

# Drive Productivity Through Common Tools and Best Practices in Novel Robotics Software

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Matt Robinson, SwRI

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## SwRI Background

- Founded in 1947
- San Antonio, TX
- Independent, not-for-profit
- Applied R&D in Natural Sciences and Engineering
- FY 2024 Revenue: \$915M
- FY 2024 Internal Research \$11M



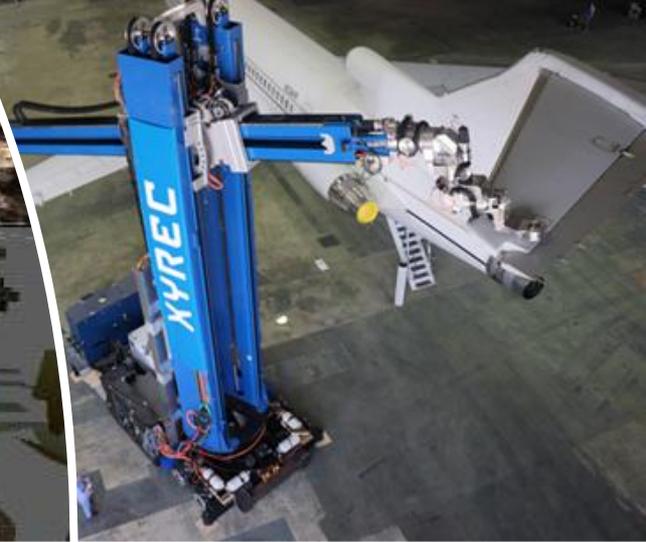
## SwRI Background

- 1500 acres
- 11 technical divisions
- 2.4 million sq. ft. of laboratories, test facilities
- ~2700 employees

Robotics

# SwRI Robotics

- Advanced robotics software
- Custom robotics
- Vehicle autonomy
- Machine vision and perception
- Industrial automation and controls
- System integration



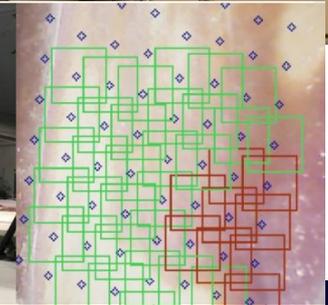
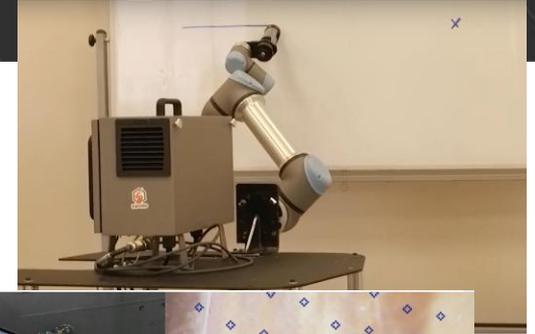
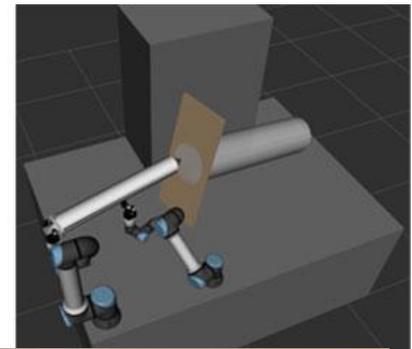
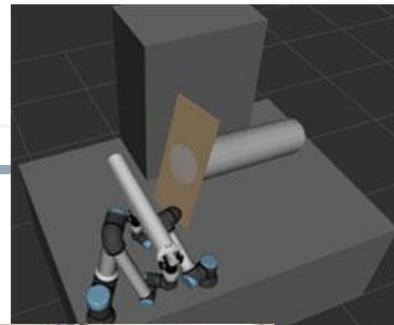
# About the speaker

- Eight years running ROS-Industrial Consortium & running advanced robotics programs
- 13 years at Caterpillar supporting advanced robotics and value stream optimization through technology
- BS & MS – The Ohio State University – working at EWI studying advanced materials joining & process optimization



# Research Areas

- Complex applications in dynamic environments
- Stringent robotic & process control
- Advanced perception and motion planning
- Novel learning frameworks to create new capabilities



