Digital Engineering Use Cases

Machine Prototyping
Easily design and build the next generation of machines with confidence

Virtual Commissioning
Design, test, validate, & commission machines before they go into service

Throughput Analysis
Optimize throughput with real-time 3D simulation of dynamic processes
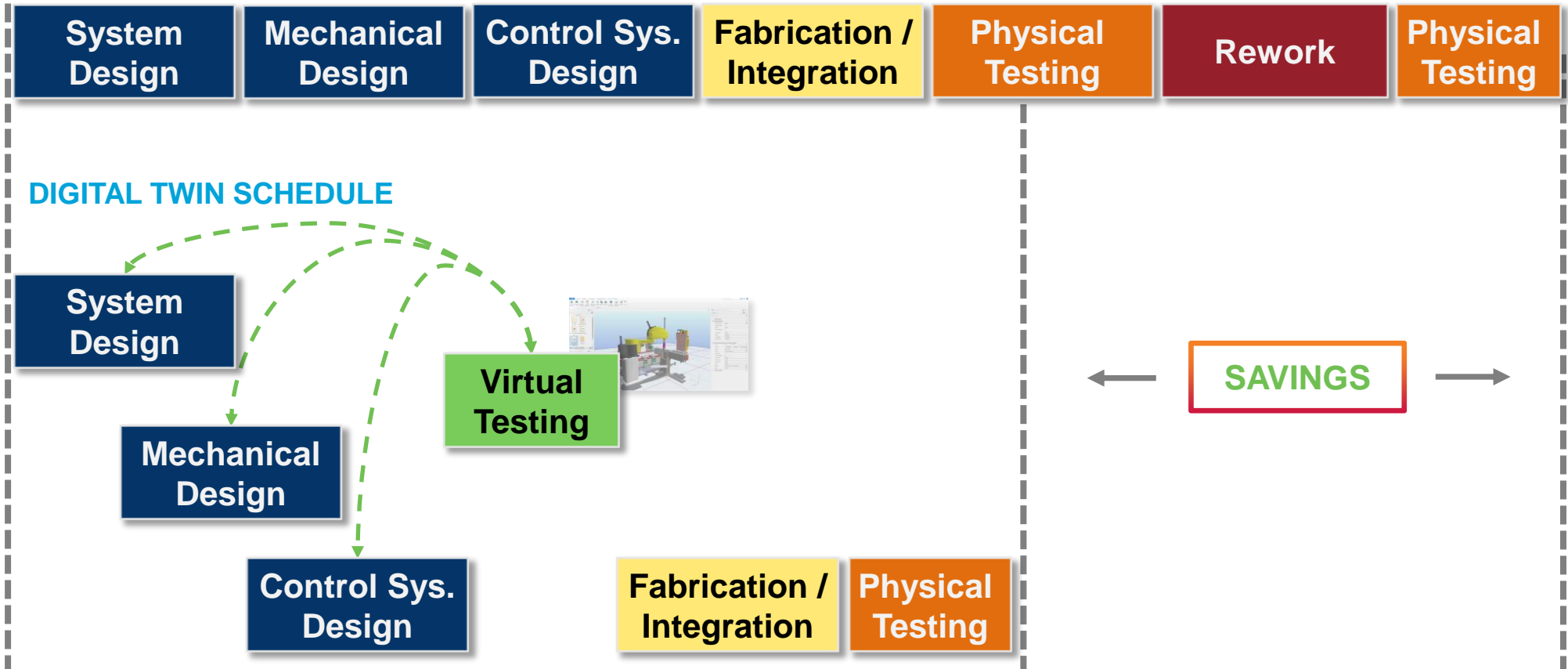
Operator Training Simulators
Reduce risk by training your workforce in a safe, virtual environment

Digital Twin Workflow

Mitigates risks and adds flexibility in your projects

Improve project delivery timeline

| System Design | Mechanical Design | Control Sys. Design | Fabrication / Integration | Physical Testing | Rework | Physical Testing |

Improve quality of design

DIGITAL TWIN SCHEDULE

System Design

Reduce hardware dependencies

Virtual Testing

Mechanical Design

SAVINGS

Reduce commissioning risks

Control Sys. Design

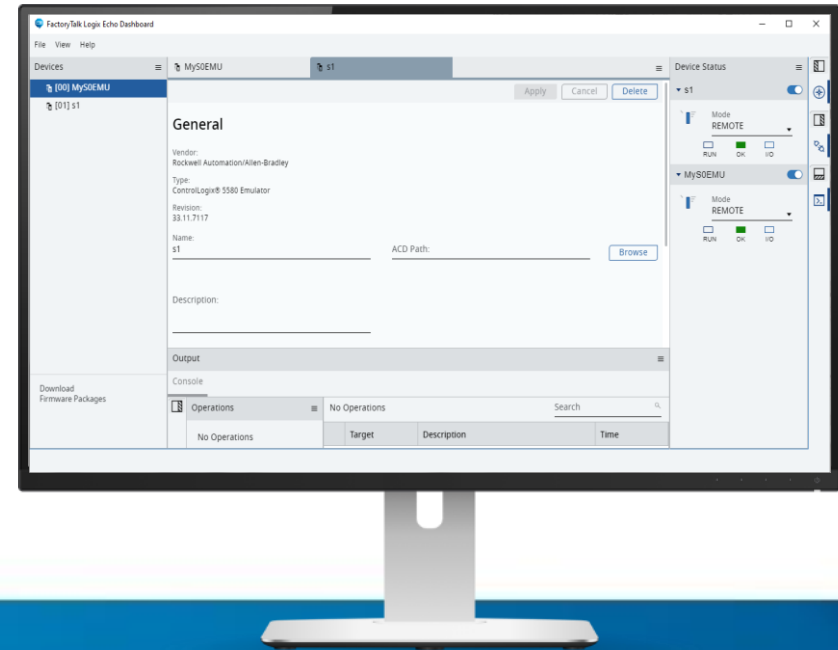Fabrication / Integration | Physical Testing

PUBLIC

Logix Echo

V1.0

Emulate ControlLogix®
5580 Controllers

- Fully test your control code in a safe, virtual environment

- The emulated chassis supports up to 17 controllers

- Execute controller project as designed without modifications

Ethernet Connectivity

- Front port of controller emulated

- Produce/Consume and MSGs between emulated controllers

- Connect to HMI or other software with Class 3 MSGs

SDK (Public Interface)

- Interface with high fidelity process simulators and Operator Training Simulators (OTS)

- High-speed data exchange

- Virtual time-scaling

- Snapshots

PUBLIC

Access is Similar to a Physical Controller

Configuring an emulated controller is fast

- Get the corresponding emulator firmware kit from the PCDC
- Create emulated controller instance with appropriate firmware revision and IP address
- Configured controllers appear in FactoryTalk® Linx software
- Create up 17 emulated controllers in one emulated chassis

FT Logix Echo

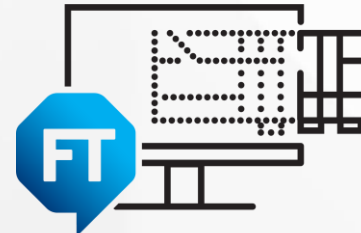## Apply Same Project to Physical or Emulated Controller

Same Project File

No changes to the project file required. The same project file developed for the physical controller will download to the emulator. The I/O tree will be maintained, all languages and instructions supported.

Studio 5000 Logix Designer® Project File

Logix Echo
Co-located

Logix Echo
Remote

Allen-Bradley

PUBLIC
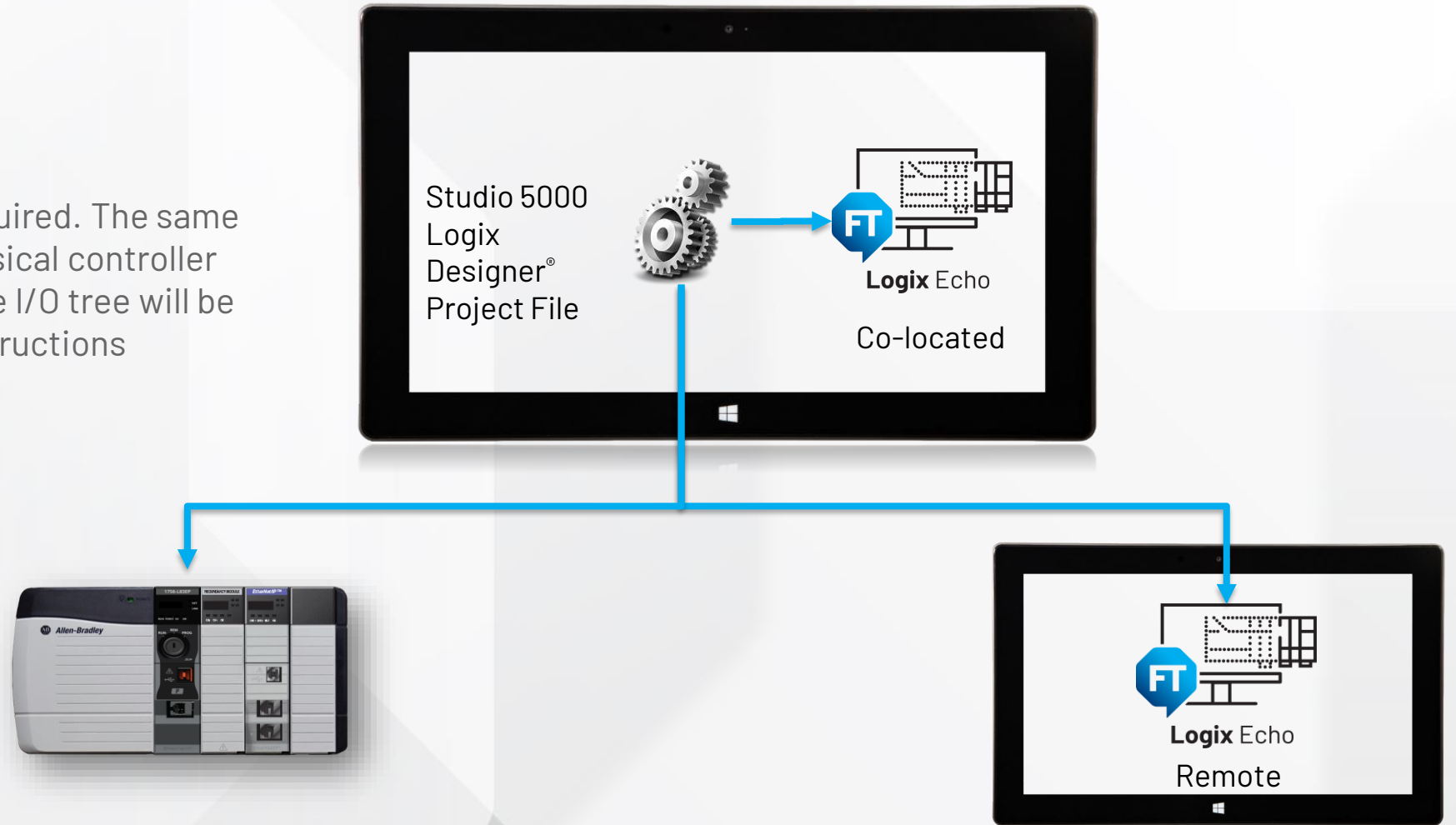
Logix Echo

Supported Controllers

ControlLogix® 5580 Controllers

All –E, –XT, –NSE and –P controllers

Logix Echo

Firmware version 33 or later

Catalogs

1756-L81E	1756-L82E	1756-L83E	1756-L84E	1756-L85E
1756-L81EK	1756-L82EK	1756-L83EK	1756-L84EK	1756-L85EK
1756-L81E-NSE	1756-L82E-NSE	1756-L83E-NSE	1756-L84E-NSE	1756-L85E-NSE
1756-L81EXT	1756-L82EXT	1756-L83EXT	1756-L84EXT	1756-L85EXT
1756-L81EP		1756-L83EP		1756-L85EP

Future Releases: GuardLogix® 5580, CompactLogix™ 5380 and Compact GuardLogix® 5380 Controllers
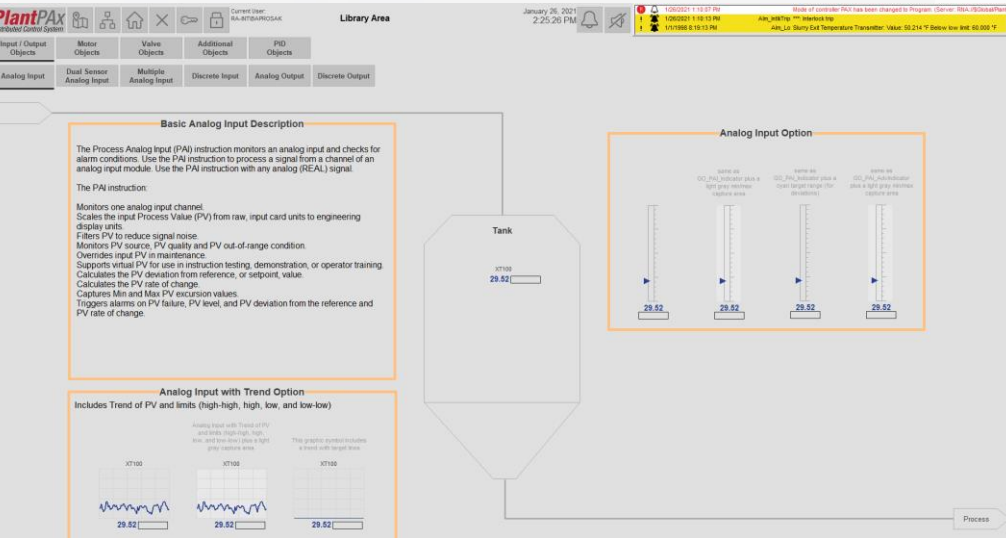
PUBLIC

Logix Echo

V1.0

Simulate Control Code and HMI Interaction All from a Single Workstation or Distributed

