- Output: System Requirements and Traceability Matrix, Project Charter, and Risk Assessment.

Phase 2: Hardware and Software Selection

- Select the appropriate controller, communication modules, and required I/O conversion kits.
- Choose the virtualization platform (e.g., VMware, Hyper-V) and configure a validated image OS.
- Output: Costs Estimate, Approved Bill of Materials (BOM), network design, system architecture diagrams, and Change Control Submission.

Phase 3: Developing a Project Strategy

- Proposal: Describe the current situation, proposal, and business justification.

- Implementation Plan: Outline the steps/deliverables needed to achieve the project goals.
- Timeline and Milestones: Establish a schedule with key deadlines and checkpoints.
- Resource Allocation: Determine how resources (personnel, materials, budget) will be utilized.
- Effectiveness Check: Specify the conditions under which the system will be released.
- Output: Stakeholders Triage and Change Control Submission.

Phase 4: Migration and Integration

- Stakeholders' approval is granted for the change control.
- Perform pre-change full image backup.
- Migrate the existing PLC application from the legacy platform to a modern controller environment, translating register/file-based addressing into structured, tag-based programming.
- Replace the obsolete PLC in the control panel and install the new controller.
- Configure the PLC and I/O modules, as well as the VFD.
- Create the new MS Windows Server where the runtime project will be hosted.
- Implement HMI migration, configuring the runtime on the upgraded Windows Server platform.
- Output: PLC Program Source Code, Updated HMI Files, Migration Plan Report.

Phase 5: Validation and Compliance

Conduct a complete Computer System Validation (CSV) following GMP guidelines:

Installation Qualification (IQ)

- Verify the correct installation of all hardware components.
- Ensure that all components are certified by a Nationally Recognized Testing Laboratory (NRTL), such as UL.
- Verify that each component is registered in the equipment inventory and that spare parts are available in the inventory system.

Operational Qualification (OQ)

- Perform screen navigation verification.
- Conduct a logical access level configuration verification.
- Perform alarms/interlocks verification and functional testing to ensure consistency in logic behavior.
- Ensure reports meet ALCOA data integrity expectations.
- Verify the data quality and accuracy of tags recorded in the data historian system.
- Perform a Manufacturing Execution System (MES) functional test.
- Complete project backups
- Ensure the system meets GMP, data integrity, and cybersecurity requirements.
- Output: Validation Protocols, Test Reports, Final Validation Summary Report, Quality Assurance Return to Service.

Phase 6: Documentation, Training, and Handover

- Develop and deliver updated system documentation:
  - User Manuals
  - Computer System Validation Documents
  - Wiring Diagrams
  - Standard Operating Procedures (SOPs)
- Train operational and maintenance personnel on the new system.
- Perform system handover and finalize post-validation monitoring strategy.
- Output: Training Records, System Support Plan, Final Project Closure Report.

Data Collection and Analysis

Data will be collected throughout the project lifecycle to support:

- Validation results (e.g., source code review approved, 100% logic matched expected results, test pass/fail rates, discrepancy(s) solved).

- Downtime avoidance during cutover.
- Risk assessments and mitigation plans.
- Project schedule adherence.

These will be analyzed using basic quantitative metrics (e.g., migration accuracy, number of system incidents/deviations post-implementation) and qualitative observations (e.g., end-user feedback, performance improvements).

Research Schedule

Figure 1 outlines the project milestones and their corresponding expected completion dates.

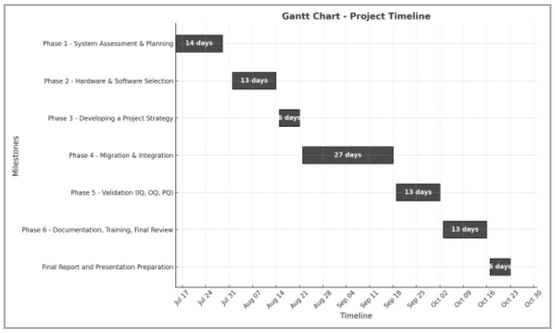


Figure 1

Gantt Chart Showing Project Milestones and Durations

Summary

This methodology provides a disciplined and traceable framework to achieve the project’s technical and regulatory objectives. By combining systems engineering practices and standards with industry-specific validation procedures, the proposed approach ensures that the modernized control system will be reliable, compliant, and maintainable, contributing to the long-term operational continuity of pharmaceutical manufacturing processes.

