automation intelligence

VIRTUAL COMMISSIONING [PLAYBOOK]

A STEP-BY-STEP GUIDE TO **FASTER STARTUPS AND REDUCED RISK** USING THE LATEST TECHNOLOGY.

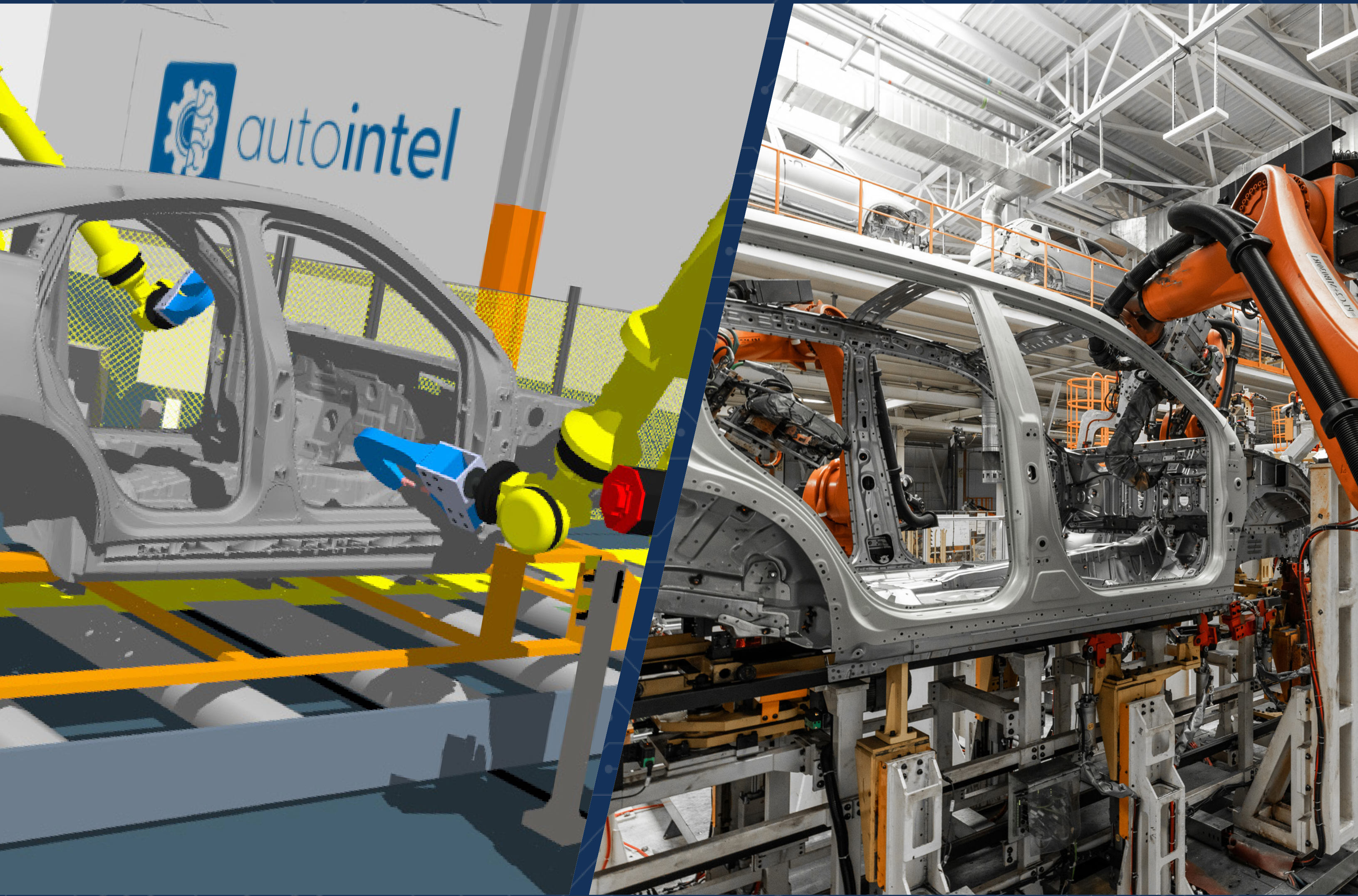


TABLE OF **CONTENTS**

EXECUTIVE **SUMMARY**

As companies strive to maintain a competitive edge, traditional commissioning methods—where machinery and systems are set up and tested physically—are increasingly being complemented by virtual techniques. This playbook is your comprehensive guide to virtual commissioning, an advanced approach that leverages digital technologies to simulate, test, and optimize systems before they are physically implemented.