Step 1: create Logix application and run in Studio 5000® Logix Emulate™
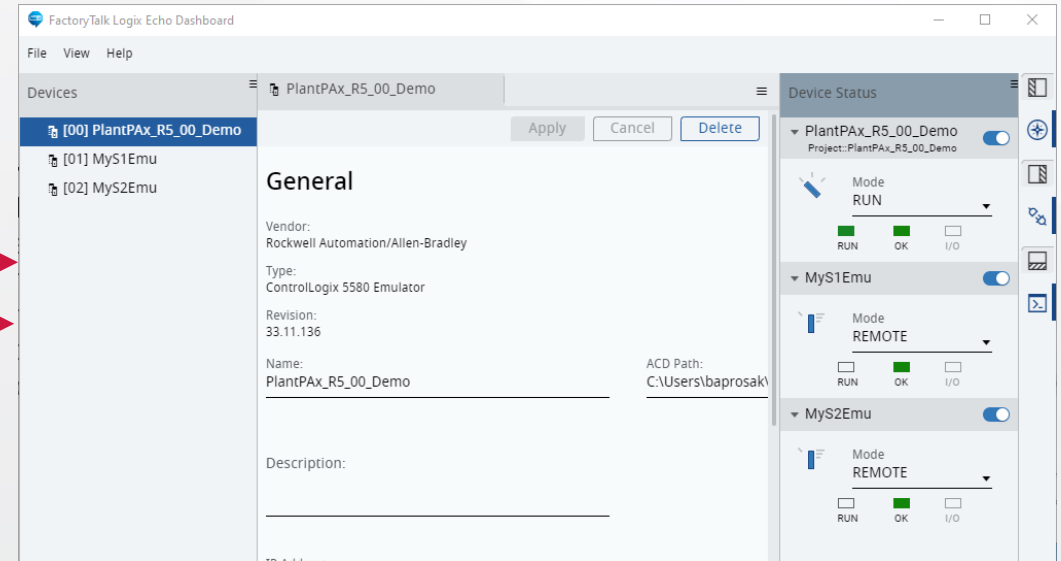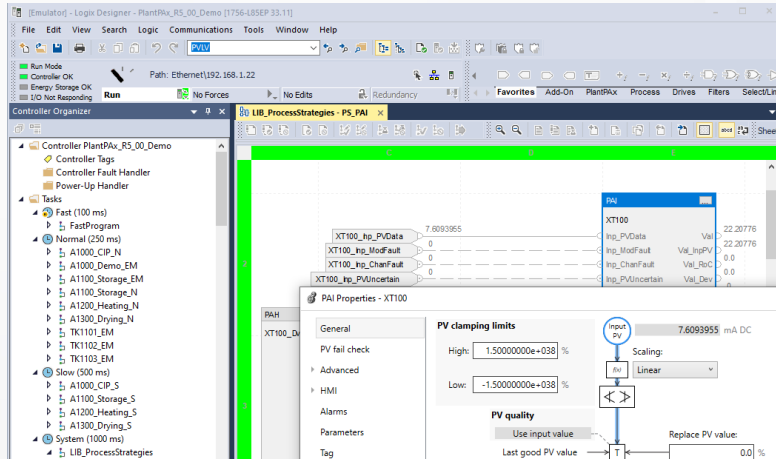
Step 2: Existing HMI shortcut(s) will work provided the emulated controller is at same IP as physical controller

V1.0

Support for SD Cards

- By default, a virtual SD card is attached to a controller (as a folder on your Windows directory)

- You can backup/restore projects, read/write data from the controller applications, log, just as you would with a physical SD card in the controller.

- Unlike the physical controller:

  - Firmware is not stored to the virtual SD

  - The content is stored unencrypted

PUBLIC
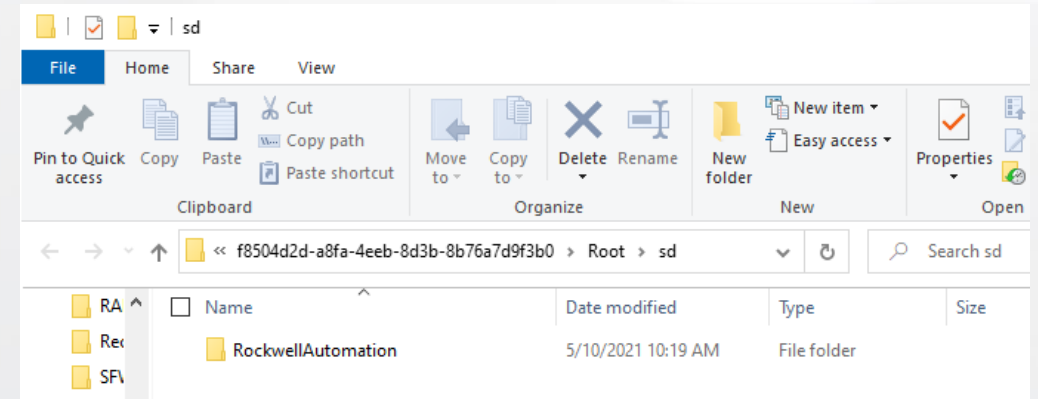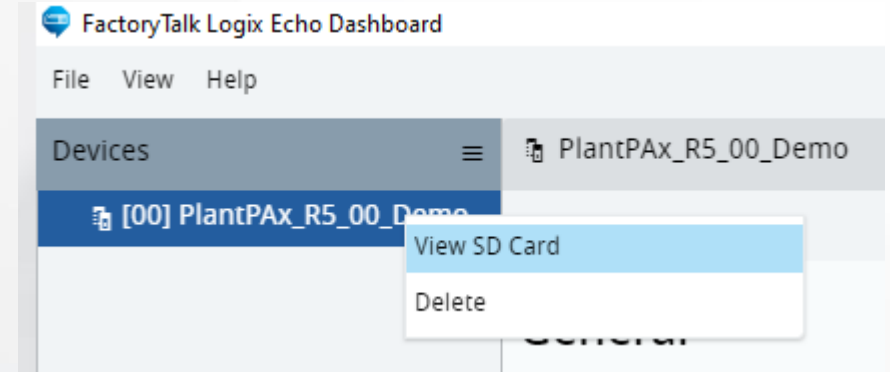
Studio 5000 Logix Designer® to Emulator Instance

Studio 5000 Logix Designer® can download over Ethernet. It can also bridge through one emulator instance connected over Ethernet to another emulator instance through the emulated backplane.

Studio 5000 Logix Designer®
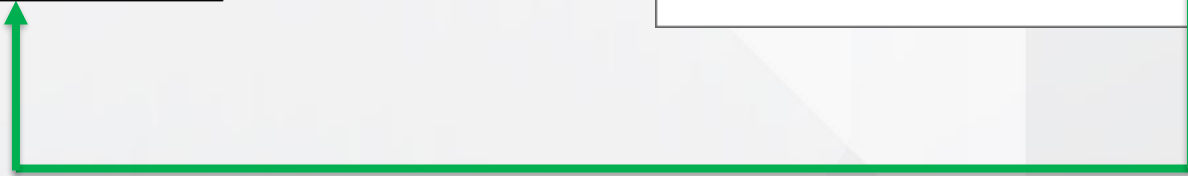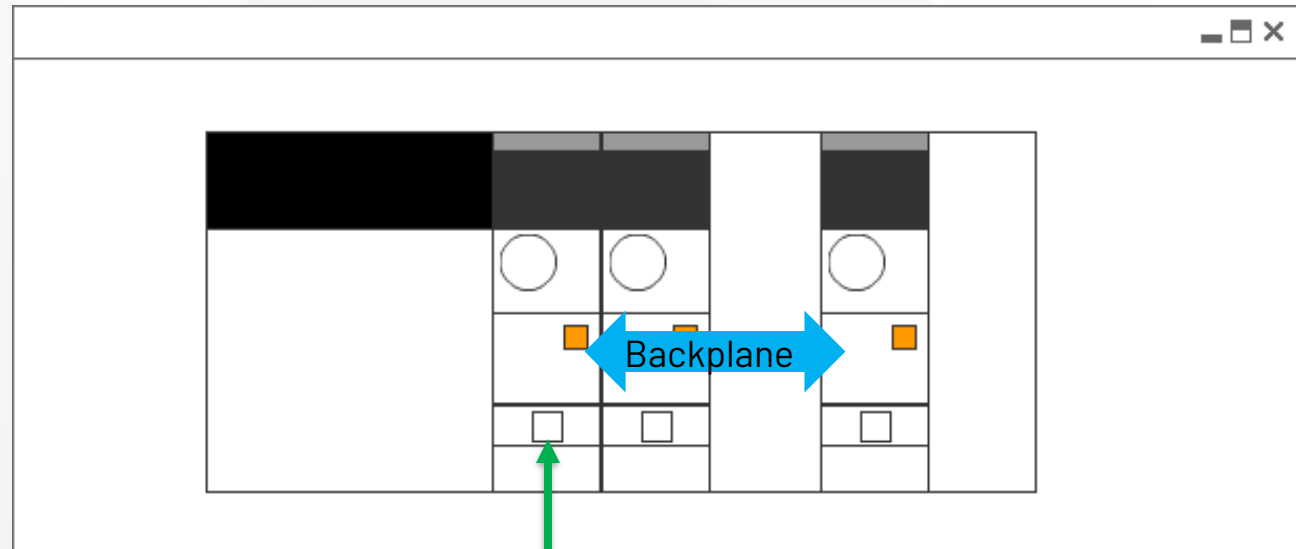
Backplane

Ethernet

Emulator-2-Emulator Communications

Class 1 (Produce/Consume) or Class 3 (Messages) communication between emulator instances can be established across:

- the emulated backplane
- Ethernet using the EtherNet/IP protocol.

Backplane

Ethernet

FT Logix Echo
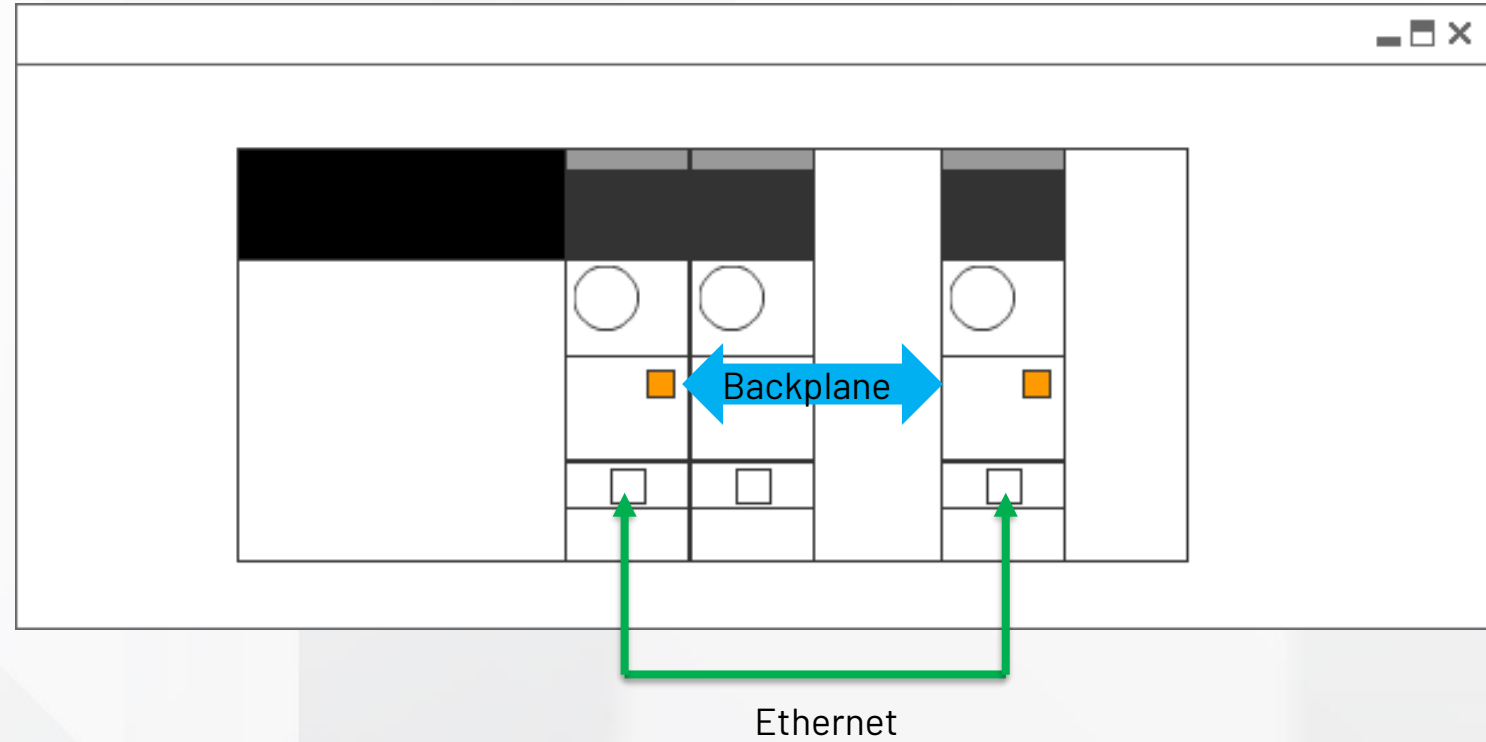
Emulator-2-HMI/Other CIP-based software

Class 3 (Messages) communication between emulator instance and HMI/other CIP-based software:
- Over EtherNet/IP
- Bridged over backplane to EtherNet/IP