RESULTS AND ANALYSIS

This section documents how the project’s lifecycle-management and modernization objectives were executed and verified using a Computer System Validation approach. The work replaces an obsolete Allen-Bradley SLC-500 platform with a CompactLogix 5380/, migrates HMI/SCADA to Studio 5000 solution and FactoryTalk View SE on Windows Server 2022, and preserves field terminations through conversion hardware, all while sustaining GMP compliance and minimizing production disruption.

Phase 1: Assessment and Planning

The planning phase began with a complete assessment of the installed system: an SLC-5/05 (1747-L551B/C) controlling a blender driven by a PowerFlex VFD, with safety devices and sensors, a PanelView Human-Machine Interface (HMI), Supervisory Control and Data Acquisition (SCADA) oversight, and Manufacturing Execution System (MES) batch interfaces. Obsolescence and compliance risks were significant: the SLC-500 family has been discontinued, and the Windows Server 2012 R2 HMI host reached the end of extended support, which ended on October 10, 2023, creating concerns regarding reliability and cybersecurity. After this date, Microsoft ceased providing updates and technical support, although Extended Security Updates (ESU) remain available under subscription until October 13, 2026 [9]. Migration requirements were set: (1) retain EtherNet/IP networking, (2) reuse cabinet wiring via 1492 conversion hardware to shrink field work and downtime, (3) convert RSLogix 500 logic to Studio 5000 with targeted manual rework, (4) upgrade the server to the latest Windows Server OS within a hardened virtualized environment, and (5) apply complete CSV (IQ/OQ, PQ as applicable).

User and functional needs were captured as Process User Requirements (availability, safety, data integrity, usability, maintainability, compliance) and translated into General/User Requirements (performance/scan times, interlocks/alarms, role-based access control (RBAC), networking, historian/reporting, backup/DR, cybersecurity). Each requirement was linked to design elements and verification steps in IQ/OQ/PQ, creating a clear traceability path. A risk assessment using a severity–occurrence–detection matrix highlighted top hazards—cutover wiring errors, logic conversion mismatches (timers/CPT), data-integrity loss, firmware/keying issues, and server security gaps. Countermeasures reduced most risks to Low: conversion kits to avoid re-terminations, bench testing of the Studio 5000 project, equivalence testing (alarms/interlocks, HMI paths, historian tags), a validated backup/restore and rollback plan, and controlled temporary modifications (TMX).

Phase 2: Hardware and Software Selection

Alternatives were compared against standard criteria (wiring compatibility, migration effort, performance/scalability, lifecycle support/spares, cybersecurity/integration, GMP/CSV readiness, cutover risk, and total cost). Evaluated alternatives were the following:

A. CompactLogix 5380 + 5069 I/O conversion kits.
B. Staged 1747-AENTR + CompactLogix
C. ControlLogix 5580 + 1756 I/O
D. Micro800

The selected path—CompactLogix 5380 with 5069 I/O (Option A)—balanced cost, risk, and lifecycle support. 1492 conversion kits enable partial reuse of existing terminal wiring; Studio 5000 tools provide a starting point for code conversion; and long-term support is strong. Staged migration via 1747-AENTR (Option B) minimized near-term work but prolonged dependence on aging 1746 I/O; ControlLogix 5580 (Option C) offered maximum headroom at higher cost/complexity; Micro800 (Option D) lowered hardware cost but raised engineering/validation effort.

SCADA was targeted for FactoryTalk View SE on Windows Server 2022 (the latest approved compatible OS), chosen for vendor support, cybersecurity features, and virtualization benefits. A preliminary total cost estimate (~$84,518; including 10% contingency) covered controller/I/O hardware, server, licenses, validation package, and engineering labor. While material, this investment mitigates obsolescence, improves compliance/reliability, and aligns with the expected 10–15-year lifecycle.