# Agenda for today

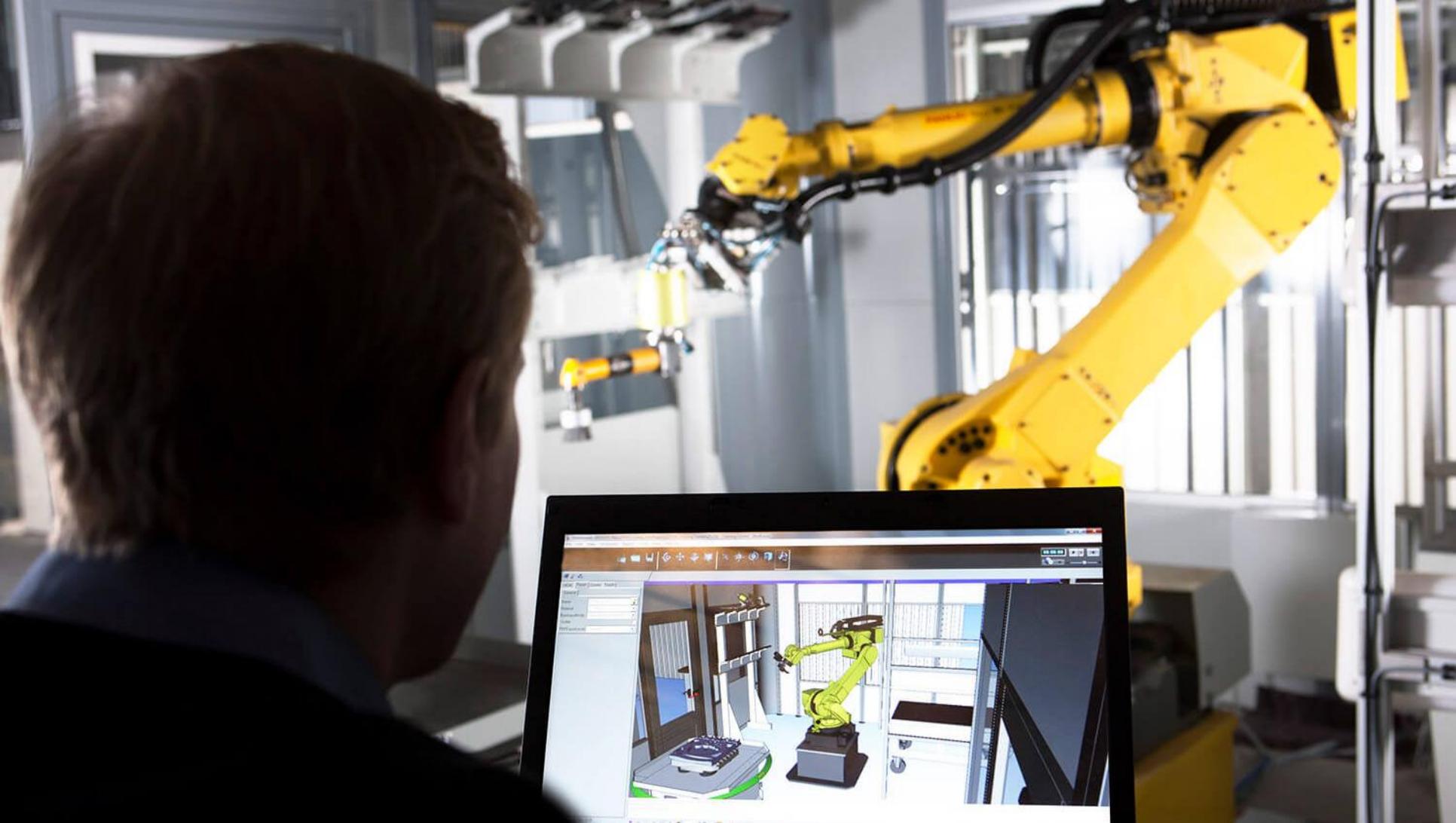
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- What is the role of software in robotics?
- What are some examples of openness impacting interoperability?
- Why should we care?
- What we are doing
- What is next