At Automation Intelligence, we have successfully conducted virtual commissioning projects for clients in automotive manufacturing, consumer products, retail/eCommerce, warehouse logistics, and many other industries.

Through our experience, we developed this document that will guide you to adopt a high-quality virtual commissioning process for capital projects. This playbook, just like every other aspect of our business, is industry agnostic and applies broadly to industrial automation across different markets and facility types.

VIRTUAL COMMISSIONING 101: A PRIMER

What is virtual commissioning?

Virtual commissioning (VC) is the practice of using a physics-based model to validate and fine tune the design, control logic, and performance of a system or machinery in a virtual environment. VC includes connecting the real-world control code (PLC, HMI, MES, robotics systems, etc.) to a virtual model-- essentially tricking the controllers into thinking they're running the real system. This process occurs before actual deployment on the factory or warehouse floor, allowing for early detection and resolution of potential issues.

Why should you utilize VC?

Faster initial controls development and testing.

Access to a VC environment allows controls engineers to develop their code with instant feedback. We can also validate, in real-time, the progress your OEMs are making with controls development.

Anyone who has completed an industrial automation project in the past knows that controls are always the critical path. Without VC, controls engineers typically start their controls development process at power on. This is the last step and typically gets compressed.

Faster start-up

By addressing controls code issues virtually, we remove a significant amount of time spent in the field (**typically 50% or more**).

Lower risk of impacting production time

Time is money when you have to shut down production during testing and validation on the factory floor. By utilizing VC, you can uncover and resolve hundreds of issues within your control systems ahead of time, with zero impact to production.

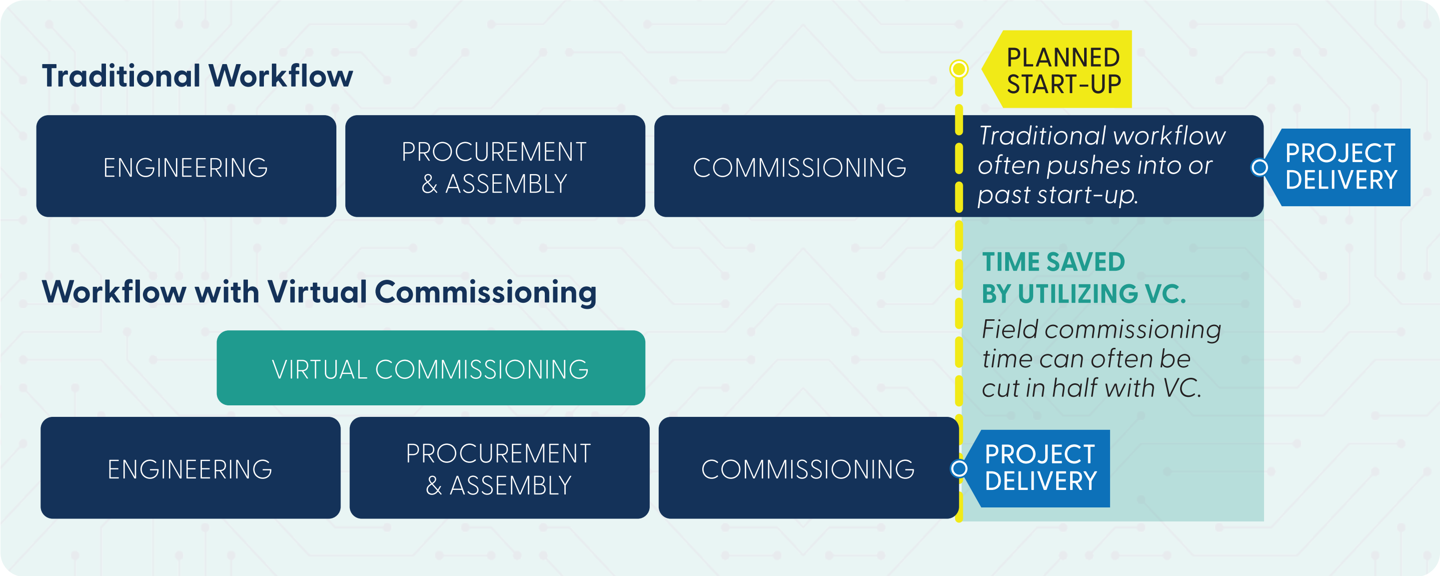
You never know what you might find.

In-person FATs do not afford the same access as VC. With a physics-enabled, virtual model, we can test more scenarios in a faster and safer environment.