PUBLIC

Logix Echo
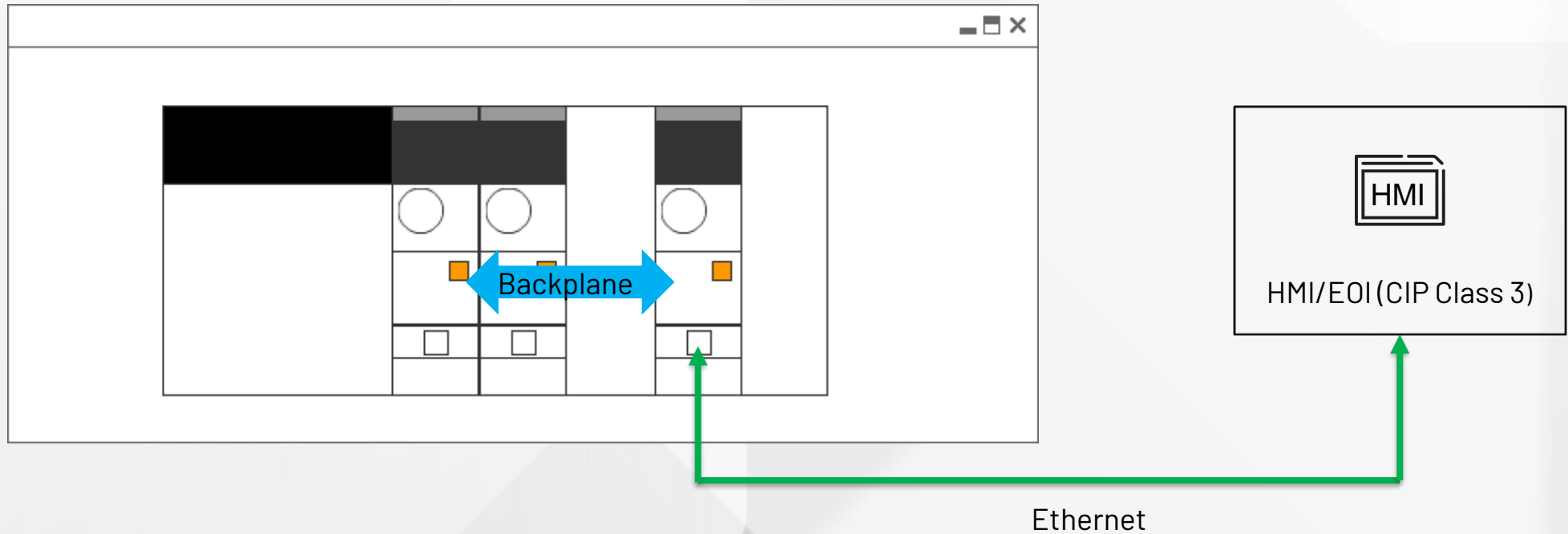
Remote connections to Emulators

Remote instances of Studio 5000® Logix Emulate™ and HMI software can communicate with the emulator instances over Ethernet.

- When Studio 5000 Logix Designer® is not installed on the same OS as FactoryTalk® Logix Echo certain workflows are disabled that depend on Logix Designer application services (that is Creating an emulator from ACD, program Download through FactoryTalk® Logix Echo dashboard or API)

Workstation or Virtual Machine #1

Backplane

Workstation or Virtual Machine #2

Studio 5000 Logix Designer®

HMI

HMI/EOI (CIP Class 3)

Ethernet

FT Logix Echo

V1.0
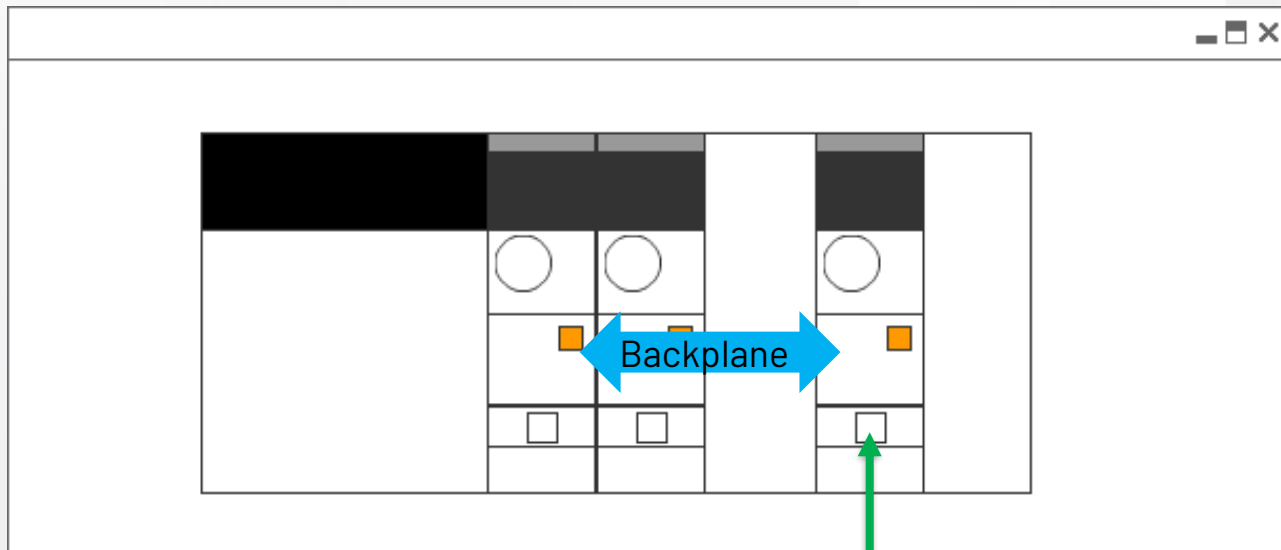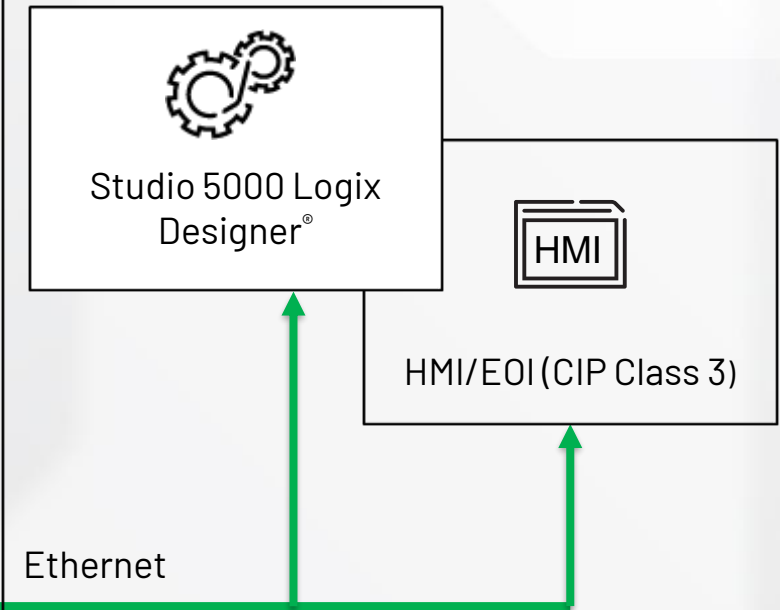
IP address Considerations

- Only one controller needs an IP address assigned (the rest of the controllers can be bridged to through the Ethernet connected controller, over the backplane

- The dashboard will only present IP addresses that are configured on the workstation including the loopback address, reserved in Windows for testing, 127.0.0.1.

- After assigning 127.0.0.1 to an emulator, you can reassign the IP address to any loopback address (127.x.x.x) on the general properties pane of the controller.

- Alternatively, if you have administrative privileges, additional IP addresses can be assigned to your network adapters to support additional controllers on Ethernet.

Important

- Studio 5000 Logix Designer® will not allow you to use loopback addresses for the controller in the I/O tree, helping help prevent you from using loopback addresses for Produce/Consume messages between emulators over Ethernet.

PUBLIC

Maximum Achievable Specifications

- Class 1 Produced/Consumed messages between emulators: 20,000 pps

- Class 1 chassis total: 160,000 pps

- Class 3: 700 messages/second

- Class 3 chassis total: 3,700 messages/second

- Minimum RPI: 15ms

Important

- As the software runs as a normal user program, it can and will be interrupted by other Windows services and processes adversely impacting performance

- Despite 99.9% of messages getting successfully transmitted/received, CIP connections will occasionally time out due to interrupts from other Windows services

Performance – Installation Hardware Requirements
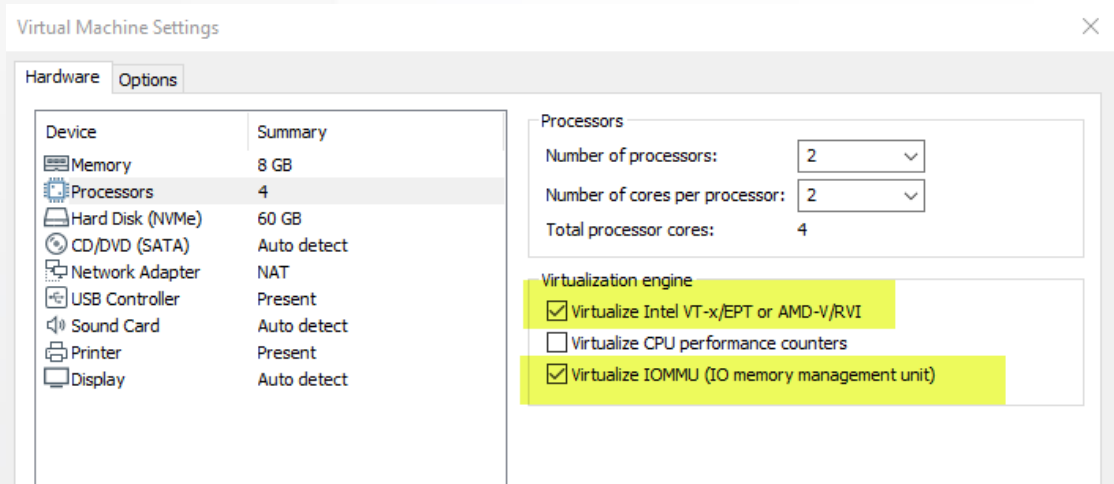
CPU – 2.2 GHz Intel Core i3 or faster processor:

- At least one logical core for the OS

- At least two logical cores for the core FactoryTalk® Logix Echo application

- At least one logical core per emulated controller instance

- Additional logical cores dependent on additional software installed on workstation

Memory – at least 8GB:

- 2GB for the base FactoryTalk® Logix Echo application

- 256MB per emulated controller instance (4.52GB for full 17 controller emulated chassis

- Additional memory for OS and other software applications

Virtual Machine Consideration

- Use Intel Virtualization Technology

Virtual Machine Settings

Hardware | Options

Device	Summary
Memory	8 GB
Processors	4
Hard Disk (NVMe)	60 GB
CD/DVD (SATA)	Auto detect
Network Adapter	NAT
USB Controller	Present
Sound Card	Auto detect
Printer	Present
Display	Auto detect

Processors

Number of processors: 2

Number of cores per processor: 2

Total processor cores: 4

Virtualization engine

☑ Virtualize Intel VT-x/EPT or AMD-V/RVI

☐ Virtualize CPU performance counters

☑ Virtualize IOMMU (IO memory management unit)

PUBLIC

V1.0

Note on Building the Project

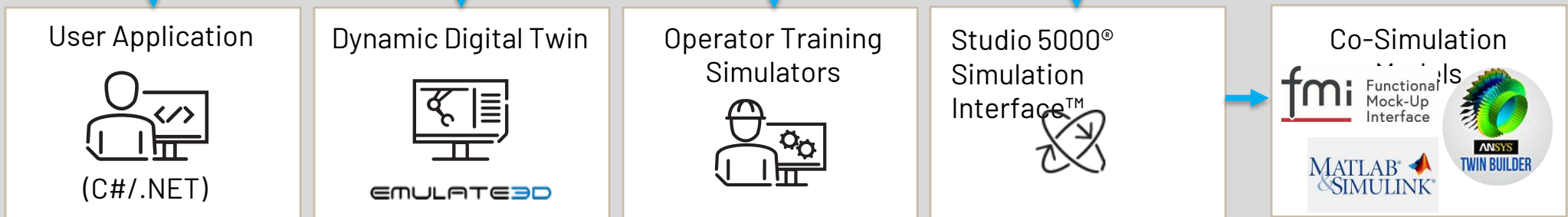- Studio 5000 Logix Designer® will build for the physical controller by default

First Download

- If you build before connecting to the emulator, the build process will be repeated when connecting to the emulated controller for the first time

- Subsequent downloads are typically 2x faster than on physical controllers

PUBLIC
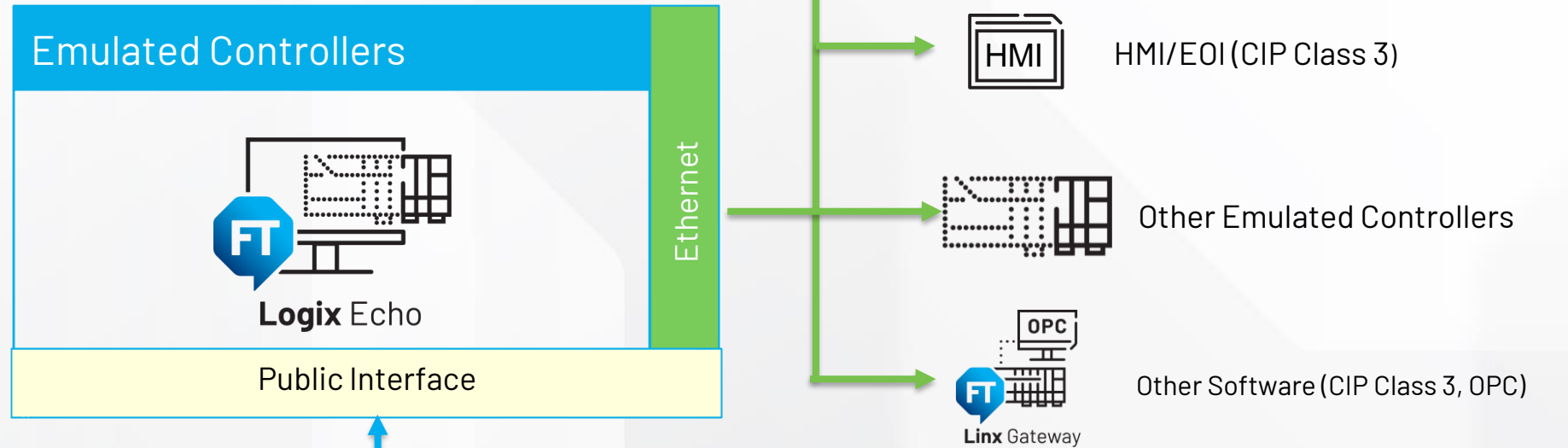
FactoryTalk® Logix Echo SDK

Integrate FactoryTalk® Logix Echo into your own Software Applications

Integrate all FactoryTalk® Logix Echo functionality into your own software application. Use the SDK and API locally to build applications to connect directly to controllers for simulation and data analysis