Phase 3: Project Strategy

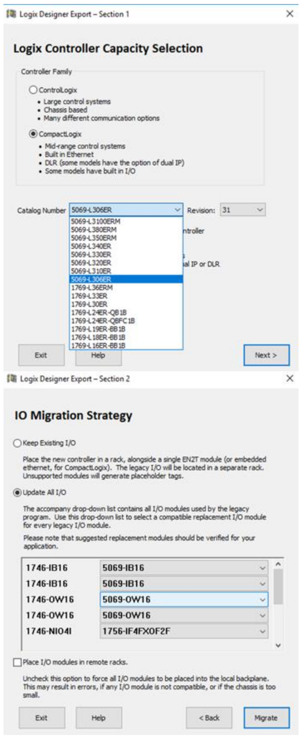
Under formal Change Control, the strategy defined and approved: (i) proposal and business justification; (ii) an implementation plan covering controller and conversion hardware commissioning, Studio 5000 configuration/testing, FTView SE installation, and EtherNet/IP integration; (iii) a 12-week schedule; (iv) resources across Automation, IT, and Quality; (v) release conditions (successful IQ/OQ/PQ, audit-trail verification, training/SOP readiness); and (vi) outputs (complete Change Control implementation evidence, IQ/OQ/PQ executed protocols, CSV documentation updates, and final summary report, etc.).

Phase 4: Migration and Integration

Server staging. A new Windows Server 2022 VM was provisioned and hardened (patching, firewall, domain join, antivirus). FactoryTalk View SE was installed to provide centralized HMI/SCADA, alarms/events, and 21 CFR Part 11-aligned audit trails; Studio 5000 was installed as the PLC engineering environment.

PLC Project migration. The RSLogix 500 PLC project was exported to a Studio 5000 (.ACD) using Logix Designer Export with controller parameters (CompactLogix 5380 5069-L306ER, Rev 31) and the “Update All I/O” strategy to map 1746 modules to 5069 equivalents.

The conversion produced a functional baseline but flagged multiple Possible Conversion Errors (PCEs) that required manual adjustments—e.g., timers normalized to millisecond base, counters reviewed, and CPT expressions with numeric literals adjusted to avoid time-base and integer-math discrepancies. Legacy file-based addressing (N/B/T/C) was preserved as tag arrays to aid SCADA continuity (e.g., N7:0 → N7[0], B3:1/2 → B3[1].2, T4:0 → T4[0]). ONS instructions required dedicated BOOL storage in Logix to replace reused legacy bits. After refactoring, HMI/SCADA references were re-verified to ensure address consistency.


Logix Designer Export – Section 1

Logix Controller Capacity Selection

Controller Family

○ ControlLogix
- Large control systems
- Chassis based
- Many different communication options

● CompactLogix
- Mid-range control systems
- Built in Ethernet
- DLR (some models have the option of dual IP)
- Some models have built in I/O

Catalog Number: 5069-L306ER

Revision: 31

Logix Designer Export – Section 2

IO Migration Strategy

○ Keep Existing I/O

Place the new controller in a rack, alongside a single EN2T module (or embedded ethernet, for CompactLogix). The legacy I/O will be located in a separate rack. Unsupported modules will generate placeholder tags.

● Update All I/O

The accompany drop-down list contains all I/O modules used by the legacy program. Use this drop-down list to select a compatible replacement I/O module for every legacy I/O module.

Please note that suggested replacement modules should be verified for your application.

1746-IB16	5069-IB16
1746-IB16	5069-IB16
1746-OW16	5069-OW16
1746-OW16	5069-OW16
1746-NIO4I	1756-IF4FXOF2F

☐ Place I/O modules in remote racks.

Uncheck this option to force all I/O modules to be placed into the local backplane. This may result in errors, if any I/O module is not compatible, or if the chassis is too small.