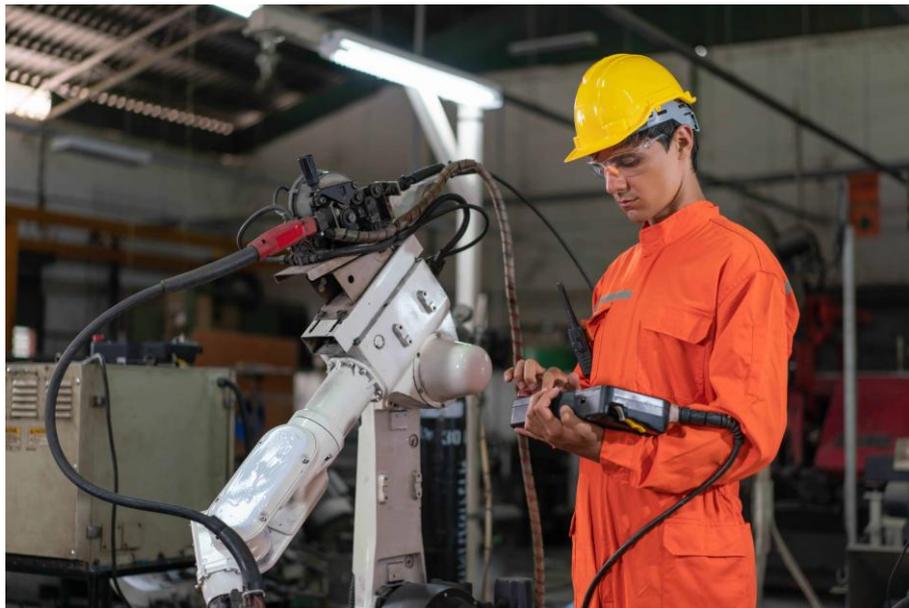
# Background

- Industrial robotics has been the domain of technicians and industrial engineers through the mid-90s
- Software development was the domain of mainframe/IT until the advent of the web in the late 90s and subsequently the app movement of the mid to late 00s
- Contemporary computer science and robotics begin at this point to come together due to acceleration of compute capability and size of compute hardware

