INVIO AUTOMATION

Pitfalls and Approaches for Project Integrations with Multiple Technology Classes

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Goals for the day

KEY TOPICS TO COVER INCLUDE:

1. Industrial automation projects are multi-faceted – what are some approaches to ensure success?
2. How do these projects unfold, in practice?
3. Lessons learned from an Integrator

Please ask questions at any time during our discussion

Presentation Timing = 40 min

Length of prepared content = ~25 min

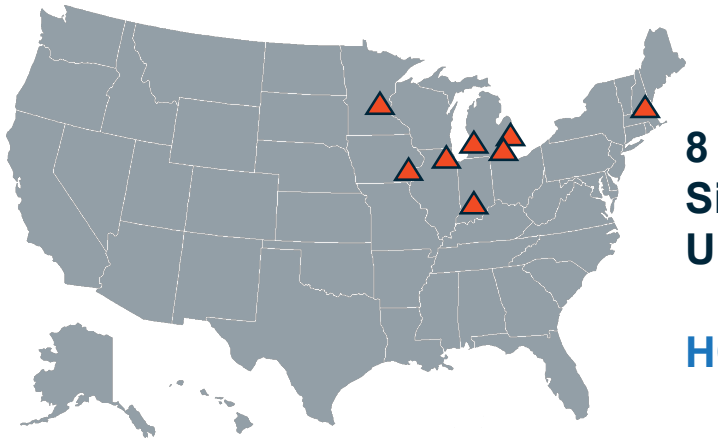
INVIO AUTOMATION

Invio is your partner for what's possible

About Us

We design, implement, & sustain automation for the largest operations in the world

- ASSEMBLY CELLS
- AUTONOMOUS MOBILE ROBOTS (AMR)
- ROBOTIC AUTOMATION
- ASSEMBLY & WELD TOOLING
- FACTORY OF THE FUTURE CONSULTING
- CONTROLS ENGINEERING & START-UP SUPPORT



8 Manufacturing Sites across the United States

HQ: Michigan, USA

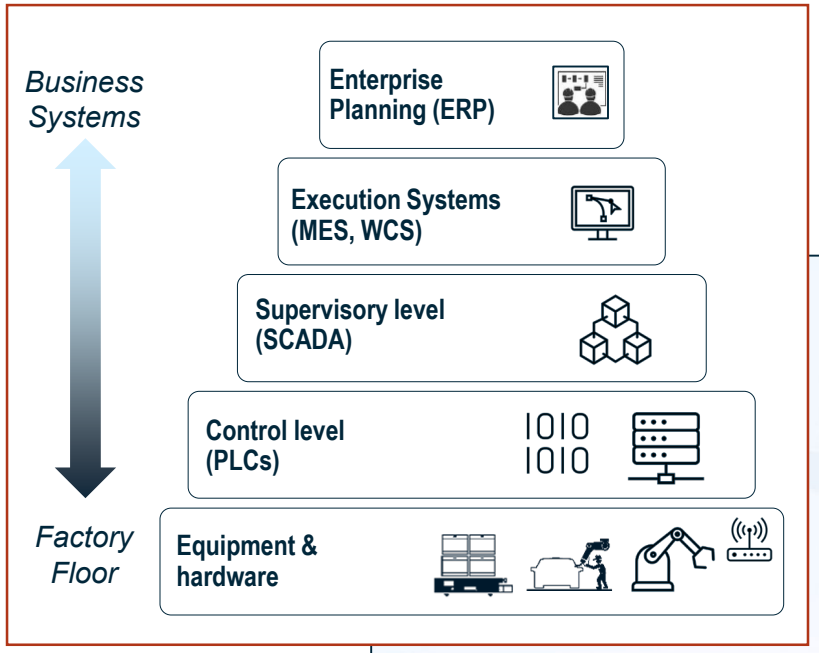
Representative Customers

NOT EXHAUSTIVE

Entegris, Takeda, Abbott, lisi MEDICAL, Kimberly-Clark, Insulet, HOLOGIC, CooperSurgical, HARRY'S, BAYER, Whirlpool, stryker, Johnson & Johnson, CORNING, 3M, Medtronic, CANTEL, Cargill, GE APPLIANCES, Vestas, First Solar, 24M, S&C, G&W Electric, Engineered to order. Built to last., SC Johnson, Carrier, SUB-ZERO, LM WIND POWER, a GE Renewable Energy business, GE Renewable Energy, Schneider Electric, SIEMENS, Gerber, pepsi, gm, Ford, LUCID, STELLANTIS, Yoplait, ICE MOUNTAIN, NISSAN, VOLVO, Mercedes-Benz, TOYOTA, mahindra, MOTOR HARLEY-DAVIDSON COMPANY, MAGNA, RIVIAN, JR AUTOMATION ESYS, FREIGHTLINER, Peterbilt, POLARIS, JLG, KENWORTH, JOHN DEERE, CAT, KOMATSU, CNH INDUSTRIAL, Gibson, OSHKOSH, HYSTER-YALE, Logisnext, iFIT, amazon, LifeFitness, StanleyBlack&Decker, VANDERLANDE, CIRRUS AIRCRAFT, symbotic, CONVEYX, MHS, AIRBUS, BOEING

Building the Factory of the Future

The landscape of factory automation extends across the production floor and up the industrial technology stack



The Challenge

Automation is increasingly a strategic imperative – how can we best ensure success?

"We need to increase our annual volumes by 3x in the next 3 years, but we can't find labor"

"This area of our facility is notorious for us to retain our workers, how can we improve it?"

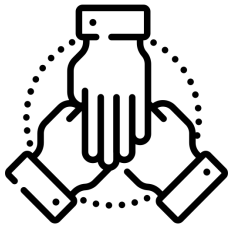
"Our company is starting an Industry 4.0 transformation – where's the most 'bang for our buck'?"

"We have a project and we need the new system to tie-in seamlessly with all of our current systems"

"We're launching a new product, and want to incorporate best practices in Design for Assembly"

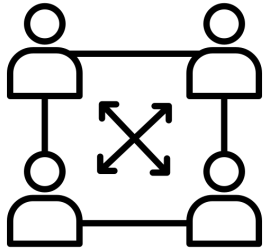
Best Practices

What are the best teams doing to implement complex automation projects?