The SDK documentation kit contains:

- Detailed explanations of all API functions and their uses with sample code
- NuGet package, which includes .NET Standard 2.0 assemblies that allow access to API. (Installable in any .NET application that supports .NET Standard 2.0)
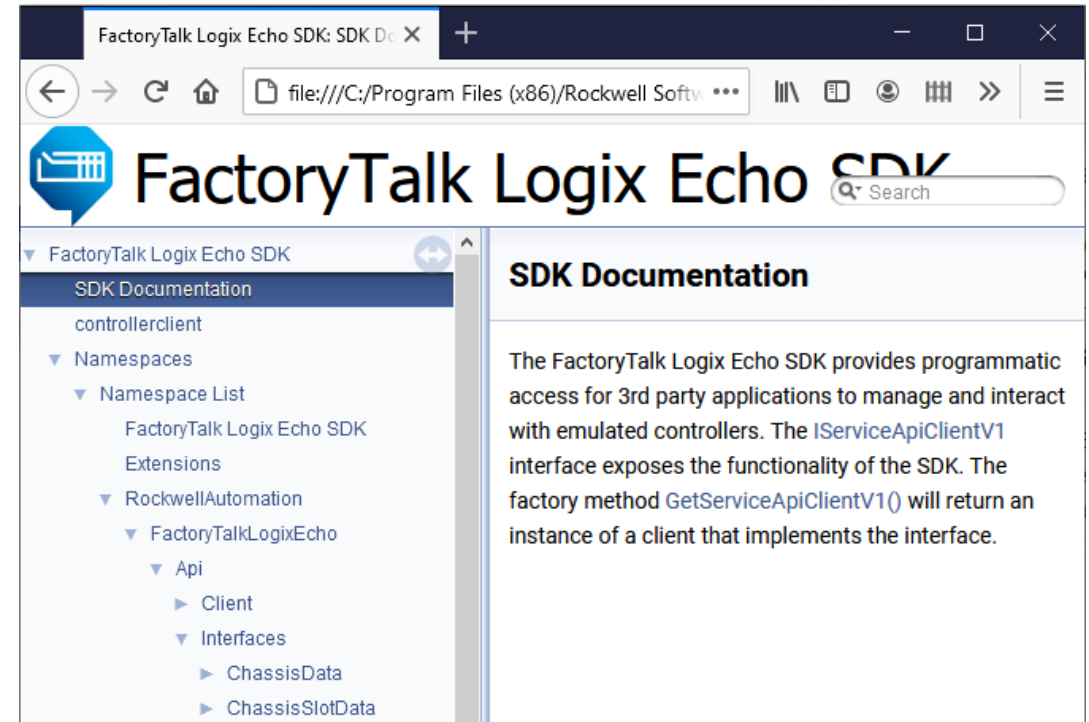
Two Sets of APIs:

- Service API: Use to manage the system and to perform all the functions that can be done from the dashboard
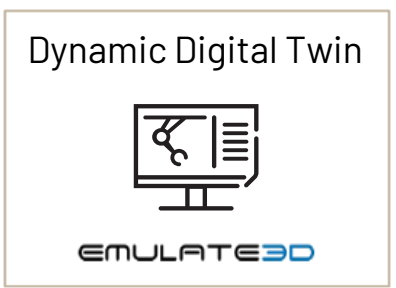- Controller API: Use to control the execution, scale time, and access tags in an emulated controller

Emulate3D™ Integration

Introduction: A note about Free-Running vs. Co-Simulation Modes

Free-Running mode:

- By default the virtual timing model of the emulated controller tracks real-time (windows system time) as closely as possible (to within a few milliseconds), we refer to this as 'Free-Running mode'.
- In the event there are not enough computing resources to track the system time, the model will begin skipping Continuous Task scans (and will set a fault once too many scan skips are necessary to keep up)

FMI for Co-Simulation

- Through the API, the emulator can be switched into Co-Simulation mode using the FMI for Co-Simulation Interface. This is an open standard interface for coupling simulation models in a co-simulation environment. The data exchange between models (for example the controller model and the plant/machine model in Emulate3D™) is restricted to discrete communication points. In the time between, the models are solved independently from each other. A time master application (in our case Emulate3D™) controls the data exchange between the models and the time synchronization.

Functional Mockup Interface for Co-Simulation

Available in Emulate3D™ 2020 minor release at launch of FactoryTalk® Logix Echo

Integration using Co-Simulation and Data Exchange API

- Enables E3D model and controller model to be synchronized
- Supports time-scaling (Change between Free-running mode and Co-Simulation mode)
- Modifying Continuous Task Fidelity (skip task scans)
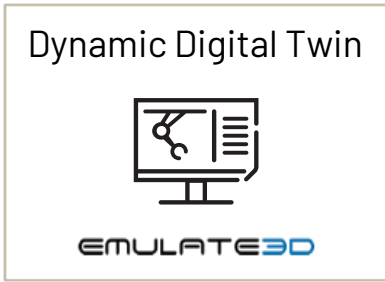
Integration over Class 1 or Class 3

- E3D can communicate over EtherNet/IP just like physical controllers

Emulate3D™ Integration

Available in Emulate3D™ 2020 minor release at launch of FactoryTalk® Logix Echo

Example 1:

- E3D runs as fast as possible with Controller in **Co-Simulation** mode
- Emulate3D™ reports the controller can be scaled to ~3x
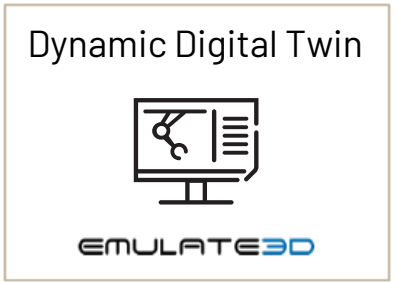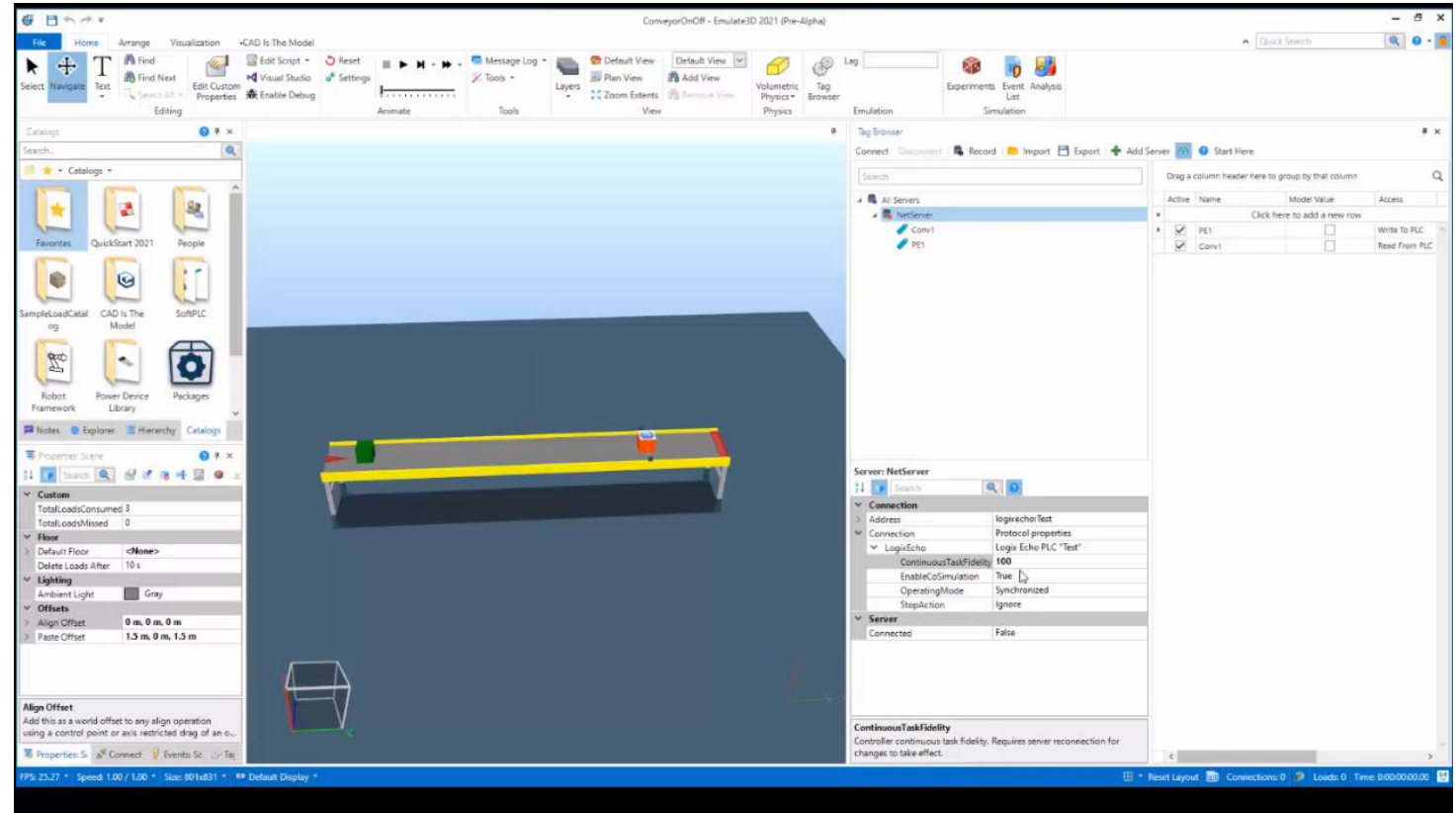

PUBLIC

Emulate3D™ Integration

Available in Emulate3D™ 2020 minor release at launch of FactoryTalk® Logix Echo

Example 2:

- Emulate3D™ runs as fast as possible with Controller in **Co-Simulation** mode
- User reduces the **Continuous Task Fidelity to 10%**
- Emulate3D™ reports the controller can be scaled to ~11x-12x

Operator Training Simulators

High-Speed Data Exchange and Co-Simulation Interface for Integration with OTS

Overview

- Use your own or third-party party simulation tools to interact with emulated controllers to create and simulate the plant responses

Benefits

- Provides dynamic, real-time responses like the actual plant

- Train operators in specific scenarios in a safe, fully functioning virtual system using the actual displays from operations

- Develop and test new control strategies or plant optimizations in a lab environment