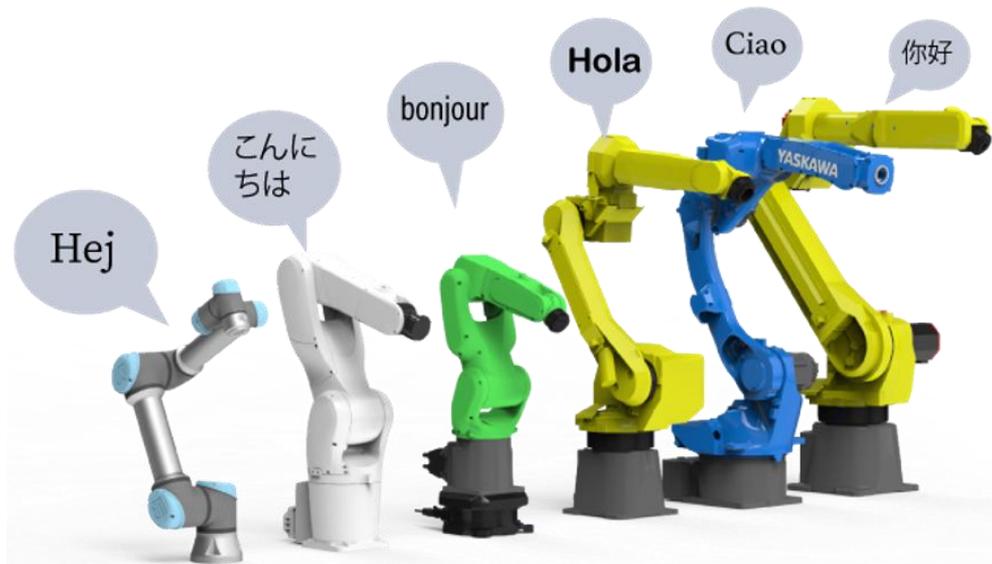




# Robotics & Software



# Learn to program... again and again...



# Meanwhile in 2008



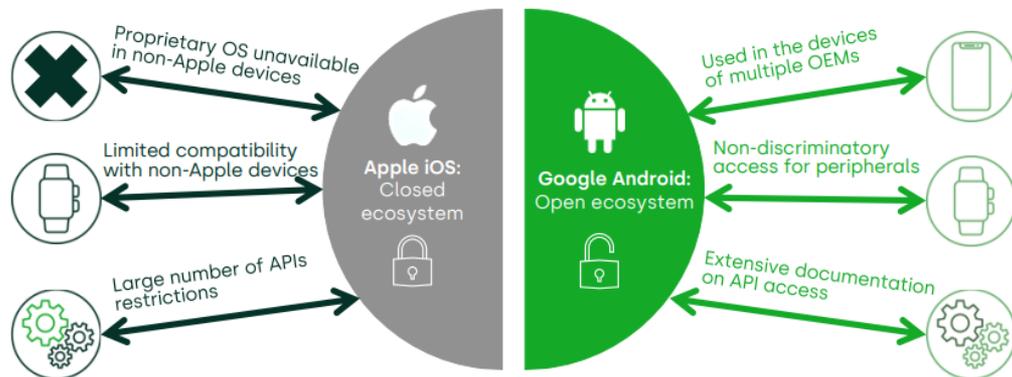


android



# A change in approach to software

- Could this apply to robotics?

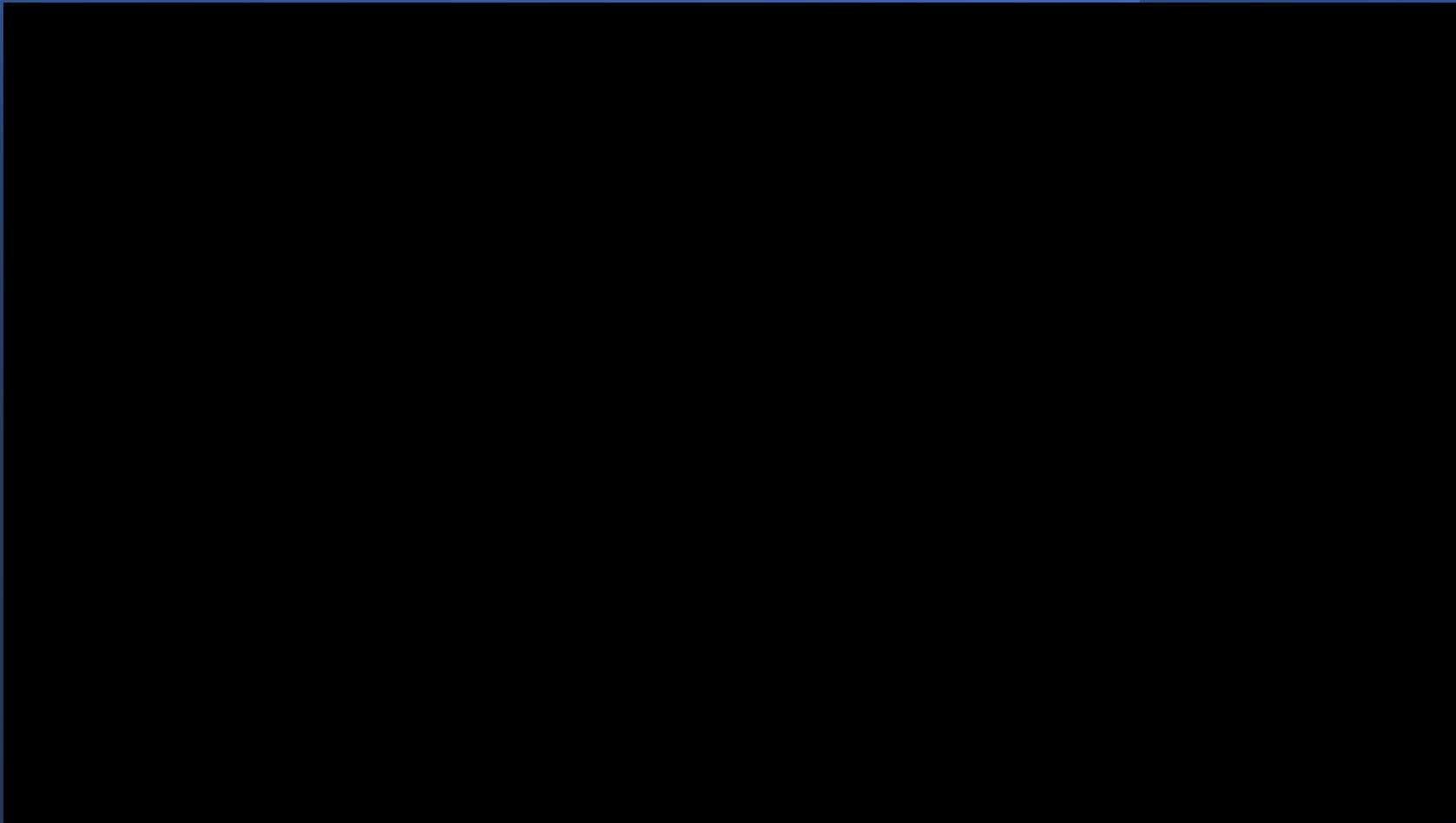


# For robots...

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## ROS - Robot Operating System

The Robot Operating System (ROS) is a set of software libraries and tools that help you build robot applications. From drivers to state-of-the-art algorithms, and with powerful developer tools, ROS has what you need for your next robotics project. And it's all open source.