In rare occurrences, we find issues like mechanical interferences which require the design team to redesign part of the system. We hope this isn't the case, but if it is, discovering those types of problems early on is considerably less expensive than finding out much closer to, or during, on-site commissioning.

Better trained site personnel

VC allows operators, maintenance, and site engineers to see how the equipment is supposed to operate weeks or months



prior to go-live. This enables owners to learn how to operate the equipment in a realistic environment and how to handle situations when things go wrong.

When should you do VC?

Typically, you want to begin the VC process when the mechanical design is complete and controls are at least 50% complete. Aim for having the virtual FAT executed prior to power on (and ideally long before in person FAT).

Who should consider utilizing VC?

If any of the following apply, you should consider utilizing VC:

- Tight-timelines
- High-value productive time
- New technology
- Past issues with start up
- For Suppliers, this is a strategic client.

How much does VC cost?

In most cases, fees for performing VC should be about 1-3% of the total automation CapEx investment.

Note: Some companies are now stipulating that virtual commissioning be a deliverable for all CapEx projects.

What should you look for in a VC partner?

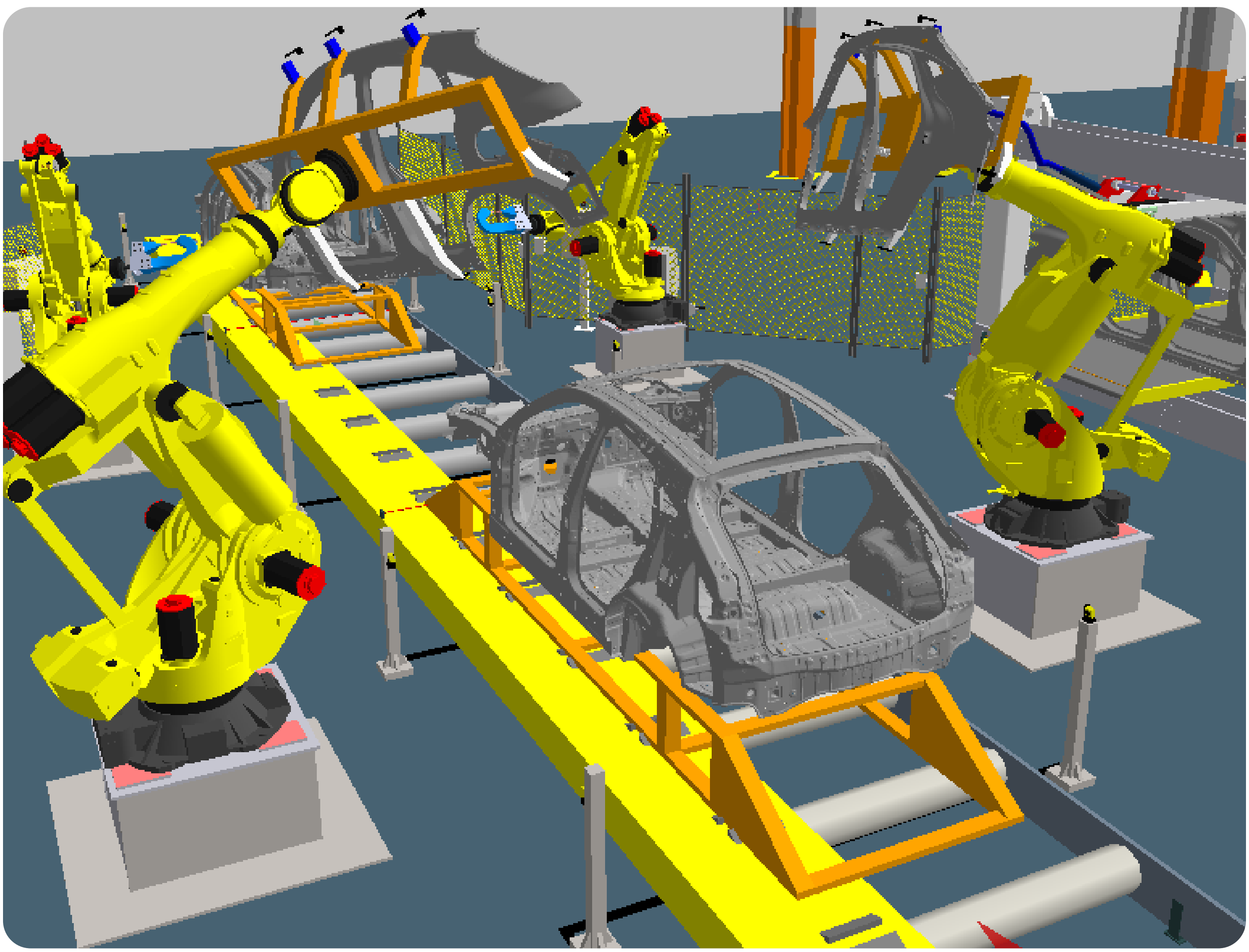
Should you decide to pursue VC for your CapEx project, you will need to select a consulting company to build and test the virtual model.