Emulated controllers

Operator Training Simulator

PUBLIC

Snapshot Capabilities
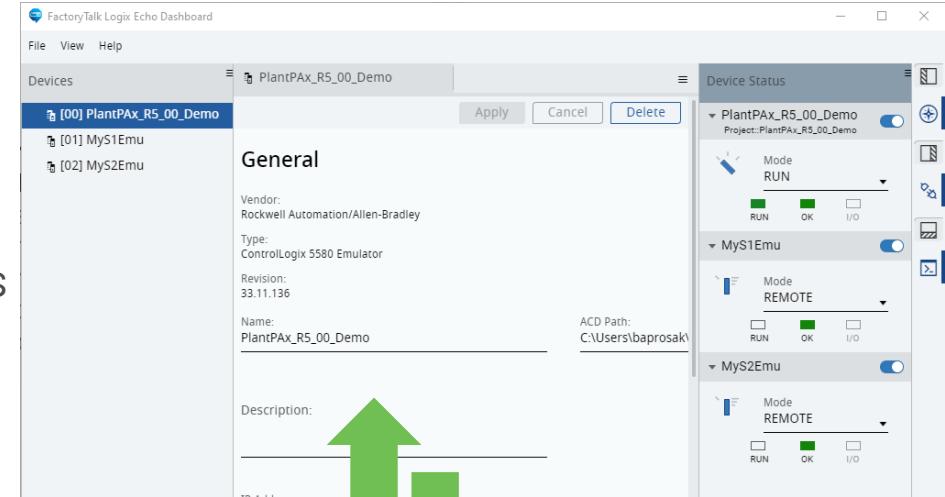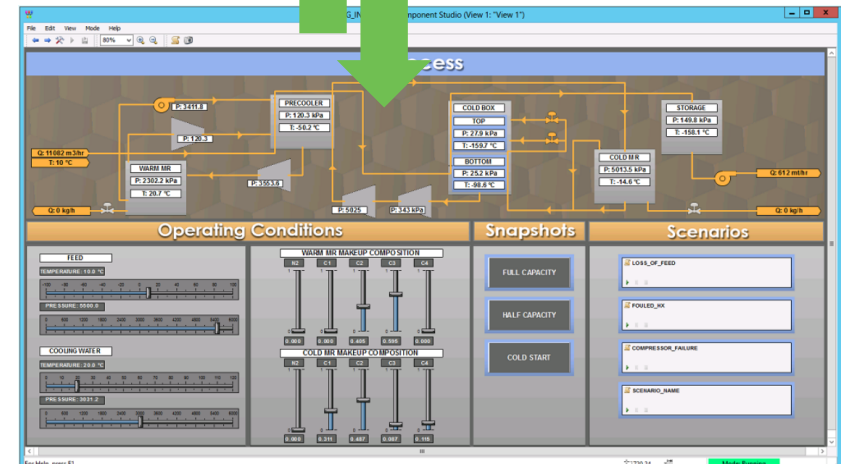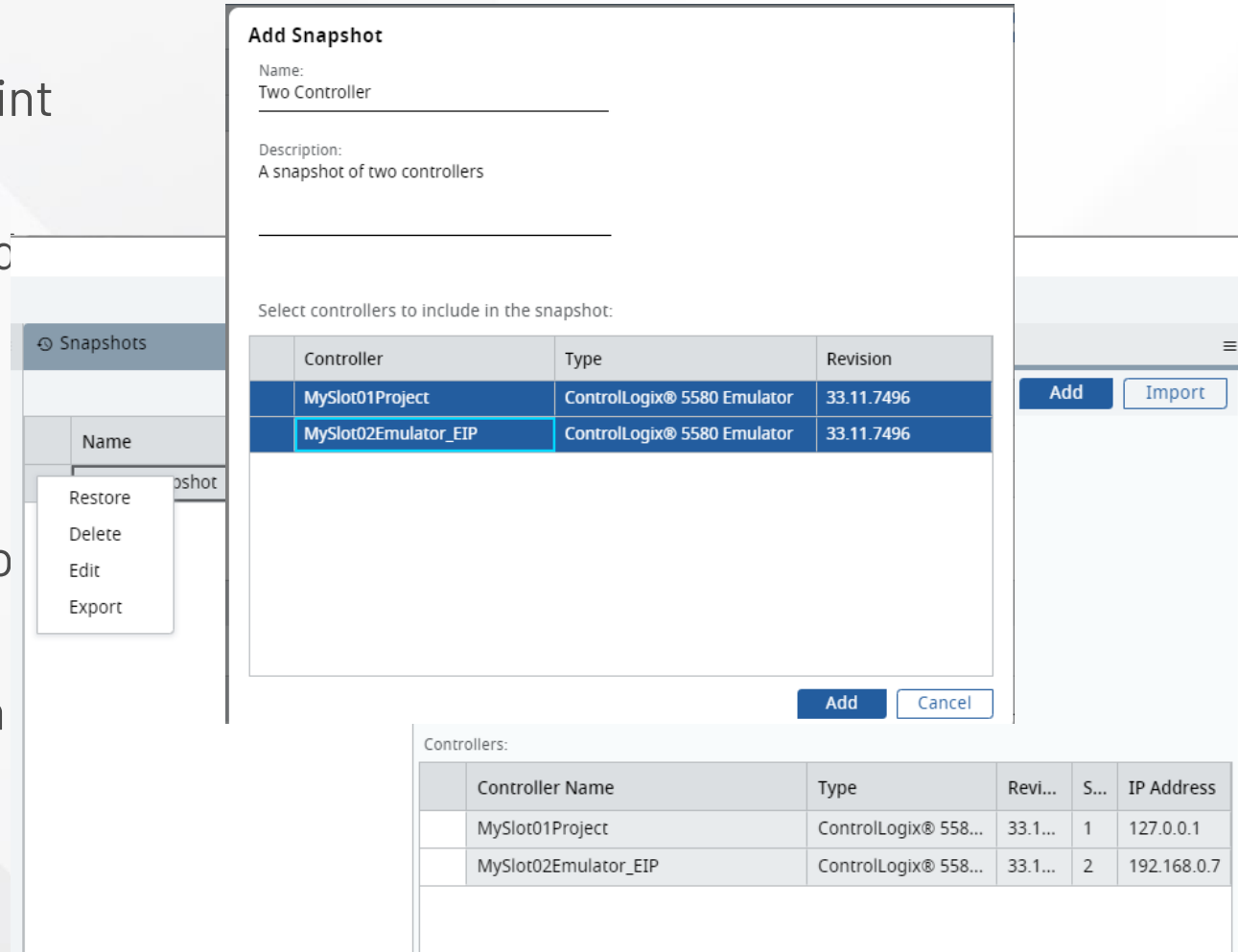
Snapshot Concept

Save one or more controller's state at a specific point in time that can latter be restored

- Includes controller time, application tag data and execution context

Use Cases

- Operator Training Simulators: Restore training scenarios that are difficult or time-consuming to recreate

- Automated Testing: Continuously recall a known scenario for testing

Add Snapshot

Name:
Two Controller

Description:
A snapshot of two controllers

Select controllers to include in the snapshot:

Controller	Type	Revision
MySlot01Project	ControlLogix® 5580 Emulator	33.11.7496
MySlot02Emulator_EIP	ControlLogix® 5580 Emulator	33.11.7496

Add   Cancel

⏱ Snapshots

| Name |
|---|
| ...pshot |

Restore
Delete
Edit
Export

Add   Import

Controllers:

Controller Name	Type	Revi...	S...	IP Address
MySlot01Project	ControlLogix® 558...	33.1...	1	127.0.0.1
MySlot02Emulator_EIP	ControlLogix® 558...	33.1...	2	192.168.0.7

Saving a Snapshot

A "Power Cycle Persistence Snapshot": We take an entire capture of the controller (static and dynamic data, like what happens during a power down of a physical controller)

Sequence of Events

- Snapshot Command: To help prevent data integrity issues that the controller is paused at the end of task scanning (beginning or end of continuous task (or idle if no continuous task)

- The controller powers down to save dynamic and static data

- Power up of the controller (first scan and pre-scan skipped)

- The full state is captured as a snapshot

Snapshot Command

Stop Controller at Safe Spot

Power Down of controller

Snapshot saved

FT Logix Echo
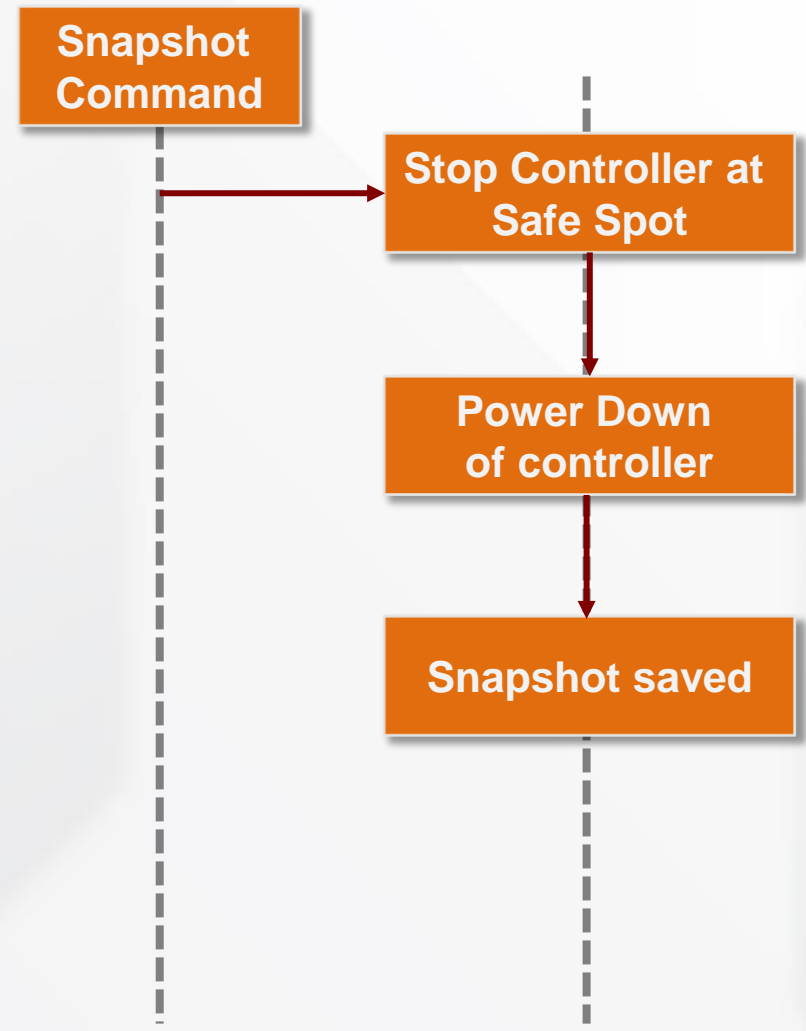
Restoring a Snapshot

Replaces over existing controllers

Sequence of Events

- Snapshot Restore: Turns off existing controllers. Controllers must be present in target slots of the snapshot restore. Inconsistencies presented to the user.

- The persistence files are replaced with the files from the snapshot

- On power-up the controller restores and resumes user execution, skipping first scan or pre-scan operations

- While the IP address from the snapshot will be applied to the controller, it will not bind to the IP address unless that IP is present on the workstation

Snapshot Restore

→ **Turns off existing controller**

↓

Replaces Persistence Files

↓

Power-up (no pre/first scan) of controller

↓

Snapshot Restored

Logix Echo
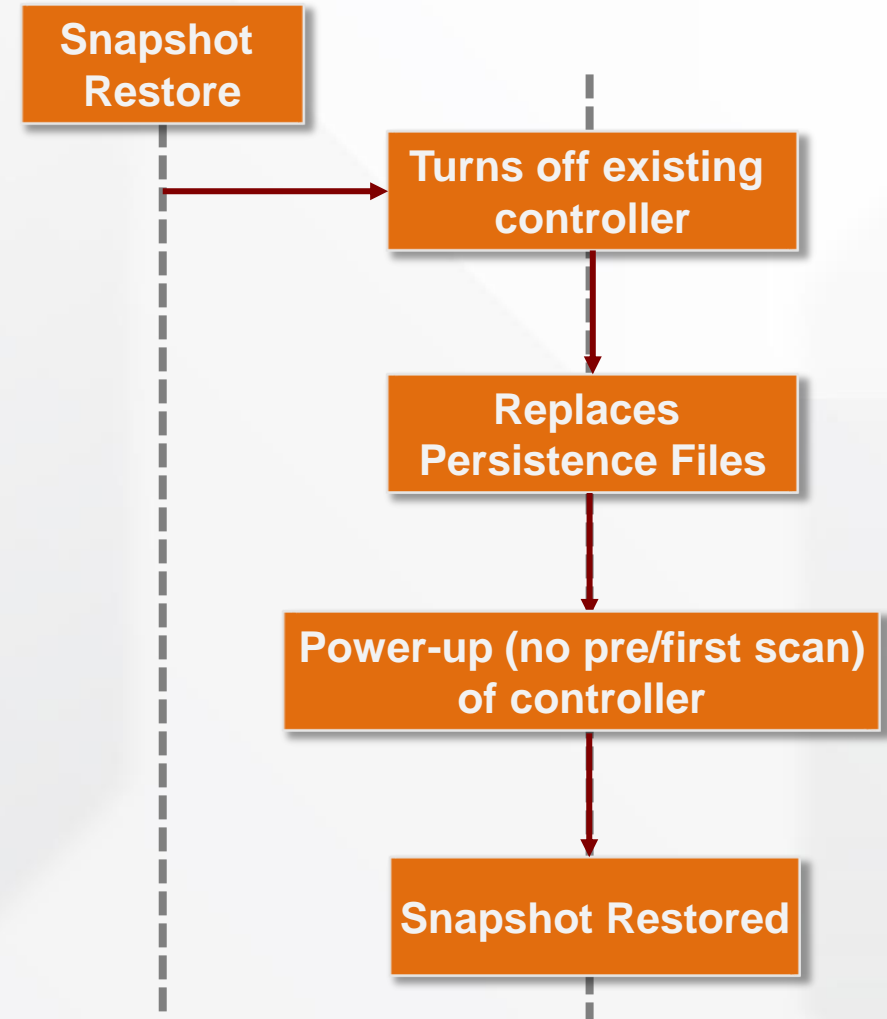
Integration with Studio 5000® Simulation Interface™

V1.0

Studio 5000®
Simulation
Interface™

Connect

Leverage Studio 5000® Simulation Interface™ to map tags in your emulated controller to variables in your mathematical model for precise simulation scenarios

Supported Interfaces

- Functional Mockup Interface: Open standard for model data exchange. Import FMI 2.0 co-simulation compliant models in Studio 5000® Simulation Interface™

- MATLAB with Simulink. Exchange data with Simulink models.