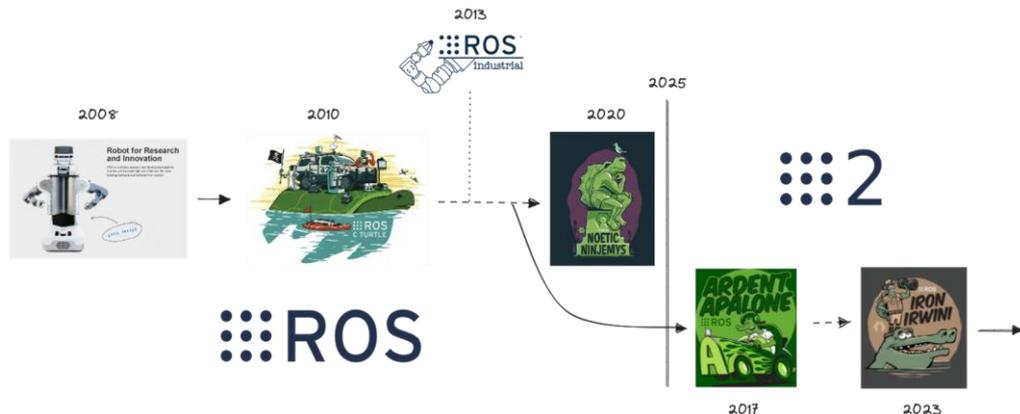
# Open-source Robotics

- Why?

- Shorten development time
- Global community for support
- Interoperability

- ROS (Robot Operating System)

- Open-source
- Maintained by the Open Source Robotics Foundation



# ROS-I Mission

- Mission
  - What do we work on?
  - How should our tools work?
- Where are we now?
- Where do we want to be?



# Strategy for Development



Environment Layer (Movelt, Tesseract, Dart, etc.)