Figure 2

Logix Designer Export Tool - Migration Process

VFD I/O migration. The existing PowerFlex 70 over EtherNet/IP simplified cutover. Instead of hardwired signals, communications were re-established, and tags were reassigned in Studio 5000. Table 2 shows some of the legacy words/bits, improving readability and HMI binding while preserving behavior as follows:

Table 2

VFD I/O Conversions

Function	Studio 5000 (Module-Defined Tag)
Start command	**Write:** PowerFlex_VFD:O.DriveLogicCmd_Start/ **Feedback:** PowerFlex_VFD:O.DriveLogicRslt_Start
Stop command	**Write:** PowerFlex_VFD:O.DriveLogicCmd_Stop / **Feedback:** PowerFlex_VFD:O.DriveLogicRslt_Stop
Clear fault	**Write:** PowerFlex_VFD:O.DriveLogicCmd_ClearFaults/ **Feedback:** PowerFlex_VFD:O.DriveLogicRslt_ClearFaults
Forward / Reverse	**Write:** PowerFlex_VFD:O.DriveLogicCmd_Forward, PowerFlex_VFD:O.DriveLogicCmd_Reverse / **Feedback:** PowerFlex_VFD:O.DriveLogicRslt_Forward, PowerFlex_VFD:O.DriveLogicRslt Rslt_Reverse
Speed reference (command)	PowerFlex_VFD:O.SpeedCommand
Output frequency (feedback)	PowerFlex_VFD:I.OutputFreq
Drive ready	PowerFlex_VFD:I.DriveLogicSts_Ready

SCADA re-binding. FTView SE tags were updated to point to the new controller tag model. This clarified graphics, tightened alarm configuration, and strengthened traceability. The following Table 3 **Error! Reference source not found.**shows a comparison of some examples of Legacy vs. Modern Addressing in PLC and SCADA:

Table 3

Legacy vs. Modern Addressing in PLC and SCADA

RSLogix 500 (Legacy Addressing)	Studio 5000 (Tag-Based Equivalent)	FactoryTalk View SE (SCADA Data Source Address)
O:4/3 → Output module slot 4, bit 3 (e.g., motor start)	Local:4:O.Data.3	::[blender]Local:4:O:Pt03.Data
I:1/0 → Input module slot 1, bit 0 (e.g., start push button)	Local:1:I.Data.0	::[blender]Local:1:I:Pt00.Data
B3:4/2 → Binary file 3, word 4, bit 2 (e.g., Pause Bit)	B3[4].2	::[blender]B3[4].2
N7:0 → Integer file 7, element 0 (e.g., setpoint)	N7[0]	::[blender] N7[0]
T4:8 → Timer file 4, timer 8 (e.g., overspeed check)	T4[8]	::[blender] T4[8].ACC

Field installation. The SLC-500 chassis was safely de-energized and removed under LOTO. To minimize re-termination, a 1492 base plate and conversion kits were installed using existing mounting points and terminal blocks. The 5380/5069 stack was mounted on a DIN rail with correct spacing and bonding and powered by a 24VDC supply. The controller received a static IP on the managed Ethernet/IP network, the I/O tree was configured (firmware/keying/RPI), and the project was downloaded and verified online (healthy connections, no faults).

Phase 5: Validation and Compliance

A complete CSV was executed per GMP and 21 CFR Part 11. Installation Verification confirmed correct hardware/software installation (controller, I/O, network, Windows Server 2022 VM, FTView SE), vendor certifications (UL), inventory/spares registration, and preventive maintenance updates. Because the conversion kit preserved terminal wiring, the field-testing scope focused on critical alarms/interlocks and I/O (EtherNet/IP VFD command/status and analog feedback validation).

Operational Qualification on Table 4 covered complete screen-navigation testing; RBAC challenges against a validated role matrix (operators, maintenance, engineers, and administrators); positive/negative security tests (including lockout and idle timeout); and functional sequences in manual/auto modes against URS/FDS limits. VFD RPM was checked by tachometer and reconciled with HMI values within tolerance. A Performance Verification Test confirmed recipe-loading behavior (local and MES modes) and unchanged equipment performance. Historian tags reported “Good” data quality communication testing met accuracy/consistency criteria. Validated PLC (ACD) and HMI/SCADA project backups were produced. No deviations were obtained during the validation qualification exercise, and the Final Validation Summary supported QA Return-to-Service.