- New: Import and reduced order model digital twins

Studio 5000®
Simulation
Interface™

fmi Functional Mock-Up Interface

MATLAB® & SIMULINK®

ANSYS TWIN BUILDER
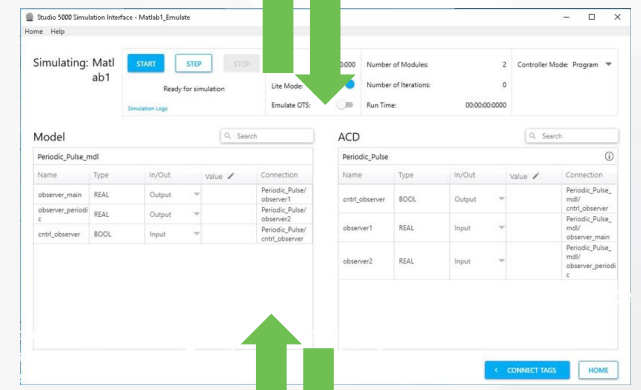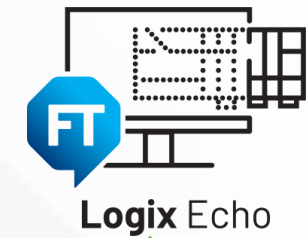
FT Logix Echo V2

FT Logix Echo — V2
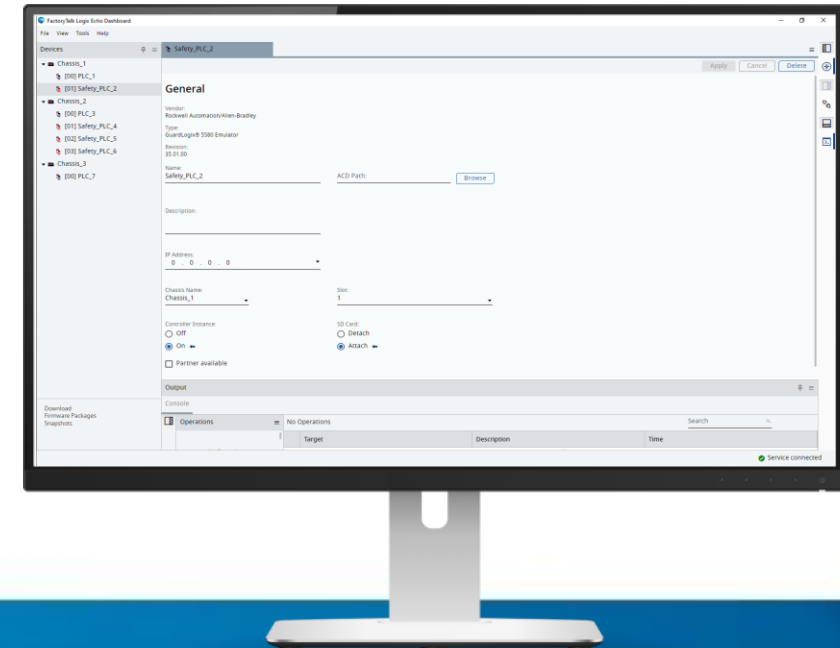
Emulate GuardLogix® 5580 Controllers

- Fully test your standard and safety control code in an isolated, virtual environment

- Execute controller project configured as SIL2/Pld and SIL3/PLe as designed without modifications

Architecture & interfacing enhancements

- Multiple chasses instances in one node

- Produce/Consume and MSGs between emulated controllers in another chassis

- Echo API enhancements

Axis Test Mode

- 5580 ControlLogix® & GuardLogix® Standard task motion logic and CIP Motion drive connection emulation

- Low Fidelity CIP Motion axis/drive simulation model for Kinetix, PowerFlex® CIP Motion drives and 5730 iTRAK®

Now Available

Rockwell Automation

Emulated GuardLogix® 5580

GuardLogix® 5580 Controller Emulation

- Fully test your safety control code in a safe, virtual environment

- Execute controller project as designed without modifications. The I/O tree will be maintained, all languages, instructions and task types supported

- All functionalities introduced in FactoryTalk® Logix Echo V1 apply to GuardLogix® Emulator

  - Virtual SD Card

  - Emulator 2 Emulator Ethernet and Backplane communication (Class 0/1 & 3)

  - Snapshot – controller state save

  - Service and Controller API
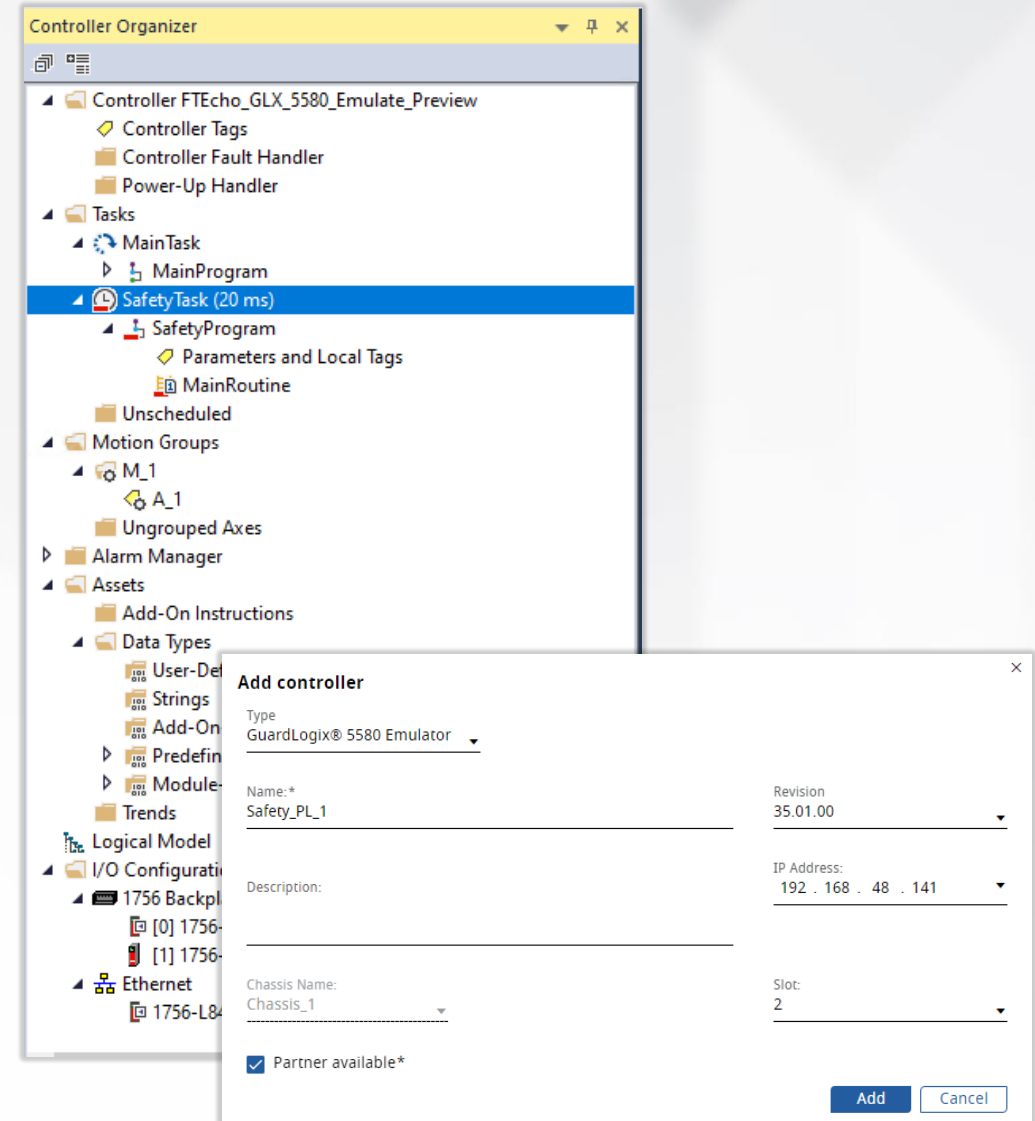
Emulated GuardLogix® 5580

GuardLogix® 5580 Safety Controllers

All -ES -ESK controllers and safety partners

Logix Echo

Firmware version 35 or later

Catalogs

1756-L81ES	1756-L82ES	1756-L83ES	1756-L84ES	1756-L8SP
1756-L81ESK	1756-L82ESK	1756-L83ESK	1756-L84ESK	1756-L8SPK

Future Releases: CompactLogix™ 5380 and Compact GuardLogix® 5380 Controllers

Rockwell Automation

Emulated GuardLogix® 5580

Safety task

- Emulation of both **standard** and **safety tasks**
- Safety instructions set execution within the safety task
- Safety Add-On instructions support

Main Task   **Periodic Task**   **Event Task**   **Safety Task**

Controller Organizer

- Controller FTEcho_GLX_5580_Emulate_Preview
  - Controller Tags
  - Controller Fault Handler
  - Power-Up Handler
- Tasks
  - MainTask
    - MainProgram
  - SafetyTask (20 ms)
    - SafetyProgram
      - Parameters and Local Tags
      - MainRoutine
  - Unscheduled
- Motion Groups
  - M_1
    - A_1
  - Ungrouped Axes
- Alarm Manager
- Assets
  - Add-On Instructions
  - Data Types
    - User-Defined
    - Strings
    - Add-On-Defined
    - Predefined
    - Module-Defined
  - Trends
- Logical Model
- I/O Configuration
  - 1756 Backplane, 1756-A
    - [0] 1756-L84ES FTEc
    - [1] 1756-L8SP FTEch
  - Ethernet
    - 1756-L84ES FTEcho_

Task Properties - SafetyTask

General | Configuration | Program Schedule | Monitor

Type: Periodic

Period: 20 ms

Priority: 10 (Lower number yields higher priority)

Watchdog: 20.000 ms

OK | Cancel | Apply | Help

Emulated GuardLogix® 5580

Safety levels support

- Both **SIL2/PLd** and **SIL3/PLe** safety levels are supported
- Safety Partner mimicking in Echo Dashboard and API
  - Chassis slot reservation
  - Partner available configuration parameter
- No parallel emulation of Safety Partner module

Rockwell Automation

FT Logix Echo
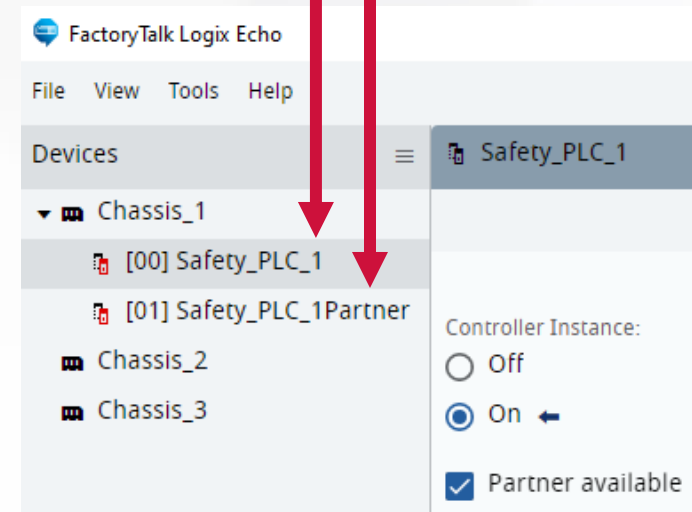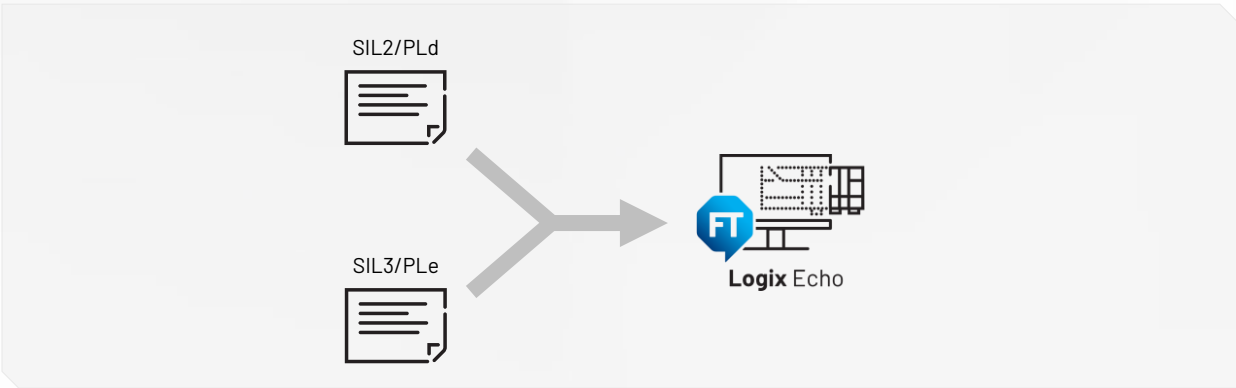
Emulated GuardLogix® 5580

Safety signature

- Project with a safety signature can be downloaded without any modification (signature remains unchanged)

- Generation of imitated signature for training purposes (valid only for Echo controller)

SIL2/PLd, SIL3/PLe → Logix Echo

Controller Properties - L8zS_TMP_1

| Redundancy | Nonvolatile Memory | Capacity | Internet Protocol | Port Configuration | Security | Alarm Log |
| General | Major Faults | Minor Faults | Date/Time | Advanced | SFC Execution | Project | Safety |

Safety Application: Unlocked   Safety Lock/Unlock...