When selecting a partner for this role, consider the following:

- Do they have broad industry experience?
- Do they know what issues to look for and what types of scenarios should be tested?
- Do they have a strategic process to efficiently develop the model and execute all the testing and validation?
- Do they offer a cloud-based platform for collaborative work between your team, your OEM team, and your consultants?

Is there on-going value in VC?

When VC is complete, you will have a physics-enabled, digital replica of your automation system. We recommend and support our clients' continued use of the digital twin for operator/ maintenance training and as a test environment for any future controls changes.



THE **PROCESS**

PROJECT DEFINITION

Information Gathering
Milestone Schedule
Scope Clarification

KICKOFF

Team Alignment
Buyoff Checklist
Define Scope of Controls Testing

PROJECT EXECUTION

Phase I

- Creating a Test-Ready Virtual Environment
- Deployment to the Cloud

Phase II

- Development, Testing & Debug
- Controls FAT (Main Event)

POST PROJECT CLIENT ENABLEMENT

Future Use Cases

PROJECT **DEFINITION**

With any VC project, the first step is always to define and outline the full scope of work. This includes collecting detailed information on all the inputs of the system to be commissioned and creating an estimated timeline for development and delivery of the model, testing, analytics, and final recommendations. We utilize this project definition to generate a quote which captures the time and cost associated with our VC services.

What inputs are typically quoted in a VC project?

3D Mechanical Drawings

This is typically a mature set of drawings which includes part and assembly files and ideally references to electrical components like photo eyes or scanners.

Electrical Schematics

This will allow us to configure the environment to communicate the appropriate devices and map the I/O to the correct tags.

Tag List

A complete list of PLC and HMI tags and their data type and interlocks to outside PLCs as necessary.

Preliminary PLC/HMI Programs

Ideally this includes the tags and as well as most of the (untested) routines. If your programs are yet developed, that's OK. More on that later.

Functional Description

This is a document typically included in the SOW which describes the intended use of the system. This primarily allows to create the buyoff checklist, and Identify which special routines may be necessary to test the system.

Milestone Schedule

When considering the necessary resources ot execute virtual commissioning, the timeline should consider the following key project dates:

- Controls development (50% and 100% complete),
- In-person FAT
- Installation
- Go-Live

Scope Clarification

Our mission is to ensure the end user has a fast and error-free start up on site. To do that, we help the supplier by providing a virtual environment for controls development and testing. Our team of experienced virtual commissioning engineers will work with your controls team to identify and document bugs/issues along the way

We support the end user through updates on controls maturity and access to validate the system faster, earlier, and much more thoroughly than in-person buyoffs.

Note: Our team can handle just about any 3D CAD type. It helps us if the files are cleaned to limit the number of faces and vertices to less than or equal to 500,000 by removing elements that may not be relevant to virtual commissioning.

Responsibility Matrix

END USER	INTEGRATOR	AUTOMATION INTELLIGENCE
Execute Scope	Provide Documentation	Project Management
Scope & Timeline Definition	Develop Controls	Create Virtual Environment
Validate Buyoff Scenarios	Debug/Test Controls	Connect to PLCs/HMIs
Track Progress	Stipulate Buyoff Scenarios	Document Bugs/Issues
		Ensure Buyoff Ready

KICKOFF

Align Project Teams & Start Communication

The first step is to meet the stakeholders from all parties and align on the milestone dates and virtual commissioning process. Our team will start instantiating tools and environments for future issue tracking so all parties can get familiarized.

Buyoff checklist

This is the guiding light of virtual commissioning. Our teams will work together to develop and document a list of scenarios which can be objectively tested to ensure the system works as it is intended.

Furthermore, this provides us a quantifiable measurement which we can communicate to all parties to describe progress of controls validation.

It's not uncommon that this checklist is over 150 scenarios.

Define Scope of Controls Testing

Which parts of the process are in/out of scope? What systems interface with the areas in scope (e.g. AGV controller, interlocks to other machines, MES system(s))? These areas for testing must be defined.