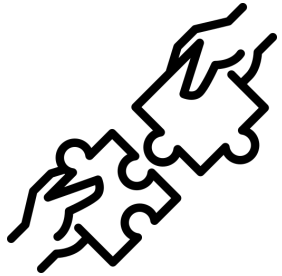
Collaboration

Identify and define problems, collaboratively



Cross-Functional Representation

Include Design, Operations, Quality, and IT



Partnership Mentality

Engage suppliers and technology partners throughout

Take the long-term view

Identify & Mitigate Risks Early

Pre-fund Discovery Engineering and Feasibility Testing

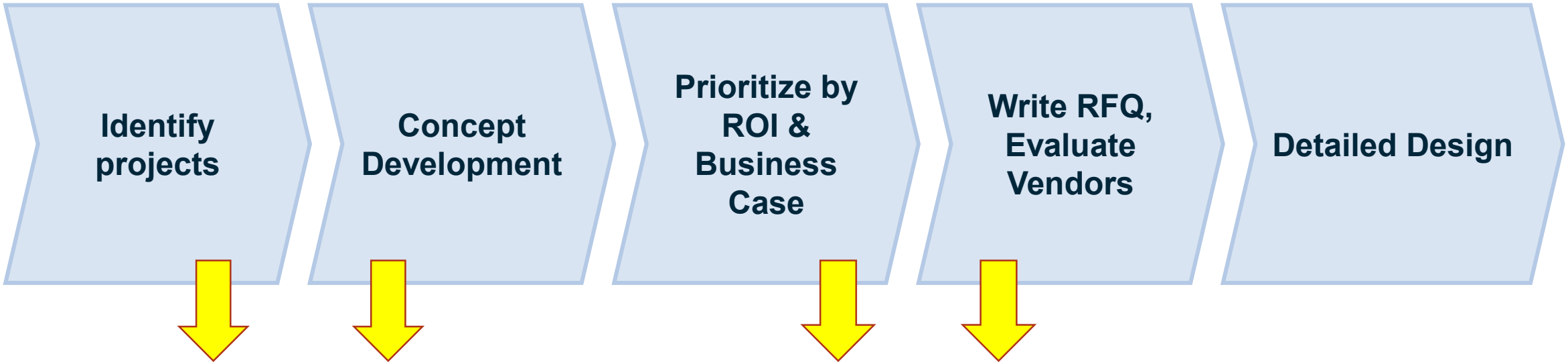
Utilize Simulation to test hypothesis

Approaches

Typical Automation Project Workflow

Frameworks

Develop a common language on how to identify opportunity, evaluate proposals, and approach projects



Frameworks

Develop a common language on how to identify opportunity, evaluate proposals, and approach projects

The 'Process Walk Worksheet' provides a structured way to identify high-ROI potential projects:

- The Automation Best Practices have been reframed in the affirmative as yes / no questions
- Score each area: more "yes" answers = a more desirable operation to revisit

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Process Walk Worksheet

Workshop: 41766
Date: 1/11/2023
Name:

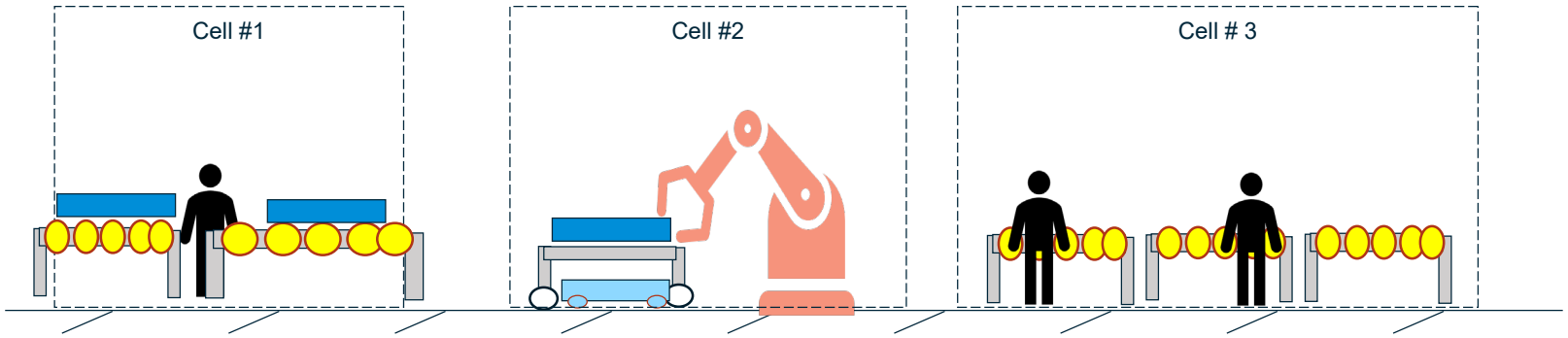
Question 1: Is the activity in the top quartile of time consumption?
Question 2: Is the process commonality (truck to truck and model to model) in the top quartile?
Question 3: Are inbound pieces well organized?
Question 4: Are there steps *absent* of work feeding, threading, and connecting harnesses, cables, and hoses?
Question 5: Is it possible to segregate steps (e.g., move offline) within the station and/or provide a safe space for new equipment to operate?
Question 6: Is this a major operator pain point and/or does an idea for improvement already exist?

DESC	Production Facility Description	Oper Desc	Q1	Q2	Q3	Q4	Q5	Q6	
AXLE SUB	AXLE SUB	AXLE SUB STA 1							
	AXLE SUB	TOUCHUP PAINT AREAS							
	AXLE SUB	VERIFY AXLE OIL							
	AXLE SUB	INST FR LUG PLATES							
	AXLE SUB	INST RR LUG PLATES							
	AXLE SUB	HOSE FRONT AXLE							
	AXLE SUB	HOSE REAR AXLE							
	AXLE SUB	OPT: DRAIN AXLE OIL							
	AXLE SUB	OPT: ADD ARTIC OIL							

Frameworks

Develop a common language on how to identify opportunity, evaluate proposals, and approach projects

Take the ‘horizontal view’



“Horizontal View” refers to following the flow through the lens of an Operator’s field of vision

- Forces team to think through critical system interfaces
- Where does the automation have dependencies elsewhere?
- Is complexity upstream driving cost downstream?

Frameworks

Develop a common language on how to identify opportunity, evaluate proposals, and approach projects

Scoring Matrix

After identifying a portfolio of projects, how do we start to prioritize where to focus?

How do we ensure vendor RFQs are solving the key pain points?

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Project Ranking Criteria

Workshop 33824.01
Date: 10/17/2023
Name: _____

%Weight	Ranking Criteria	Description
15%	Safety	Does the proposed reduce risk? Enhance ergonomics? (1 = significant improvement, 5 = limited improvement, same as existing)
10%	Variation	Degree of part-to-part or Model-to-Model variability (1 = limited variation, 5= higher degree of variation)
10%	Floor Space Availability	Degree of floor space required and/or availability of space in this area (1 = no concern, 5 = higher concern)
10%	Complexity	Degree of alignment between what the ideal automated-stated is vs. what is likely feasible
3%	Substructure	Degree of interconnection to existing systems, degree of retrofits or upgrades to other systems required
20%	Cycle Time	Assume lower score is faster/better than existing, higher score is as good or neutral.
15%	ROI	What is the qualitative assumption of achieving a favorable ROI (based on what is known now)? 1 = higher likelihood
10%	Quality	Degree to which automation allows for in-process inspection or identification of defects
3%	Hard-to-Fill Positions	Are these jobs notoriously difficult to staff? Is it a frequent area no one likes to spend their day?
5%	Flexibility / Scalability	To what extent can the proposed project be expanded upon, or scaled over time if models change?
100%		

Instructions

Score from 1-5 for each project across all criteria... "1" = BEST, "5" = WORST / MOST DIFFICULT...Lower Composite Score = better project

Project #	Opportunity Name	Safety	Variation	Floor Space	Complexity	Sub-Structure	Cycle Time	ROI	Quality	Hard-to-Fill	Scalability	COMPOSITE SCORE
1												
2												
3												
4												