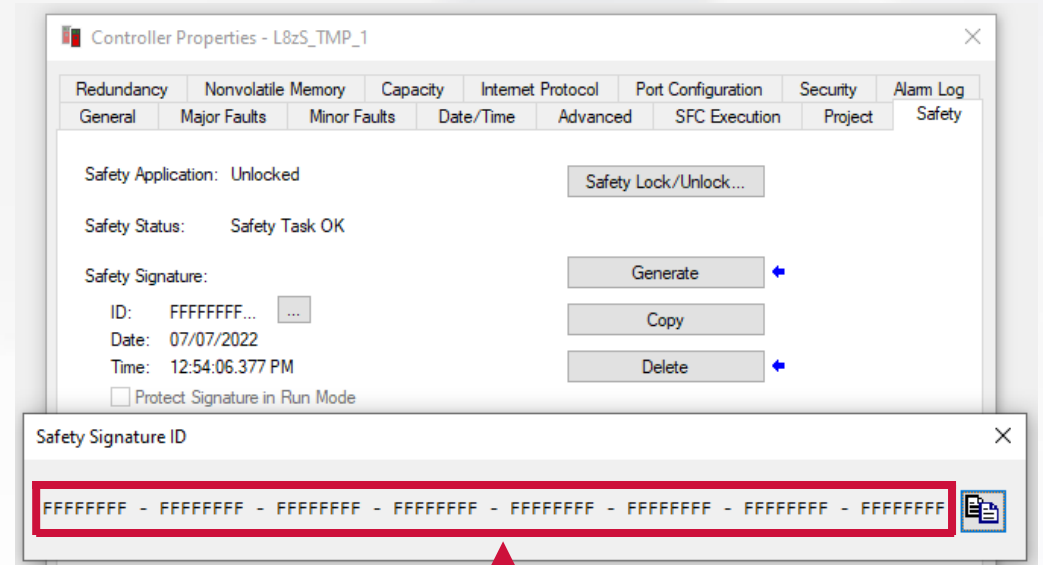Safety Status: Safety Task OK

Safety Signature: Generate ◄

ID: FFFFFFFF...   [...]   Copy

Date: 07/07/2022

Time: 12:54:06.377 PM   Delete ◄

☐ Protect Signature in Run Mode

Safety Signature ID

FFFFFFFF - FFFFFFFF - FFFFFFFF - FFFFFFFF - FFFFFFFF - FFFFFFFF - FFFFFFFF - FFFFFFFF

IMITATED
SAFETY SIGNATURE

Rockwell Automation

Emulated GuardLogix 5580

Safety IO Module-related tags Safe State

- When inhibited or faulted, the safety I/O module tag data will not be put in the Safe State so the safety I/O-related tags can be overwritten

- You can use either Studio 5000 Logix Designer tag editor or FactoryTalk Echo SDK to edit the values of safety I/O module-related tags to simulate inputs and outputs

C# user's script

EMULATE3D

Safety IO-related tags read/write

Echo API

Logix Echo

Rockwell Automation
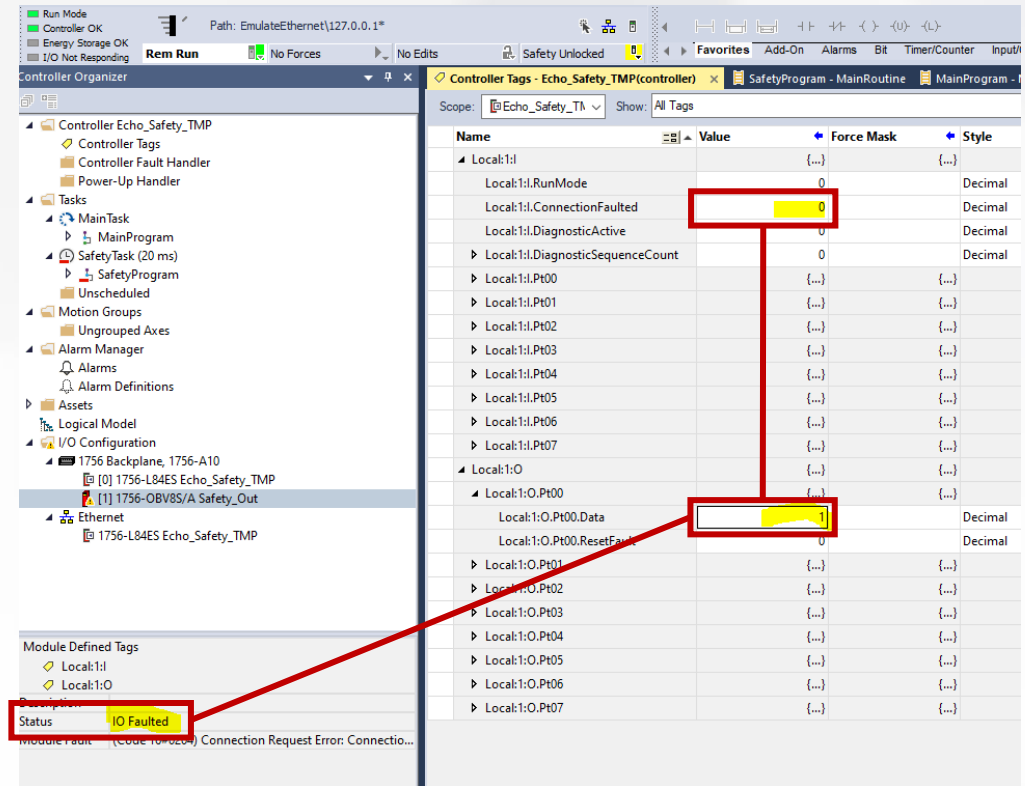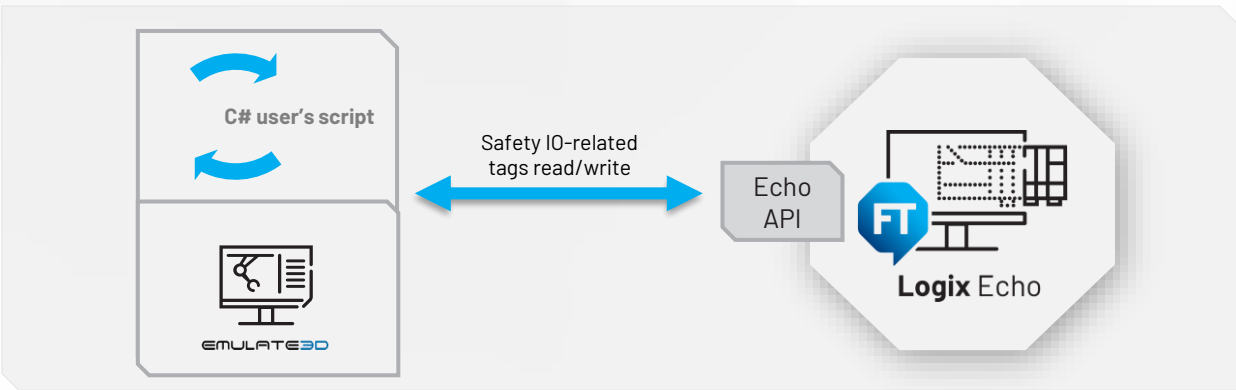
Emulated GuardLogix® 5580

Other safety feature supported

- Tags mapping between safety and standard tasks

- Project Online Editing

- Safety Produce/Consume communication between emulated GuardLogix® controller instances

- Safety Virtual SD Card handling

- Safety Lock/Unlock

FT Logix Echo

Multi-Chassis Architecture
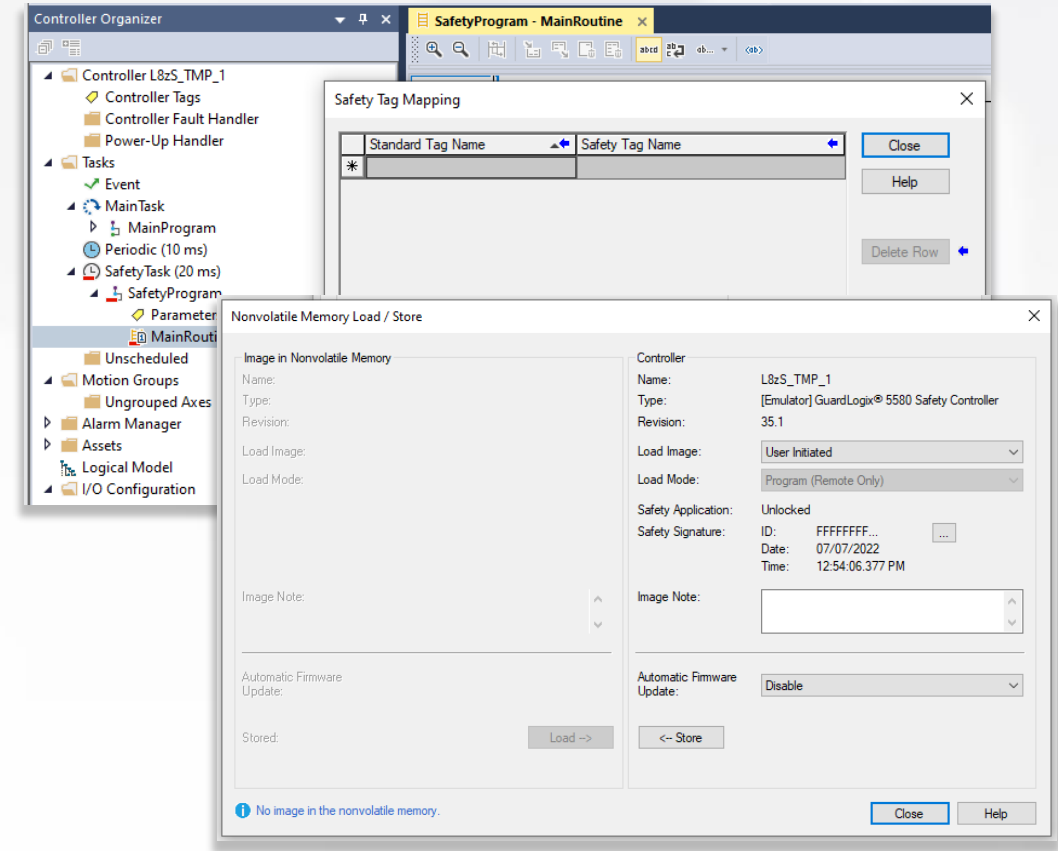
Multi-Chassis in a Single Node (PC/VM)

- Create Multiple chassis within one FactoryTalk® Logix Echo installation

- Emulate more complex distributed control systems
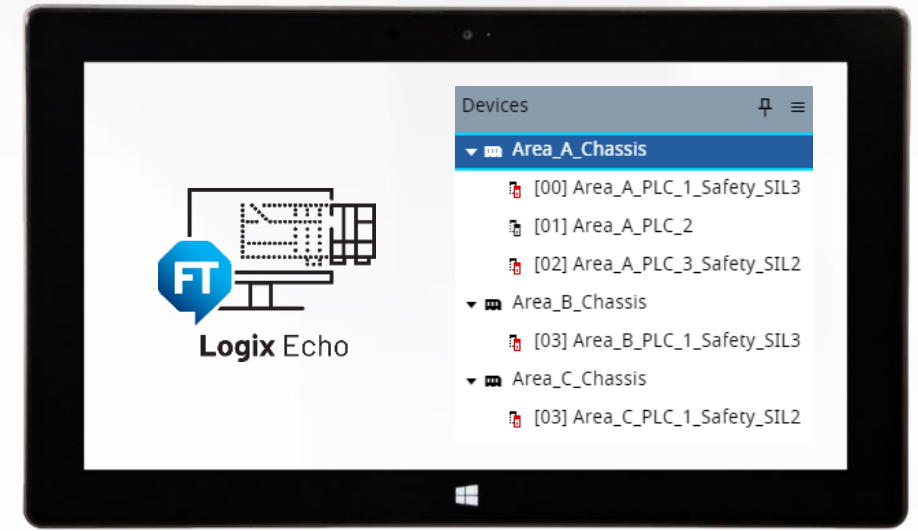
- Exceed the limit of 17 emulated controller instances

- Manage the emulated control system architecture via Echo Dashboard and Service API

- Create, restore and manage the complex control systems snapshots

Devices

- ▾ Area_A_Chassis
  - [00] Area_A_PLC_1_Safety_SIL3
  - [01] Area_A_PLC_2
  - [02] Area_A_PLC_3_Safety_SIL2
- ▾ Area_B_Chassis
  - [03] Area_B_PLC_1_Safety_SIL3
- ▾ Area_C_Chassis
  - [03] Area_C_PLC_1_Safety_SIL2

Logix Echo

Rockwell Automation

FT Logix Echo
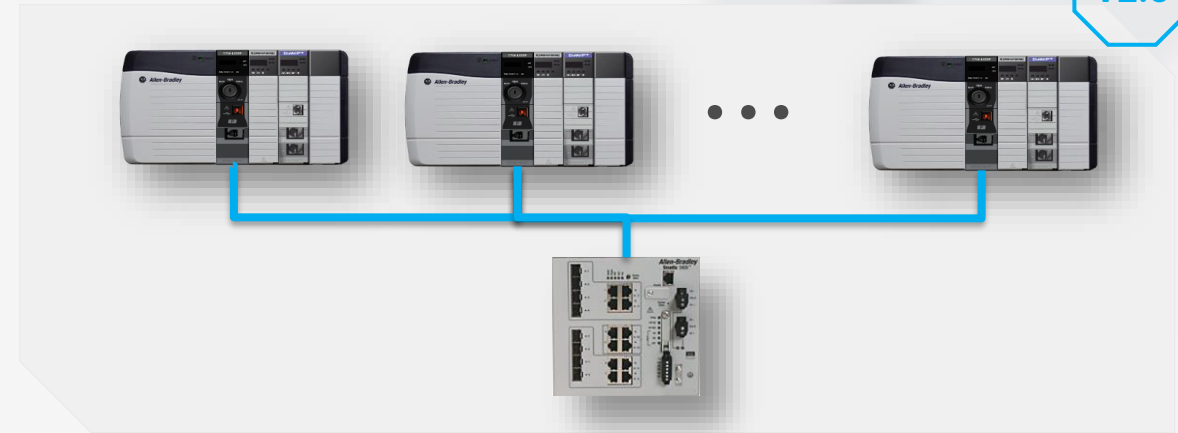
Cross-Chassis controller connectivity scenario

Class 1 (Produce/Consume) or Class 3 (Messages) communication between emulator instances in multiple, different chassis within the single Node