BUYOFF CHECKLIST

A proper buyoff checklist should cover many areas, including but not limited to:

- [ ] Safety checks
- [ ] E-stop and recovery
- [ ] Normal automatic style
- [ ] Manual mode(s)
- [ ] Maintenance functions
- [ ] Process faults and recovery

HMI CHECKLIST

Another way in which you can get a return on investment with your digital twin is to utilize it to find and fix problems with your HMI interfaces that you would have otherwise found during go-live. This testing is best executed with your safety manager, operations manager, maintenance leader, and engineering team.

During the checkout process, you'll want to test and validate these common categories. (Note that some may apply to you, others may not.)

HMI Suggested Tests

- **Tags:** Are all the buttons connected to the correct PLC tag?
- **Alarms:** Do the alarms show up the right way?
- **Alarm Priorities:** Do higher priority alarms show up ahead of lower priority alarms?
- **Recovery:** Does the HMI properly recover from a faulted state?
- **State Permissives:** Are certain buttons grayed out in the right sequence?
- **User Permissives:** Are users of the correct level able to access the appropriate screens of the HMI?
- **Stack Lights:** Do the lights show the right thing in the model? (In VR you can see the alarm from the right angles.)
- **Manual Mode:** Can you move machinery to user manipulated positions?
- **Stop/Hold Mode:** Do processes stop and restart when they are supposed to?

PROJECT **EXECUTION**

PHASE I

In the first phase of project execution, the primary focus is on developing the virtual model and deploying it in a cloud environment where all stakeholders can collaborate during testing and debug.

CREATING A TEST-READY VIRTUAL ENVIRONMENT

Overview

The meat of our scope begins with creating (or re-creating) a virtual environment for controls testing and debug. In doing so, we start with static 3D models and end with a fully functional 4D model that's ready for testing and debug.

Our team is most efficient when we can simultaneously add kinematic properties while mapping these functions to the appropriate tag(s).

3D Kinematic Model

This includes bringing to life the 3D CAD and introducing motion to any necessary components through definition of motors, servos, cylinders, etc. In this step, it's important to capture the motion profiles so the behavior of the system closely resembles the real system.

Also included in this phase is sensor placement. Things like photo eyes, proximity sensors, encoders, and scanners are placed in the virtual environment in the same location and orientation as designed.

Device & Tag Mapping

The next step is to prepare the kinematic model to interface with the controllers (PLCs/PCs/HMIs). To do this, we link the inputs and outputs in the tag list to the respective element of the kinematic model. Consistent naming conventions/standards will allow us to use our tools which automate this process. We will refer to the electrical schematics and the tag list to perform this step.

First Connection & Achieving Steady State

Once the virtual environment is prepared, we will connect the PLCs/HMIs for the first time. It's not uncommon that errors prohibit the system from operating in a steady state. In this step, we start our collaborative debug process with the client by documenting issues.

Around this time, we will deploy our model to the cloud environment for collaborative testing with the OEM controls team.

Enabling Test Scenarios

It is sometimes necessary to enable test cases which require outside intervention to stimulate a test. Examples include losing pneumatic pressure or loss of power at a control panel. Our team creates special routines and user controls to enable these tests and to ensure the system is fully functional to a host of possible scenarios.

Deployment to the Cloud

What is it?

It's a secure, globally accessible environment that allows our clients to test and validate their code without needing any special software or hardware. We have VMs for the emulation environment, HMIs, PLCs, robot controllers, and any other relevant control systems. Our team will network all the parts together so the user has a seamless experience.