Messages,  
Topics

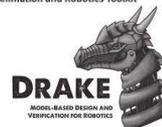
ROS 1 / ROS 2 / Middleware Layer



TESSERACT



Dynamic Animation and Robotics Toolkit



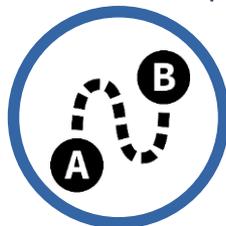
DRAKE

MODEL-BASED DESIGN AND  
VERIFICATION FOR ROBOTICS

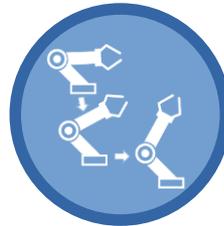
Independent of ROS



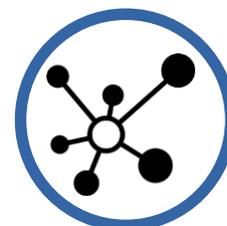
Collision  
Detection



Motion  
Planners



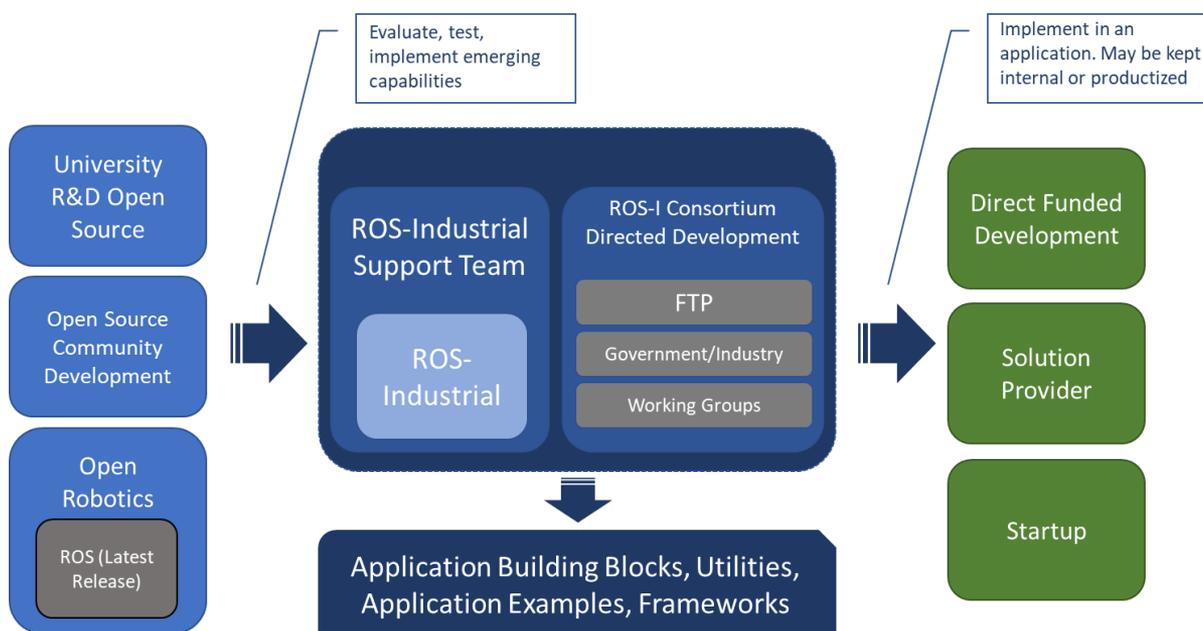
Kinematic  
Solvers



Connectivity  
Structure

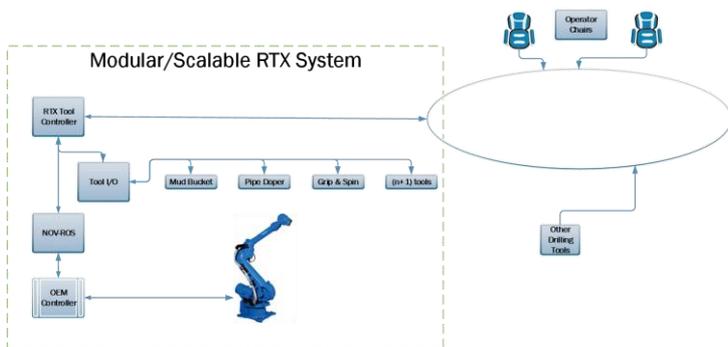
Build ROS1  
or ROS2,  
these are  
independent

# How to get capability on the floor



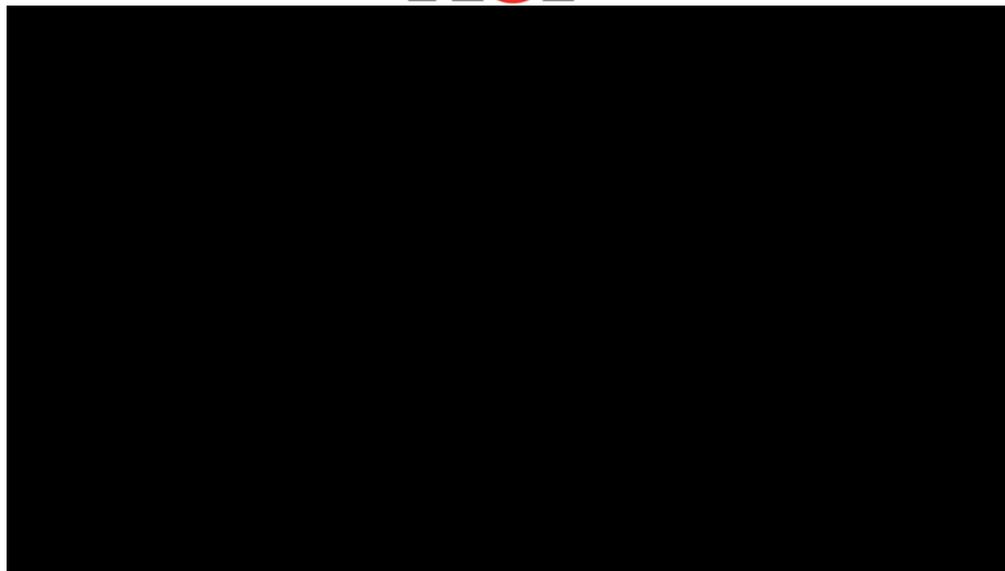
- Continued opportunity to leverage MII network for tech transition
- Many examples of Government/Industry partnerships that refine capabilities
- Startups can leverage for de-risking/scaling