Rockwell Automation
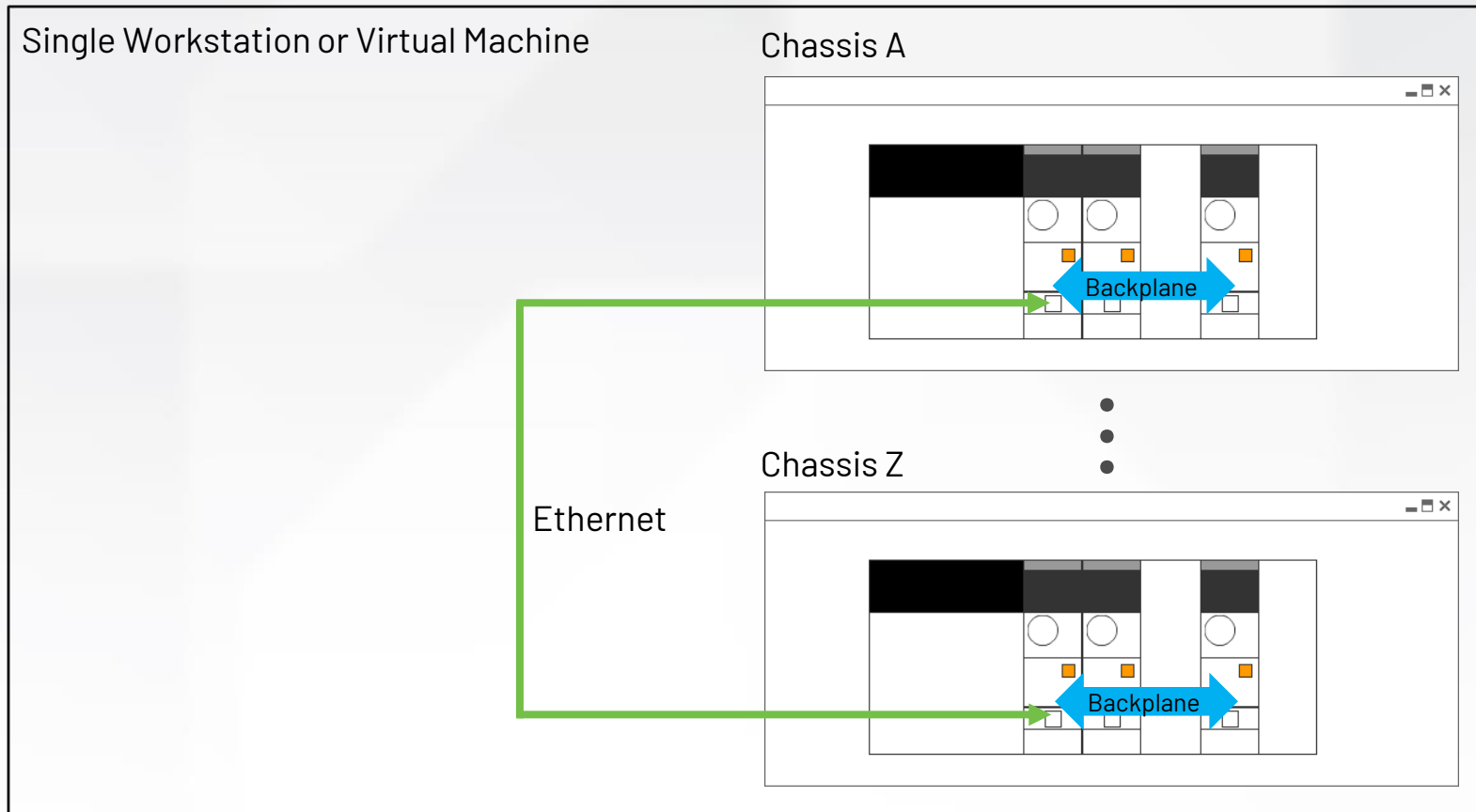
Echo API enhancements

64-bit applications support

- The Client Library is modified to support the „Any CPU" platform – both 32-bit and 64-bit applications

- Significant improvement for simulation packages users

Echo API ↔ EMULATE3D

- Co-Simulation
- Data Exchange

Logix Echo

32-bit client application

64-bit client application

Echo API

Rockwell Automation
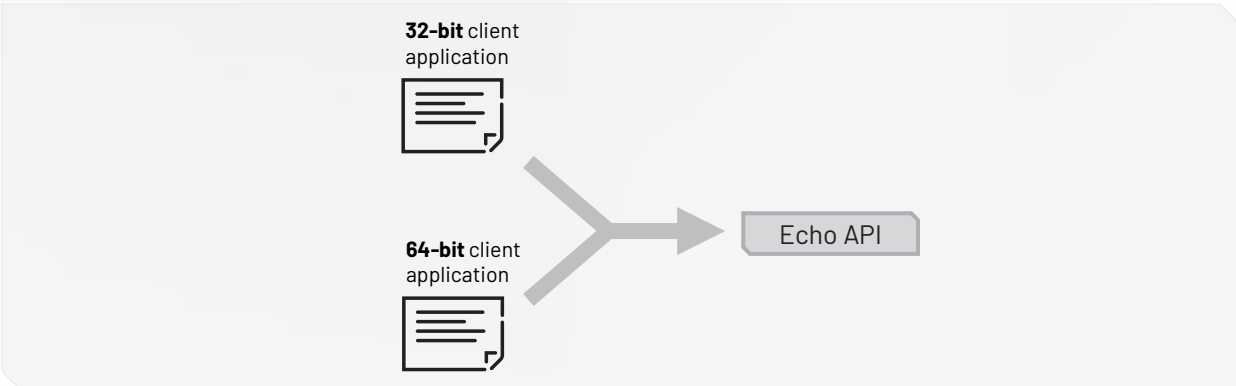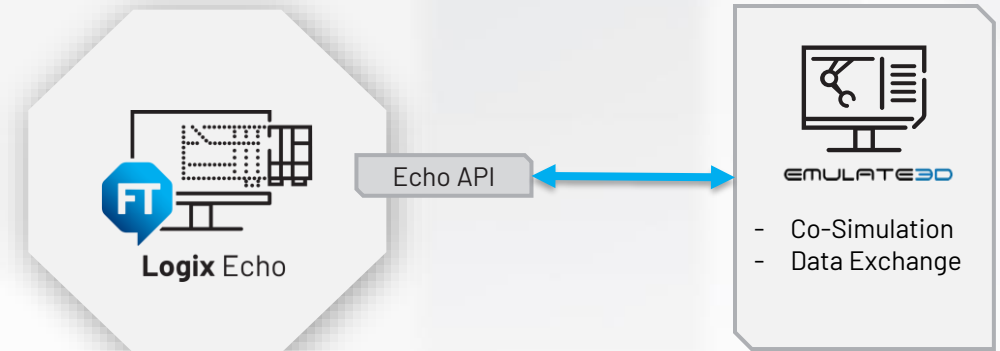
Echo API enhancements

Client Library update

- New Client Library function for returning all user application tags (controller and program scope tags)

- Individual bits access for integer tags (DINT, SINT, INT,…)

FactoryTalk Logix Echo SDK v2

▼ FactoryTalk Logix Echo SDK
  ▶ Service API Client Documentation
  ▼ Controller API Client Documentation
    ▼ Controller API Client Documentation
        Overview
      ▶ Pre-requisites
      ▶ Operating in Co-Simulation Mode
      ▶ Transfering Tag Data
        Catching exceptions
  ▶ Namespaces
  ▶ Classes

Rockwell Automation

FT Logix Echo

Motion Test Mode
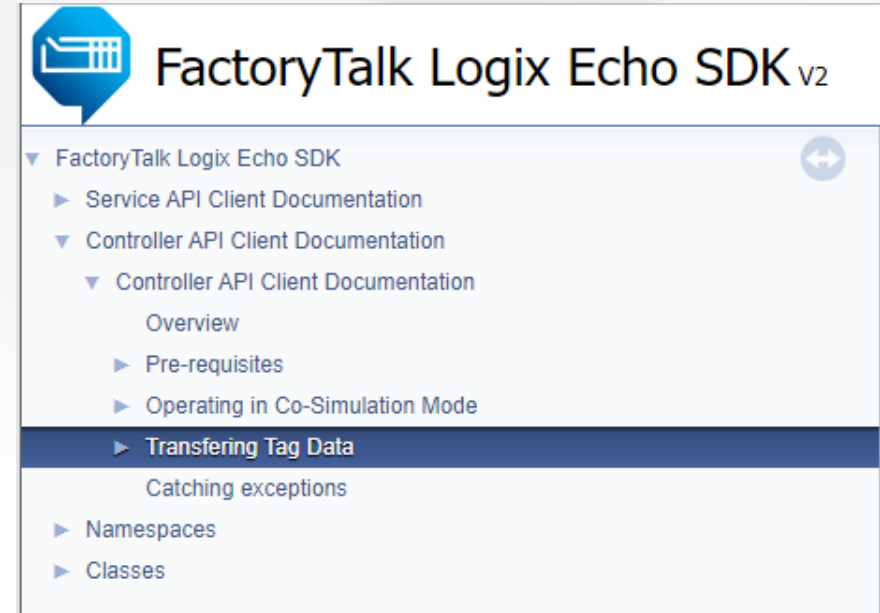
CIP Motion Axis simulation

- Build the digital twin of your assets by integrating an emulated control system with a model

- Validate and commission your motion application without connection to hardware

- Cross-controller platform feature, available for physical and emulated controllers (ControlLogix® and GuardLogix® 5580)

  - *Standard task motion logic*, CIP Motion drive connection

- Low Fidelity CIP Motion axis/drive simulation model

  - *Kinetix® & PowerFlex® CIP Motion drives , 5730 iTRAK®*

- *For the emulated controller, the Motion Test Mode is enabled by default*

Motion Test Mode

Logix Echo

EMULATE3D

Rockwell Automation

FT Logix Echo
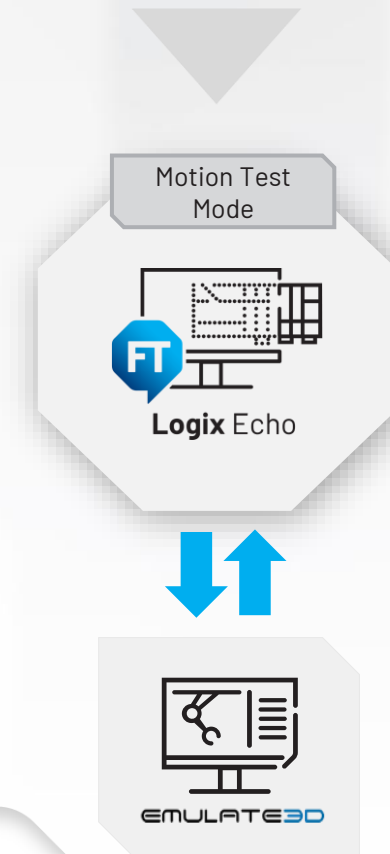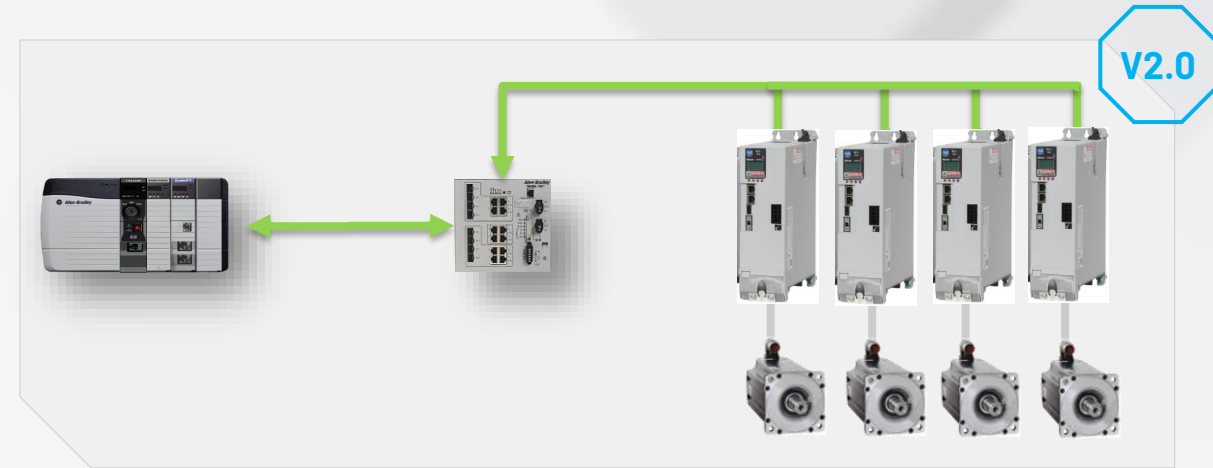
The emulator is a virtual controller, used in the development, testing and simulation environments

With an emulator, **you can**:

- Download and run logic written in any Logix language

- Be online with Logix Designer application, and all that entails

- Connect from an HMI [except for HMI Button Control (HMIBC)]

- Produce/Consume tags with other emulators

- Use MESSAGE instructions

- Use virtual axes or/and Motion Test Mode to validate and commission your motion applications without connection to hardware

- Download a project configured for redundancy, although it will always behave as a "Primary with no Partner" (simplex mode)

With an emulator, **you cannot**:

- Connect to physical I/O devices

- Connect motion axes to real drives

- Produce/consume tags with other physical controllers

- Use licensed-based source protection (precompile & encrypt)

- Emulate a true redundancy primary/secondary pair (duplex mode)

FT Logix Echo

Differences between emulated controllers and physical controllers

Functionality	Emulated Controller Behavior
Communication to physical devices	The emulated controller is restricted from establishing connections to physical devices. However, the API can be used to simulate input and output values
License-based source protection	Not supported, must be removed before downloading the project
SD card encryption	Content on virtual SD card is not encrypted or digitally signed
Automatic Diagnostics	Only controller instance diagnostics are collected. No I/O device diagnostics supported.
Email	Email functionality is not supported
USB port	Not supported
Serial Number matching	Ignores serial number matching

FT **Logix** Echo

Differences between emulated controllers and physical controllers – Con't.

Functionality	Emulated Controller Behavior
Module discovery	Not supported.
Motion support	Motion support is limited to low fidelity CIP axes simulation (Motion Test Mode) and virtual axes and consumed axes. Produce-consume virtual axes supported.
Connections between controllers	Produce/Consume messages work between emulated controllers. Other I/O modules in the I/O Tree will show as faulted.
Time-scaling	Supported through the API.
SNMP	Not supported
Redundancy	Operates only as a primary controller. High availability reports success, but the sync. with a second controller/support of sync modules is not available. Scan time does not reflect redundancy impacts.
Controller webpages	Not supported

FT Logix Echo

Differences between emulated controllers and physical controllers – Con't.

Functionality	Emulated Controller Behavior
Fault dumps	Fault dumps are always stored in the virtual SD card directory, even if detached in emulated controller properties. Important: contents are not encrypted
HMIBC instructions	HMI Button Control (HMIBC) instructions do not function (no Class 1 connection to HMI)
GSV and SSV instructions	Supports Get System Value (GSV) and Set System Value (SSV) instructions for emulated controller instances only. When GSV and SSV instructions target external objects, the instructions return the result for an unconnected device.