Table 4
URS Pass or Fail

UR ID	What was verified	Key evidence (measured/observed)	TMX result
URS-01	Bins (S/M/L) reach required speed & time	OQ test matrix across all bin sizes: worst-case speed error ≤2.1% (limit ±5%); time error ≤0.4% (limit ±1%). PQ: ≥3 qualifying batches per bin size met product criteria.	PASS
URS-02	Manual mode functions & interlocks	Jog, FWD/REV, clamp/unclamp, RPM/time set confirmed. Interlocks (guards, e-stop, overload) honored; no bypasses allowed.	PASS
URS-03	Thin-client/HMI responsiveness	Critical display open ≤1.2 s (limit ≤2 s); command acknowledgement ≤0.6 s (limit ≤1 s); session re-connect ≤9 s after link drop (limit ≤15 s).	PASS
URS-04	Safety trips go to safe state	Conducted critical alarms testing for E-Stop, overload, over-temp, VFD fault, overspeed, HMI/comm loss: safe state asserted in <300 ms; alarms logged with correct time/user.	PASS
URS-05	Recipe parameters are reproducible & versioned	Version control enabled; same recipe version reproduced identical parameter sets across runs; change history recorded.	PASS
URS-06	Batch/recipe report content	Recipe loaded in local mode, run completed. Report generated includes recipe name/version, lot/batch, parameters, operator actions, results, signatures, timestamps; sample reports.	PASS
URS-07	RBAC with least privilege	Role matrix challenge tests: Operators could not access engineering/security screens; Engineers limited to permitted edits; all attempts audited.	PASS
URS-08	Server platform supported	Windows Server 2022 VM; supported FT View SE and Services Platform versions installed. Installation evidence (versions, screenshots) filed.	PASS
URS-10	AD-based logical security	FTView groups mapped to AD; add/remove users reflected immediately; password/lockout/session timeout enforced; audit captures admin changes.	PASS
URS-11	Tamper-evident audit trails	Audit stored to SQL with restricted perms; integrity checks passed; simulated tamper attempts detected and logged; NTP time in sync.	PASS
URS-12	MES data exchange (min fields)	Recipe loaded in MES from MES and OPC UA interface	PASS

UR ID	What was verified	Key evidence (measured/observed)	TMX result
		sent/received Recipe Name, Version, Batch Number with 100% field accuracy; retry/queue behavior verified during brief comm loss.	
URS-13	UPS protects PLC/HMI; safe stop & recovery	Pull-power tests: safe stop commanded; stop alarm raised ≤ 1 s; historian tag quality remained Good; automatic recovery on power return without manual resets.	PASS

Phase 6: Documentation, Training, and Handover

Change Control was executed as a limited scope retrofit with a "no functional change" intent. Hardware/design specifications were updated to reflect the new server, controller/I/O catalog numbers, firmware, cabinet power, and the legacy-to-new I/O cross-reference created by the conversion kit. As-built drawings recorded the removal of the SLC-500 chassis and the addition of the 5380/5069 stack; field termination drawings largely remained unchanged. The I/O list and tag dictionary were refreshed to align slot/channel updates and SCADA mappings. The BOM/spares list was updated, and validation records emphasized equivalence rather than new functionality; execution links appear in the Traceability Matrix. SOPs required no revisions, since operator workflows and setpoints did not change. Asset inventory entries were updated; network topology and field wiring were preserved. A Quality Review Summary formally authorized handover and confirmed fitness for intended use. To protect sensitive information, architecture details, and repository locations are omitted from the thesis; authoritative records reside in controlled corporate systems.

In summary, results show that careful assessment, disciplined option selection, and rigorous CSV can deliver a low-disruption modernization: preserving functionality, improving supportability and security, keeping documentation current, and returning the system to service with clear evidence of equivalence and compliance.

CONCLUSION

The project demonstrates that a minimal-change retrofit—migrating SLC-500/RSLogix 500 to CompactLogix 5380/Studio 5000 and moving HMI/SCADA to FactoryTalk View SE on Windows Server 2022—can remove obsolescence while maintaining performance and GMP compliance at lower cost and with less downtime than full replacement. The upgraded system achieved functional equivalence, passed IQ/OQ (and PQ where needed), earned Quality Return-to-Service, and preserved operator workflow, cycle times, alarms/interlocks, and VFD behavior. Disruption was minimized by reusing wiring with 1492 conversion kits and re-binding (not redesigning) SCADA and historian paths; a modern platform and validated backups improved supportability.