Case Studies: End-of-line Robotic Glass Unload

Collaborative Design Workshop to Define a Future State

Project Overview

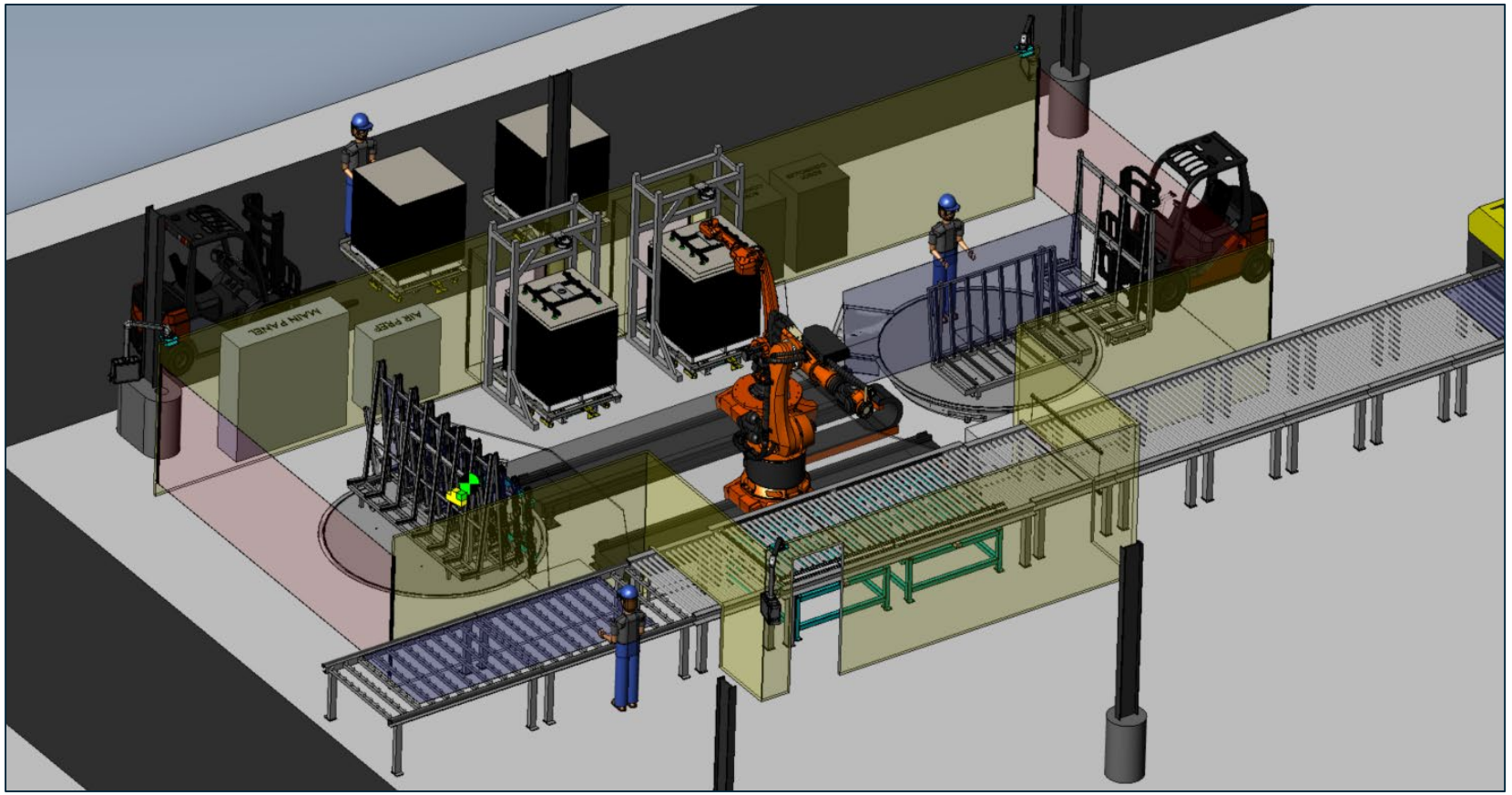
Customer required a robotic handling solution to load glass racks at end of line

Project Highlights

- Quality inspection of panels at conveyor outlet provided sortation inputs
- Vision-based inspection to determine panel position on conveyor
- EOAT design for compatibility with protective coating applied to the panels upstream
- Addition of intra-layer packaging materials to protect glass during transit out of the facility

Outcomes

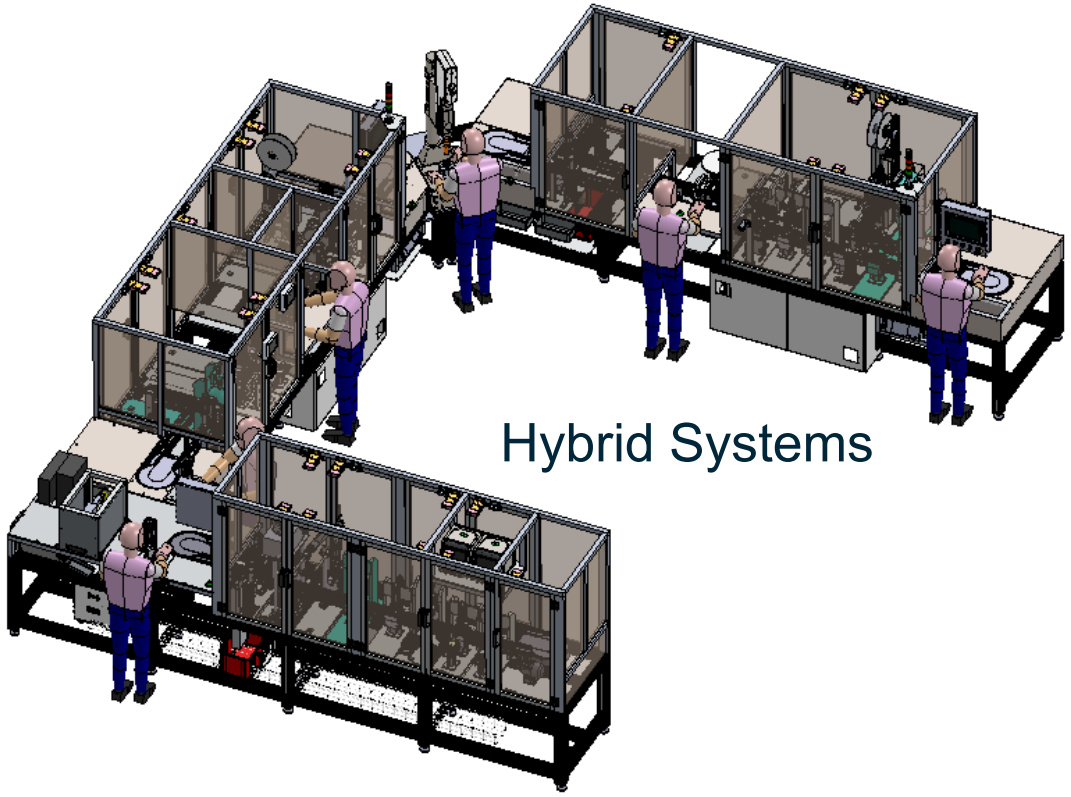
- Invio developed a dual-robot concept utilizing robotic transfer units to enable loading of racks in different zones (1 working, 1 replenishing)
- Integration of conveyor system logic with new robotic automation to include sortation / routing based on vision-inspection output



Case studies: Hybrid & Lights-Out Systems

High-Speed Assembly Automation

Fully 'lights out' production may not make sense right away, how can we split work content and establish phases of automation?