24/7 Access to the Virtual Commissioning Environment

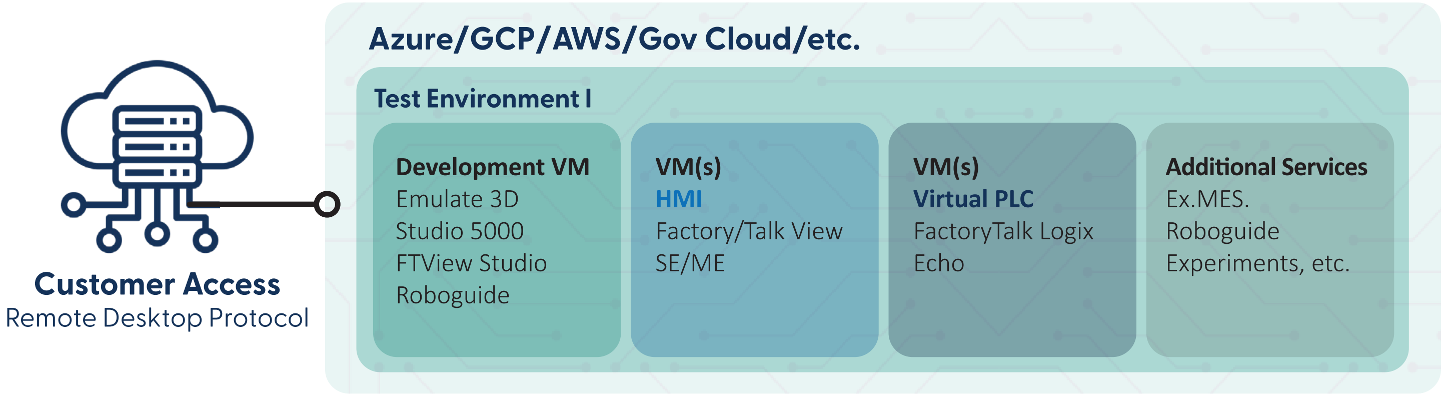
In the days before cloud-based virtual commissioning, controls engineers would need to be on a zoom meeting with our engineers to identify and resolve issues. We've made it easier by providing access to our environment so controls engineers can work at their own pace (and without others looking over their shoulders).

A Single Source of Truth

By having one, central location for the most up-to-date programs, we remove the asynchronous exchange of programs between parties. This saves time and avoids rework.

Save for Future Use

We preserve the environment after the project, so it's fast to revisit should the need arise in the future.



PHASE II

Once the model environment is set, it's time to move into the crux of the VC process. Testing and debug is a collaborative process between you, your supplier, and a consultant like Automation Intelligence. Once a pinnacle point is reached, we typically lead our clients in a virtual buyoff meeting to demonstrate that the code now meets the buyoff checklist.

DEVELOPMENT, TESTING & DEBUG

Overview

This phase starts with untested programs connected for the first time and ends with a rock-solid, thoroughly tested controls package. Along the way, our team works with the supplier by independently testing the logic and documenting specific issues on a web-based punch list. Once all the issues are resolved, we document and demonstrate the buyoff scenarios to the end user.

Identify & Track Issues

Once the supplier has a chance to develop the programs to a point where they're ready for testing, our team will validate the scenarios in the buyoff document and track any issues we find. In many cases we can automate tests to look for unused tags, jumpers, etc. that may not cause issues but don't tend to follow best practices.