# Delivering new products



## NOV RTX Productized

- modular and scalable system that can be put on any rig network
- Framework for all path planning and collision avoidance is NOV-ROS
- Prototype integration of scene awareness and people detection into RTX system
- Productization of end effectors (service parts) & roadmap for future capability



# Leverage advancements

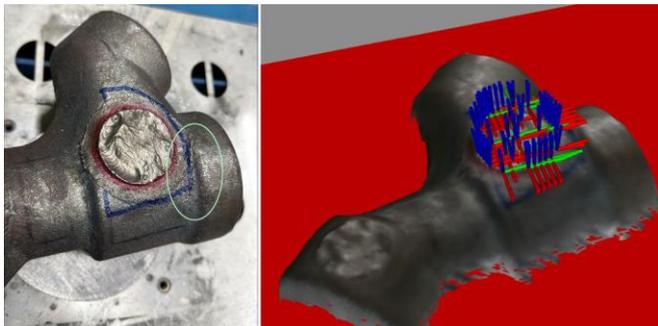
- High fidelity reconstructions
  - Learning based - NeRFs
  - Non-learning based – splatting
- Imaging at high temp
  - LWIR
- Novel processes
  - Physical embodied AI
- Rich multi-unit coordination
  - Large part processing



Point Cloud v Gaussian Splat Reconstruction (Pix4D)

# Ability to “see” is imperative for robotics

- These novel techniques are being benchmarked currently for applicability to industrial use cases
  - Typically, less features to support the underlying tech
  - Not often a lot of contrast from image to image
  - Sensitivity to environment



Open3D TSMF Reconstruction, courtesy of ISU



3DGS versus NVIDIA's GDGUT (adds ray tracing)

# High temperatures

- Advances in LWIR (long wavelength IR) are being applied in the field
- DoD investments – see in night, dust, enable robotic planning on high temp surfaces



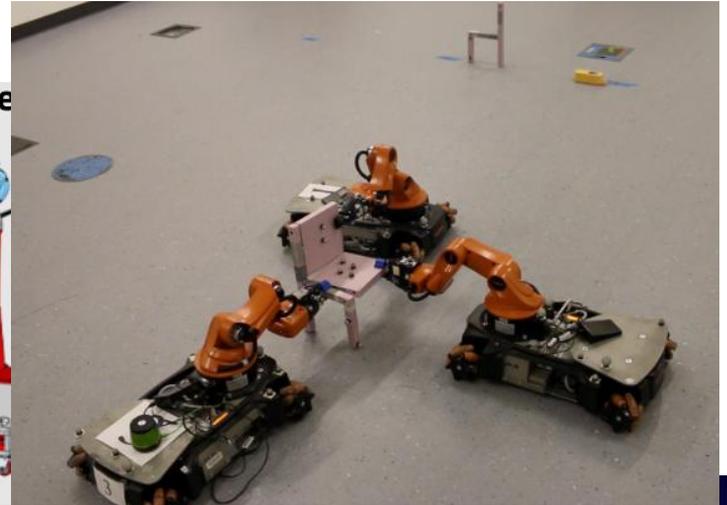
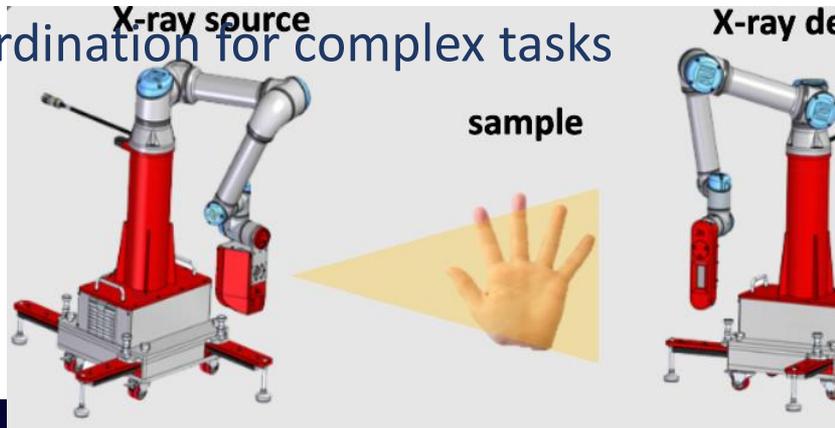
# Diffusion Policy Approaches for Motion