Hybrid Systems

Lights Out Automation

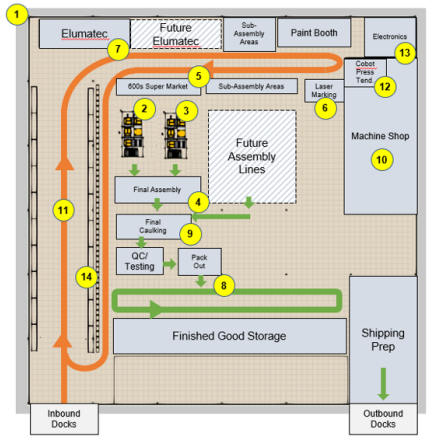
Case Studies: Workshop → Concept → Prove ROI

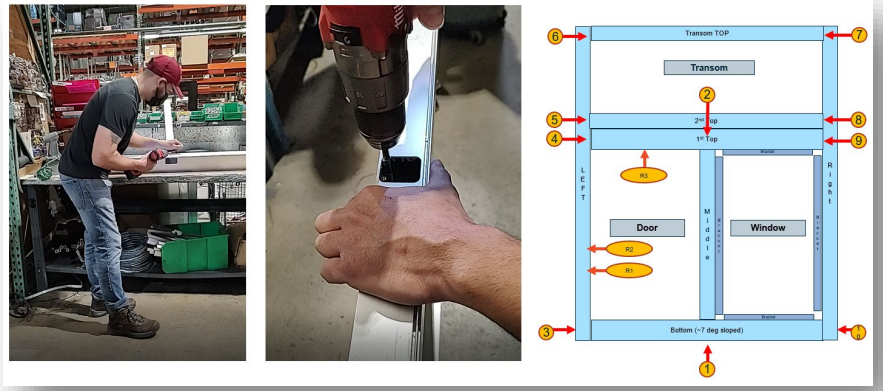
Transitioning Manual Ops to Automated Assembly

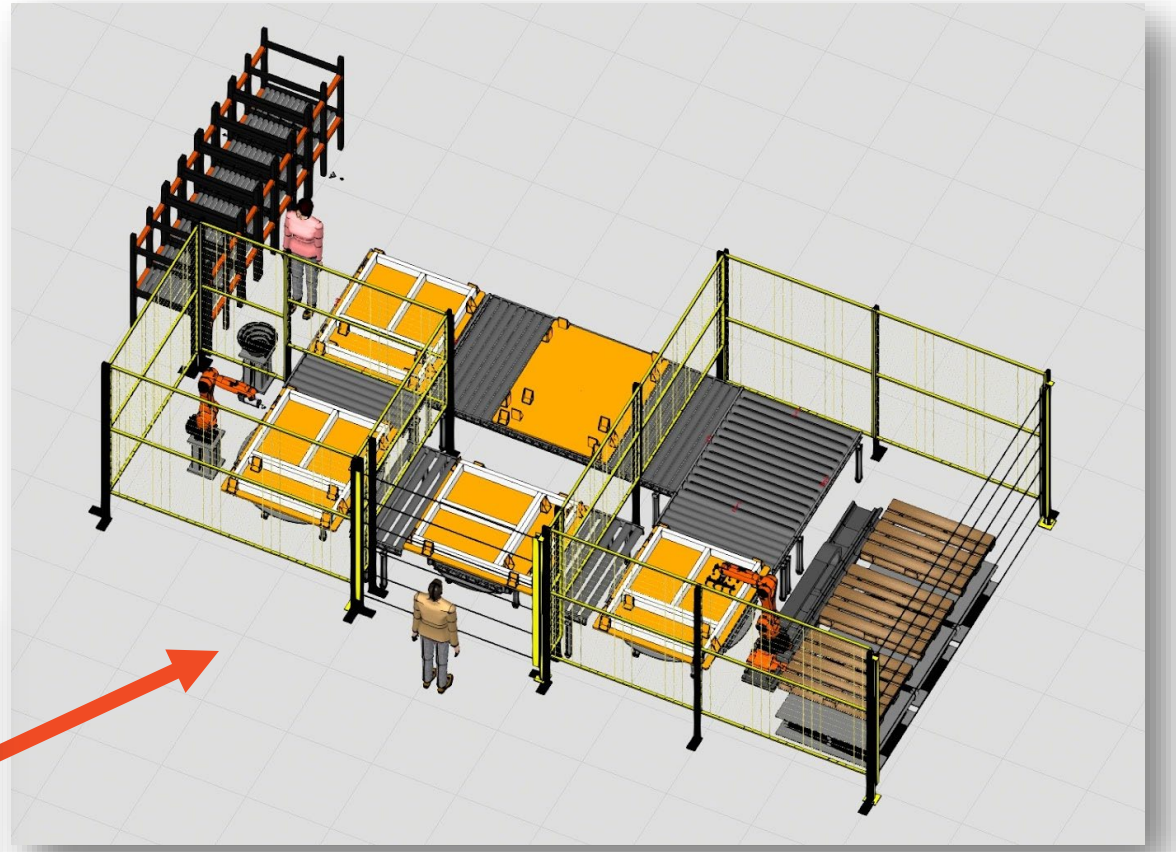
The workshop team developed a "big board" of potential ideas

Customer X **future-state is enabled by multiple sub-systems and consists of a mix of autonomous & operator-led stations and actions…**

1. Re-imagined layout to improve material flows
2. Automated frame build up w/ automated glass lay
3. Automated doors build up w/ automated glass lay
4. "600s" build fixture (AGV compatible)
5. Pick-to-light for kit building
6. Laser Marking of nameplates
7. Elumatec machine tending and transfer
8. End-of-line ergo-lift device to remove frame from build fixture
9. Automated caulking
10. Robot on mobile platform for machine / press-brake tending
11. AGVs for cart transfers
12. Cobot kit building
13. Electronics area re-configuration for improved ergonomics
14. Ergo-lift device for glass installation