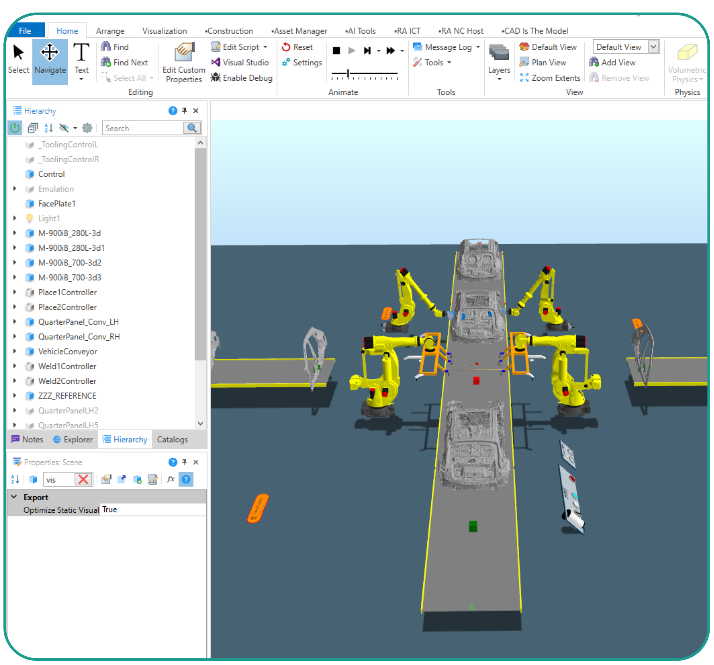
Report Status

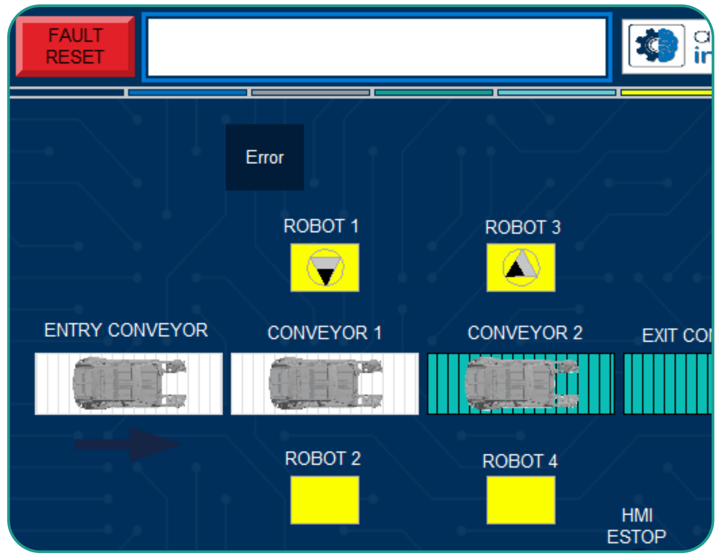
During this period, we provide our clients with a summary of what issues have been identified and addressed and what issues remain unresolved.

Preliminary FAT

Once all the known issues have been addressed, we provide our clients with a recording of the system going through the buyoff checklist. This documents the success of the system and allows the client to validate for themselves on their own time.

We call this preliminary because we still wish to validate live with the end user during a Virtual Buyoff.





VIRTUAL BUYOFF

How it works

We'll facilitate a meeting with client and supplier stakeholders during which we will demonstrate select tests from the buyoff checklist. We will also welcome tests from the audience ad hoc to show how the system performs.

In both live and pre-recorded video testing events, our team leverages live broadcast software to enable clear and professional review of all system components, including the equipment model, HMIs, PLC code, and the buyoff checklist.

What to expect

For End Users

Come up with what-if scenarios and share some of them with the facilitators. Hold back some so they can't make a work around before the main event.

For Everyone

It's not uncommon for different stakeholders to have different interpretations of how the system should operate. That's why it's critical in this step to document the issues.

It's best to note what failed, and keep going with the tests you can run. You can come back to specific issues and test again once the engineers have had a chance to resolve them.

As a stakeholder, navigating the commissioning process in a virtual environment is still much more efficient and less tense than trying finding and fixing these issues in the field.

POST PROJECT

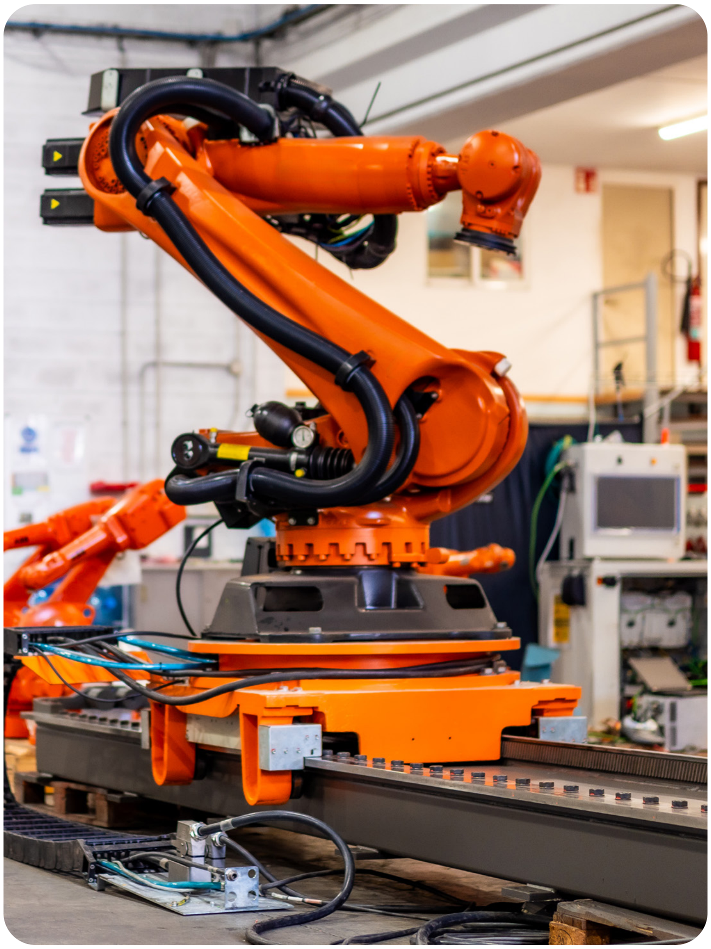
After the VC process is completed, there are still a few key steps to take before we wrap-up the project. We also wanted to share with you some common issues or things to consider in the process.