For practice, the work offers a repeatable, low-disruption playbook for regulated plants: limit scope to a like-for-like retrofit, reuse field wiring via conversion kits, and verify equivalence through CSV rather than redesign. This approach addresses obsolescence while upholding GMP/data-integrity expectations, reducing downtime and cost, and positioning assets for ISA-95/Industry 4.0 integration.

Limits include the like-for-like scope (no redundancy, no ISA-88 redesign, no extensive alarm program), some manual fixes to auto-converted logic (e.g., timer/CPT scaling), and diagnostic constraints of the PF70 EC profile versus newer AOP-based drives. Recommended next steps include adding redundancy where uptime requires it, planning migration to AOP drives for richer diagnostics and simpler tags, adopting alarm rationalization, and standardizing user-defined data type (UDT) / Add-On Instructions (AOI) libraries with automated offline tests. The bottom line is that a bounded, minimal-change retrofit can remove obsolescence, maintain GMP compliance, and maintain steady performance while creating a solid base for future improvements.

REFERENCES

[1] M. M. D. K. M. Saju Eruvankai. (2023). *Smart Approaches for Migrating Legacy Devices for Digital Manufacturing* [Online]. Available: https://www.infosys.com/services/engineering-services/white-paper/documents/digital-manufacturing.pdf.

[2] A. Ribeiro. (2024, Nov.) *Censys data reports over 145,000 exposed ICS services worldwide, highlights US vulnerabilities* [Online]. Available: https://industrialcyber.co/industrial-cyber-attacks/censys-data-reports-over-145000-exposed-ics-services-worldwide-highlights-us-vulnerabilities/?utm_source=chatgpt.com. [Accessed: July 2025].

[3] T. J. Ault. (2021). *Modernizing automation in industrial control/cyber-physical systems through the systems engineering lifecycle* [Online]. Available: https://api.mountainscholar.org/server/api/core/bitstreams/87919ae1-2854-463b-b8c6-0a84a9e035c7/content. [Accessed: June 2025].

[4] M. Constantin, N. Bizon and I. Bostan, “Upgrading Legacy Automation Equipment to Achieve Industry 4.0 Compatibility,” in *15th International Conference on Electronics, Computers and Artificial Intelligence (ECAI)*, 2023.

[5] Rockwell Automation. (2023, Nov.). *CompactLogix 5380, Compact GuardLogix 5380, and CompactLogix 5480 Controllers Specifications* [Online]. Available: https://literature.rockwellautomation.com/idc/groups/literature/documents/td/5069-td002_-en-p.pdf. [Accessed: July 2025].

[6] Rockwell Automation. (2020). *Migration solutions SLC™ 500 to CompactLogix™ 5380 control system* [Online]. Available: https://literature.rockwellautomation.com/idc/groups/literature/documents/pp/migrat-pp004_-en-e.pdf?utm_source=chatgpt.com.

[7] T. Leo. (2020, Apr 23). *Legacy SLC 500 to CompactLogix 5380 Migration, TechTalks Online Seminar, Rockwell Automation* [Online]. Available: https://res.cloudinary.com/mcrey/image/upload/v1622147029/trc/documents/TechTalks/Legacy%20Migration%20Series/Legacy-Migration-Series-Modernizing-Your-SLC-500_o0qwen.pdf.

[8] N. Govindarajan, B. R. Ferrer, X. Xu, A. Nieto and J. L. Martinez. (2016). *An approach for integrating legacy systems in the manufacturing industry* [Online]. Available: https://ieeexplore-ieee-org.uprm.idm.oclc.org/stamp/stamp.jsp?tp=&arnumber=7819247&isnumber=7819121. [Accessed: July 2025].

[9] Microsoft. (2023, May 5). Windows Server 2012 and 2012 R2 reaching end of support [Online]. Available: https://learn.microsoft.com/en-us/lifecycle/announcements/windows-server-2012-r2-end-of-support. [Accessed: August 16, 2025].