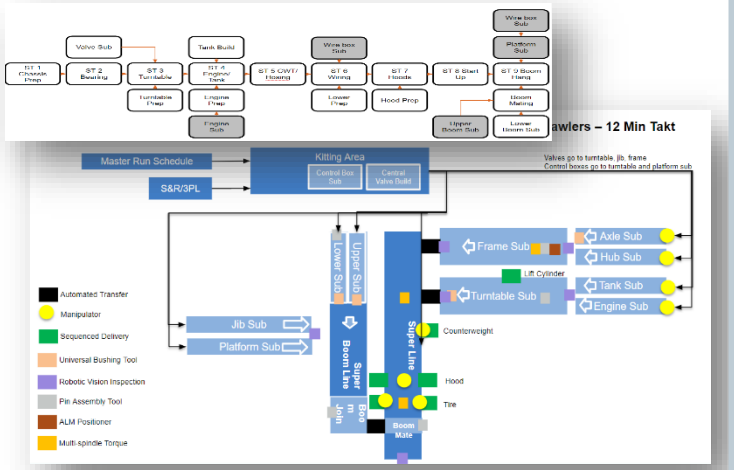


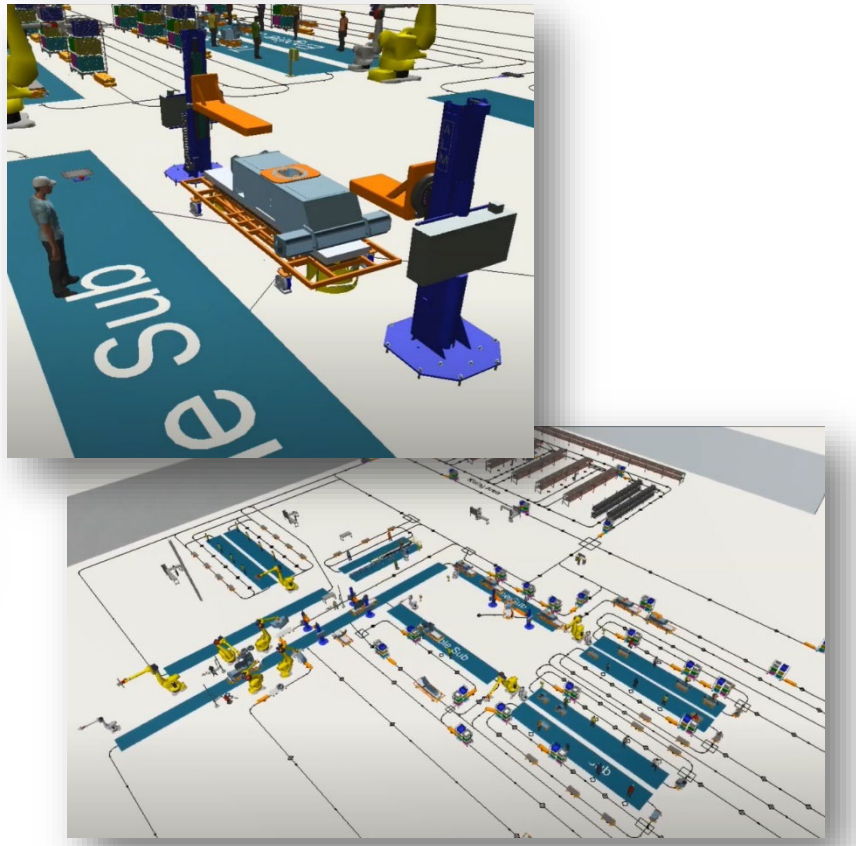


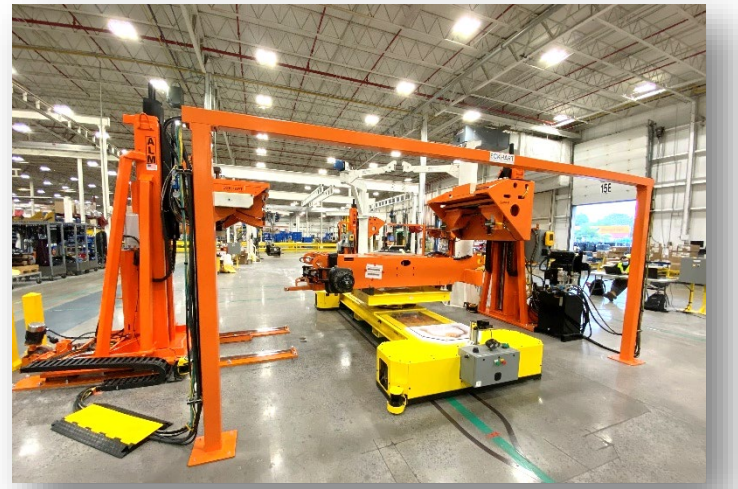


Case Studies: Value Stream Map → Simulation → Implementation

General Assembly Environments







Automation projects, in practice

Avoiding Pitfalls

RFQ Quality is Key

Poor quality RFQs have multiple downsides:

- Longer vendor evaluation period and lengthier Q&A exchanges (more emails & review meetings)
- Misunderstandings, scope growth, and/or ECOs

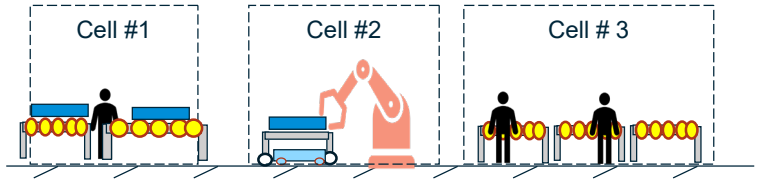
Best-in-class RFQs include:

- Clearly defined sequence of operations
- CAD (3D) – smallest part, largest part, & highest runner
- Area layout dwgs

Involve cross-functional groups early

- Prioritize gathering feedback from many viewpoints; include Operators and IT
- Host workshop with vendor partners on-site to begin Design Phase or kick-off major projects

Take the 'horizontal view'



"Horizontal View" refers to following the flow through the lens of an Operator's field of vision

- Forces team to think through critical system interfaces
- Where does the automation have dependencies elsewhere?

Spend early to save later

- Recognize there is an information asymmetry in the marketplace → who holds the risk?
- Buyer-Seller collaboration can significantly reduce overall project scope → this typically leads to more efficient outcomes for the buyer

In summary

KEY TAKEWAYS

1. Industrial automation projects are multi-faceted – what are some approaches to ensure success?
   → Cross-functional collaboration, partnership with vendor / integrator early, “spend now to save later”
2. How do these projects unfold, in practice?
   → Create a methodical approach to identifying and prioritizing opportunities to further deploy automation
3. Lessons learned from an Integrator
   → Great RFQs can pay dividends. Prioritize a high degree of collaboration, both internally and externally

All materials are available to share, please say hello after our session

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Assembly Show

Appendix

02

Automation Application Areas & Use Cases

Factory Floor automation across the value chain

Digital Solutions

Site or Enterprise

- Paperless Instructions
- Tracking & Tracing
- OEE Dashboards
- Andons & Alerts
- Digital Twin
- Augmented Workers
- SPC
- Asset Management

These initiatives are often led by Ops stakeholders, but commonly require IT resources to implement

Factory Floor Solutions

Warehouse

- AMRs / AGVs
- ASRS
- Goods-to-Person
- VLMs
- Conveyor Sortation
- Pick-to-Light
- Pick-to-Voice
- Point Solutions
- Kitting (Cobots)

Fabrication

- Machine Tend
- Robotic Weld
- Robotic Grind
- Robotic Inspect

Assembly

- Robotic Assembly
- Hard-Automation
- AGV build lines
- Automated Tooling
- Semi-Auto Tooling
- Robotic Inspection
- Lights Out Sub-Assy
- Auto.Transfers
- Process Tech.
- 3D Bin Picking