POST-FAT CLIENT ENABLEMENT

Among other things, VC yields a valuable tool that you don't want to discard after the process is complete. An emulated digital twin model of your facility can come in very handy for future uses including operator training and further testing.

This is where our clients typically decide to extend the life of their model by maintaining it in the AutoIntel cloud for ease of access. We can also perform additional updates down the road if you want to test out equipment or layout modifications before implementing anything in real life.

It's also a best practice to document the final results of virtual commissioning for all stakeholders. You may find it useful to share the process and the model internally with colleagues, and possibly even externally at a conference or symposium.



OTHER THINGS TO KNOW

#1 Roadblock to VC: Controls Delays

This is the #1 risk and is a frequent roadblock in projects. Controls are almost always the critical path at the tail end of VC projects. And controls engineers are used to testing on real-world equipment versus a digital twin. VC commonly requires that controls get started 2-3 months sooner than projects without VC.

That said, the amount of time to develop the controls is the same, we're just enabling them to start sooner. We find that this process actually reduces total debug time because controls engineers are able to set up and restart tests much faster than in the field.

Late Design Changes

It's not uncommon that different stakeholders have their own interpretations of how a system is supposed to function. That's why we start the buyoff checklist as soon as we do. This helps us avoid situations like:

- A Site Engineer is involved in the Controls FAT and wants to change the HMI screens and maintenance access routines.
- A Corporate Engineer didn't thoroughly review the buyoff checklist or SOW and expected the system to follow a different, new controls standard than the one that the supplier designed the system for.

V35 is Required for Logix Echo

If you're using AB controllers, Emulate3D requires v36 to test and validate the code using Logix Echo. This may require users to port back the changes to previous versions if they standardized on v34 or earlier. Our team is happy to support delivering a final version of the PLC code in the OEMs firmware of choice.

Resistance to change

If you encounter resistance within your organization to utilize VC, here are some of our responses to common concerns:

- **"We already did a simulation."** That is a different process that doesn't utilize real controller code to run the system, which is what ultimately winds up saving time on-site.
- **"We're just making small changes."** You never know how the behavior of different equipment and systems will be impacted. In our experience, it's best for all changes to go through at least a quick digital twin virtual validation.
- **"I don't see the value."** At minimum, VC is a fairly inexpensive insurance policy to mitigate significant risks to your worker safety and production impacts.

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COMPANY OVERVIEW

Our top goal is to provide an excellent client experience.

At Automation Intelligence, our company values center around client satisfaction, integrity, respect, and innovation. We believe in delivering more than just results, we also want our clients to enjoy the collaborative experience of working with our team.

Our company headquarters are in Atlanta, but we have experts in industrial automation and machine learning across the United States. Together, our team has extensive experience delivering value-engineered solutions in the areas of automation, machine learning, and artificial intelligence.

LAUNCHED IN 2019

HEADQUARTERED IN ATLANTA

18 ENGINEERS ACROSS THE US

PARTNERS

We are proud to partner with Rockwell Automation, global leaders in industrial automation, and Gurobi Optimization, industry leaders in decision intelligence.

Digital Partner Program BY ROCKWELL AUTOMATION

GUROBI ALLIANCE

AWARDS & CERTIFICATIONS

AutoIntel is also a certified LGBT Business Enterprise through the National LGBT Chamber of Commerce and has been named one of Georgia's Top 40 Innovative Companies.

nglcc Certified LGBT Business Enterprise®

GEORGIA'S TOP 40 INNOVATIVE COMPANIES

OUR LEADERSHIP

RICHARD SCHRADE
PRESIDENT / CO-FOUNDER

Richard is an industrial automation expert with over 10 years of experience designing and optimizing automated systems across a variety of industries.

ARI SIESSER
CHIEF SCIENTIST / CO-FOUNDER

Ari is an expert in optimizing the performance of factories, warehouses, and distribution centers using mathematical algorithms and simulation.

SHELDON SMITH
VICE PRESIDENT, TECHNOLOGY

Sheldon has over 13 years of experience in engineering, with a specialization in simulation and emulation modeling for complex manufacturing processes.

ANDREW BUYCK
DIRECTOR OF ENGINEERING – VIRTUAL COMMISSIONING

Andrew has over 15 years of experience in commercial manufacturing and defense engineering, with a specialization in virtual commissioning.

We also have an incredibly talented team of experts in mechanical, aerospace, and electrical engineering as well as computer sciences, who all collaborated on this guide.