Pack-Out

- AGV - Line to Docks
- Robot Palletizing
- Point Solutions

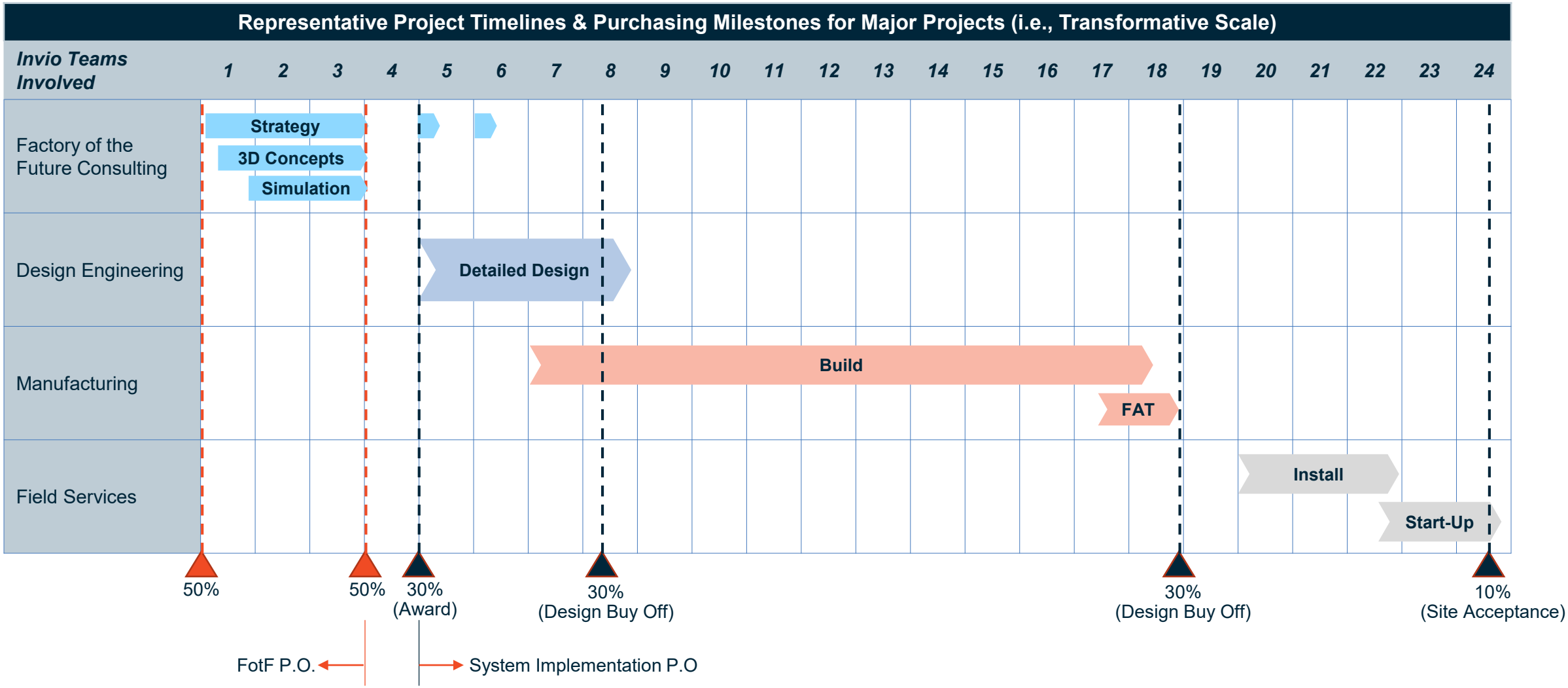
Automation project, in practice

Building the roadmap of automation initiatives

	Strategy Phase	Design Phase	Build Phase	Sustainment Phase
Key Team Members	Advanced Planning Engineers Invio Factory of the Future	Manufacturing Engineering Invio Design Engineering		
Activities	• Current state assessment • Time study • Future state visioning (Factory of the Future) • Requirements gathering	• Collaborative workshops • Design reviews	• Manufacturing @ Invio • Factory Acceptance (FAT) • Installation • Site Acceptance (SAT) • Start Up Support	• Training • Troubleshooting (virtual or in-person) • Preventative maintenance
Outputs	• 2D / 3D Concepts • Animation (Visual) • Simulation (Throughput) • Business Case & ROI • Statement of Requirements (SOR) • Request for Quote (RFQ)	• 3D Models • Build Prints • Layout Drawings	• As-Built Drawings • Manuals • FAT & SAT punch lists	• 24/7 On-Call Support • Field Services support / technicians

Automation project, in practice

Building the roadmap of automation initiatives



Applicability to Assembly Operations

Common problem areas among manufacturers and potential solutions

Challenges	*Opportunities*
High labor-density in Assembly areas	• Segment work content, automate portions, & re-balance • Cobots and work-sharing • Tooling to speed up ops • Tooling to reduce tandem lifts
Labor turnover & long training cycles	• Automation for the Dull, Dirty, Dangerous • Tooling to improve ergonomics (lift assist, torque reaction)
Non-Value-Adding Time to move materials (pushing, walking, or searching)	• AMRs / AGVs for delivery routes • Goods-to-person fulfillment solutions
Quality & inspections, or lack thereof	• Engineer in control points & poka-yokes • Vision inspections (absence / presence, labels, tracking) • Interlocking the line w/ tooling (no fault forward)

Right-sizing the automation

Finding a Cycle-Time appropriate solution

Product Takt Measured in	Hours	10-60 Minutes	1-10 Minutes	< 1 minute
Products	• Ag (non-tractor) • Mining • Tanks • Aerospace	• Trucks • Rec Sports • Specialty vehicle • Tractors	• Auto • Electrical infra. • EV Batteries • Medical Device	• Auto • Food & CPG • Home appliance • Consumer elec.
Class of Solutions	• Bay build • Cranes / hoists • Manual fixtures • Manual weld • No MES • Lineside material storage	• Pneumatic manipulators • Single-spindle secure • Robotic weld • AGVs • Mixed use kitting	• Servo manipulators • Multi-spindle secure • Robotic weld • AGVs • Kitting	• Assembly robotics • Camera scan/verification • High speed conveyor • Automated material presentation at point of use

Automation ROI

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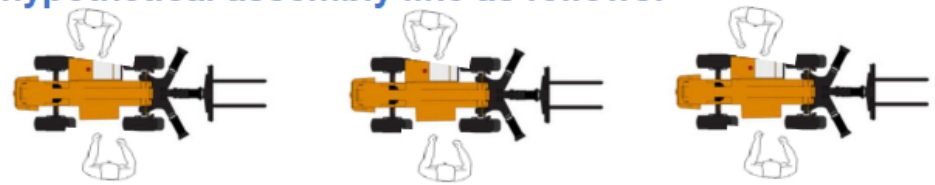
Right-sizing the automation – recognizing time savings

Finding a Cycle-Time appropriate solution

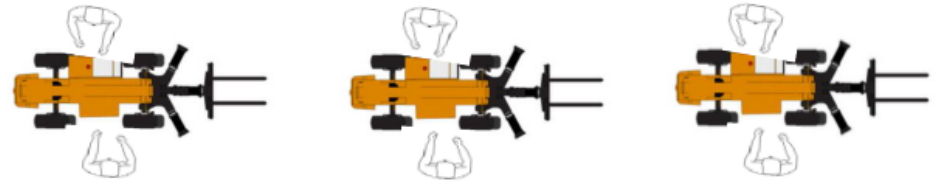
Take a hypothetical assembly line as follows:



25 minutes | 25 minutes | 25 minutes

This line has ***3 stations x 25 minute takt time x 2 operators = 150 minutes*** of operator involvement per unit

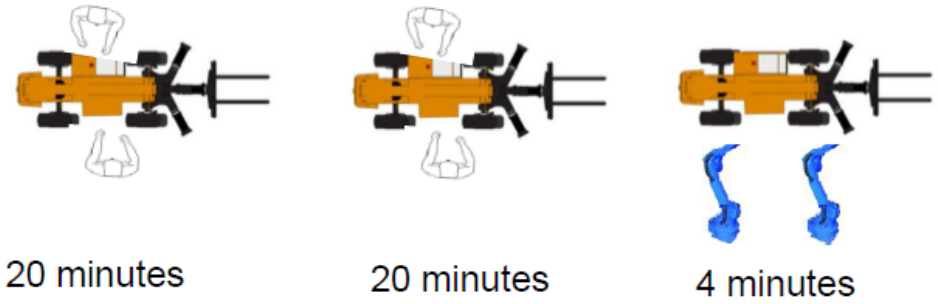
If tools allow for work to happen faster, Operator Involvement per unit goes down:



20 minutes | 20 minutes | 20 minutes

This line has ***120 minutes*** of operator involvement per unit

Full automation reduces Operator Involvement significantly:



20 minutes | 20 minutes | 4 minutes

This line has ***80 minutes*** of operator involvement per unit + ***4 minutes*** of automation time per unit

Towards an ideal Future-State

Invio Factory of the Future Consulting: Common archetypes of assembly plants

Factory of Today		***Factory of the Future***
Complexity lives on the Assembly Line	→	Complexity lives offline (kitting, subs, etc.)
Main Line includes all types of activities	→	Only high-value activities allocated Main Line time
Lots of parts & inventory stored at Line	→	Only required parts are stored; increased frequency of deliveries
Defects are not found where they are introduced	→	In-station quality checks; defects are not passed down the line
“Notorious” stations are well known among the team	→	Ergo tooling & reaction-limited devices throughout
Higher WIP inventory	→	Low WIP inventory
Unoptimized Line with too many stations	→	Optimized Main Line, fed by Sub Assembly areas

Automation projects, in practice

Building the roadmap of automation initiatives

Most projects (& funding) follows a phase-gated project approach; engineering specificity is refined over time

Typical Phase I of Projects

Factory of the Future (FotF) Workshops

- Production System Design Workshops
- Technology Concept Development
- 3D Visualization

Supplier Visits & Diligence

Additional supplier diligence by Customer; visits to Invio reference customers or past-project deployments

Additional FotF Project SOWs

- Finalize Production System Approach
- Technology Selection
- Throughput Simulation
- Implementation Plan
- Firm Price Offer Development

Gate 1

Finalized 'Go / No-Go' decision to progress to implementation phases

Detailed Design & Procurement

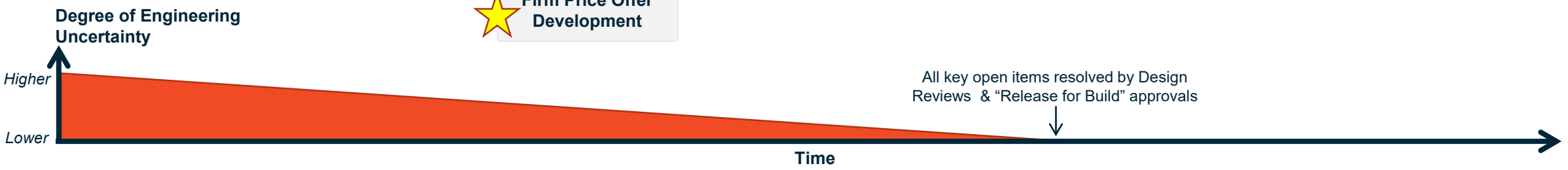
- Detailed Engineering & Design Reviews
- Procurement

Additional Gates

Additional gate reviews as needed to ensure close alignment between Invio & Customer

Manufacturing, Installation, & Start-Up

- Manufacturing (at Invio)
- Factory Acceptance
- Installation (at CAT)
- Commissioning & Start-Up



How it works: defining an automation strategy, collaboratively

Factory of the Future Consulting

How it works

On-site workshop

A cross-functional team of Invio & customer stakeholders will:

- Assess existing facility tooling
- Review plans for new facility & tooling
- Whiteboard the ideal future-state
- Prioritize areas to concept further
- Review product-specific CAD
- Document technical requirements

Engineering back at Invio

Leveraging our learnings from the site visit, Invio further develops automation and tooling concepts and executes on the deliverables

Deliverables

- 2D AutoCAD drawing of future-state layout
- 3D concepts of tooling & automation (top 5)
- 3D simulation to communicate the vision
- Investment line-items budgetary estimates
- Executive-ready report and presentation

Benefits

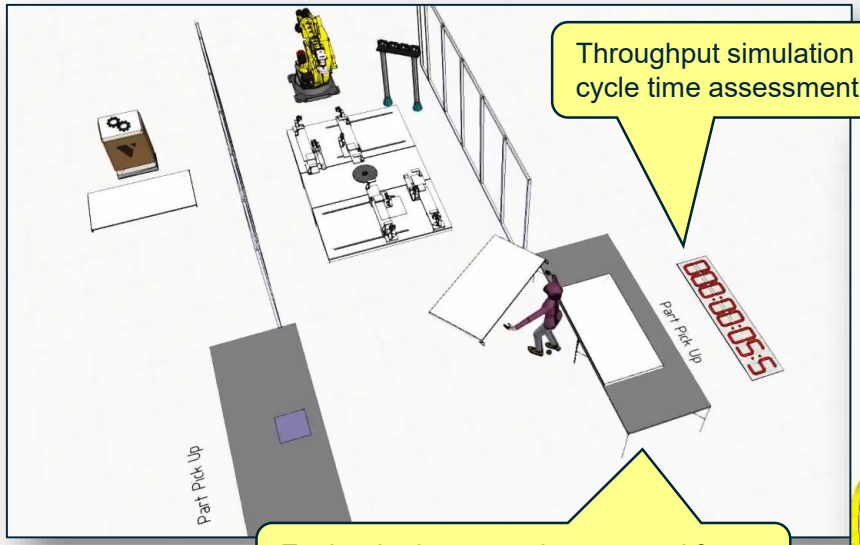
De-risk future investments by pulling forward engineering now

Ensure all groups are aligned in advance of major changes via cross-functional workshops

Uncover additional synergies that can be designed for now vs. down the road (e.g., AGV into robotic cells)

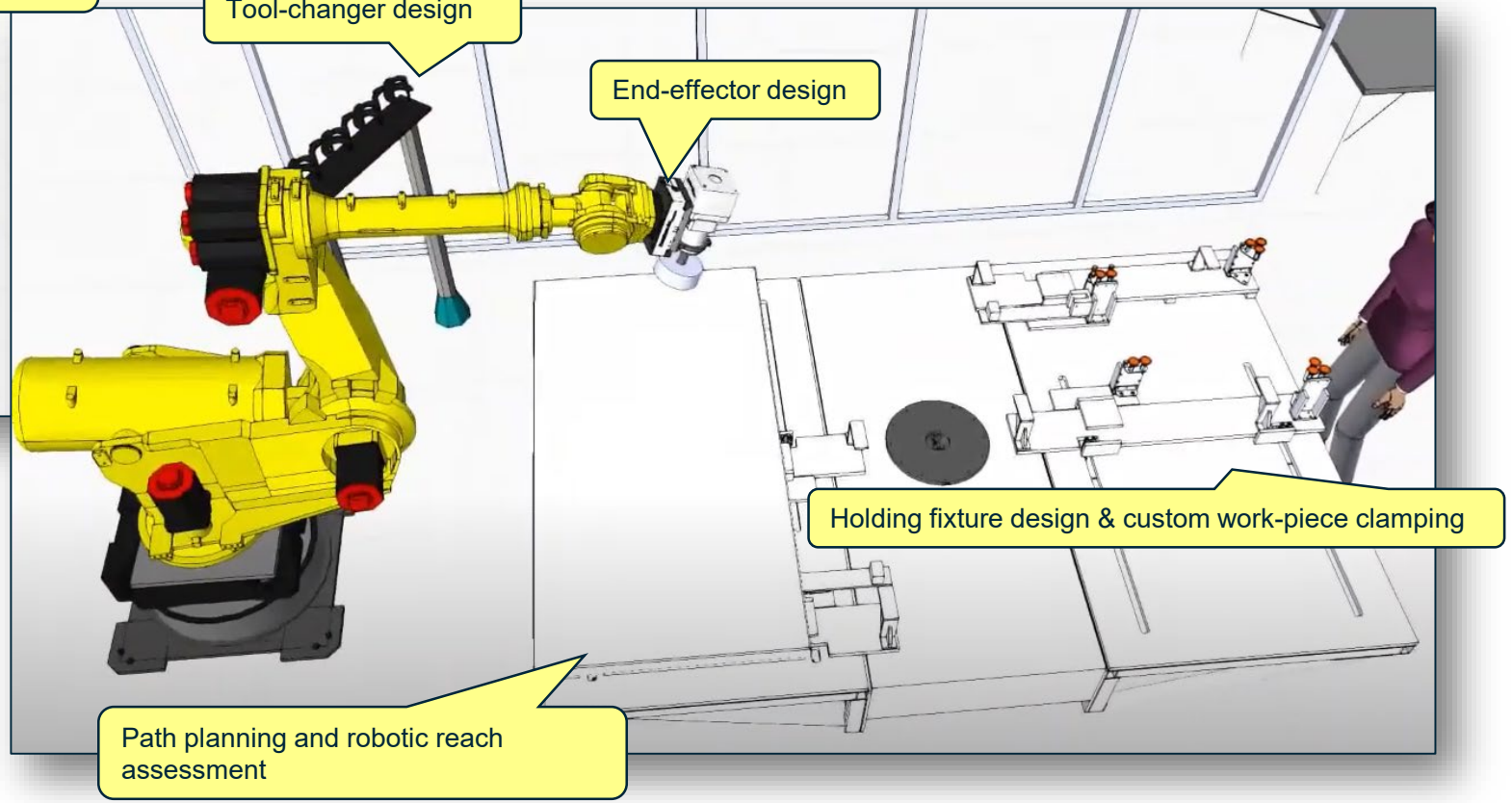
Robotic concept studies and simulation

Robotics and Flexible Automation



Throughput simulation and cycle time assessment

Each robotic system is assessed for material input / output and optimal flow



Tool-changer design

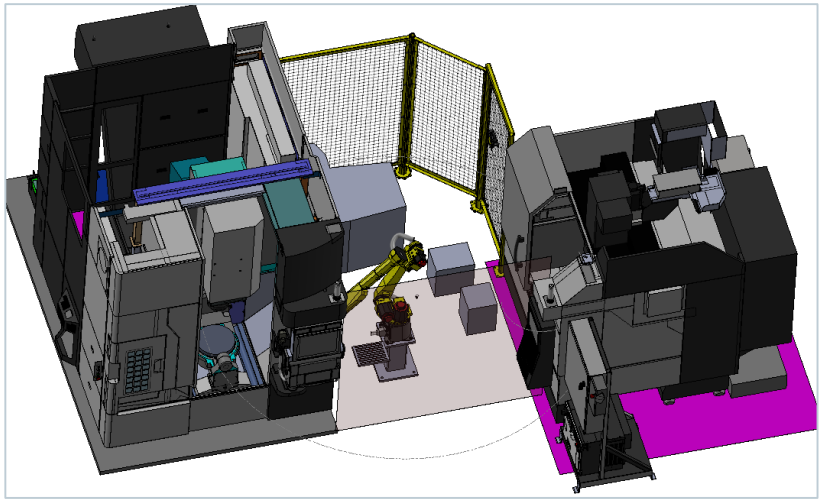
End-effector design

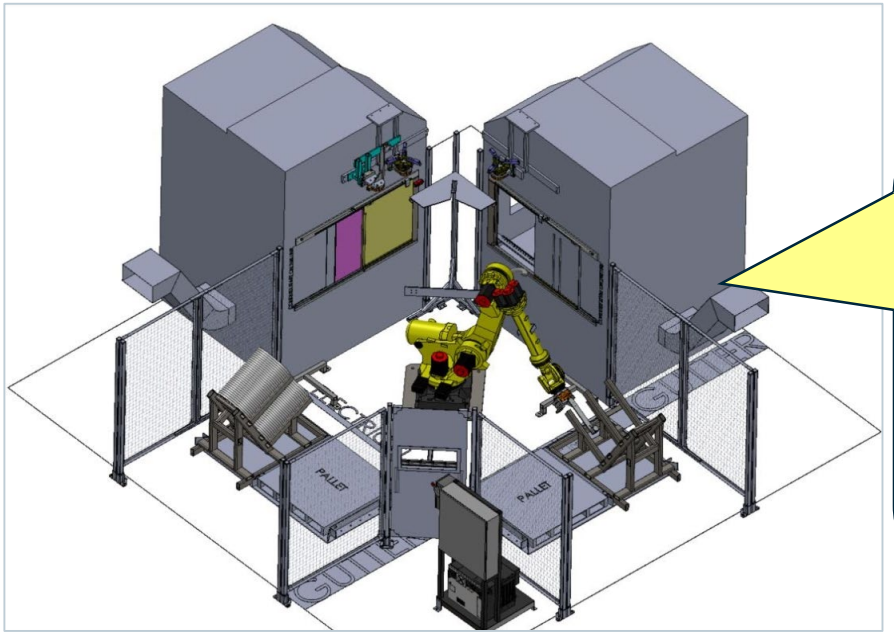
Holding fixture design & custom work-piece clamping

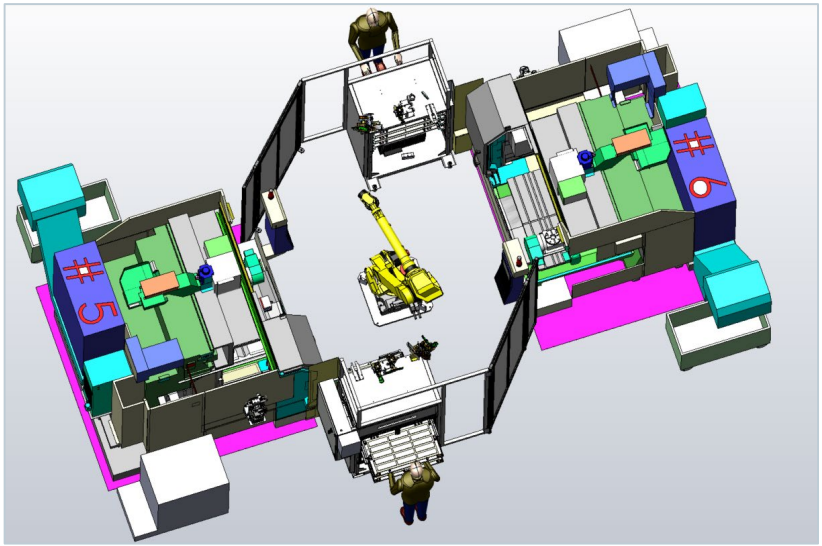
Path planning and robotic reach assessment

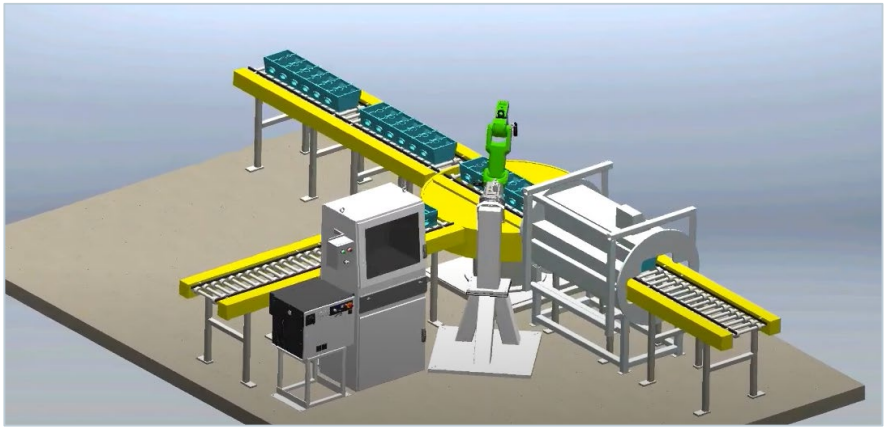
Automation assessments

Robotics and Flexible Automation









Automation assessments identify critical system elements and attributes

- Square footage consumed
- Robot reach / payload accessibility
- Material flow in / out
- Material staging fixtures
- Work-piece holding
- Tool-changers / flexibility requirements
- Safety system & guarding
- Operator interfaces
- Key technologies or auxiliary equipment