A **diffusion policy** is a type of reinforcement learning that uses diffusion models to generate sequences of robot actions based on visual input

# Multi Robot Coordination for Large Volume Tasks

- Recent ARM Institute project seeks to develop large casting inspection with agile robotic platforms
- Leveraging coordinating planning techniques enable large volume processing including NDE techniques
- Coordination for complex tasks



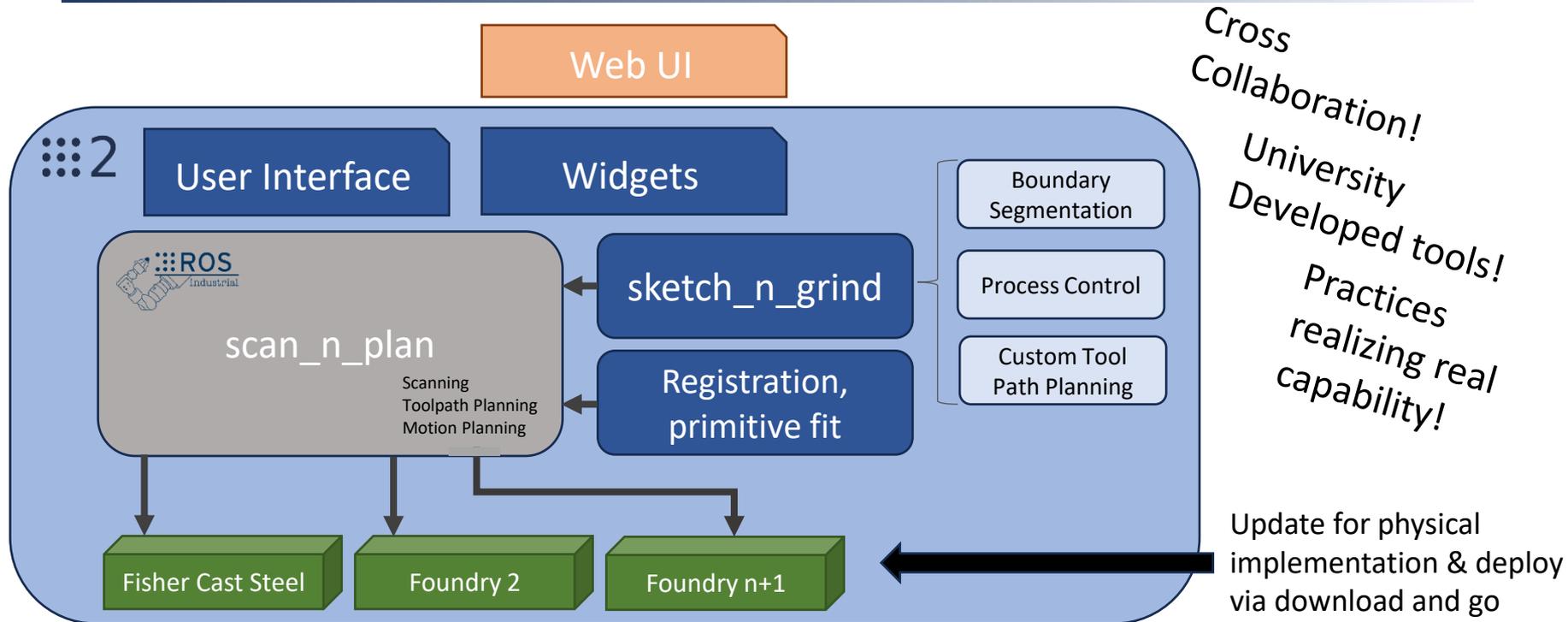
- **Multi-Robot Planning and  
Freespace Execution**

# What about foundries?

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- Core framework as foundation
- Provide a starting point for integrators/companies to leverage advances in tech
- Enable a pathway for student/university/startup innovations to make it into operational environments
- So what? – Optimize robot system and operations productivity at lower deployment/operational cost – i.e. *high uptime on high mix/low lot operations*

# Toolbox for Foundry Ops



File Panels Help

Interact Move Camera Select Focus Camera Measure 2D Pose Estimate 2D Goal Pose Publish Point Polygon Selection Tool

SFSAApplication

Start

Reset

Operation

Execute Motion Plan

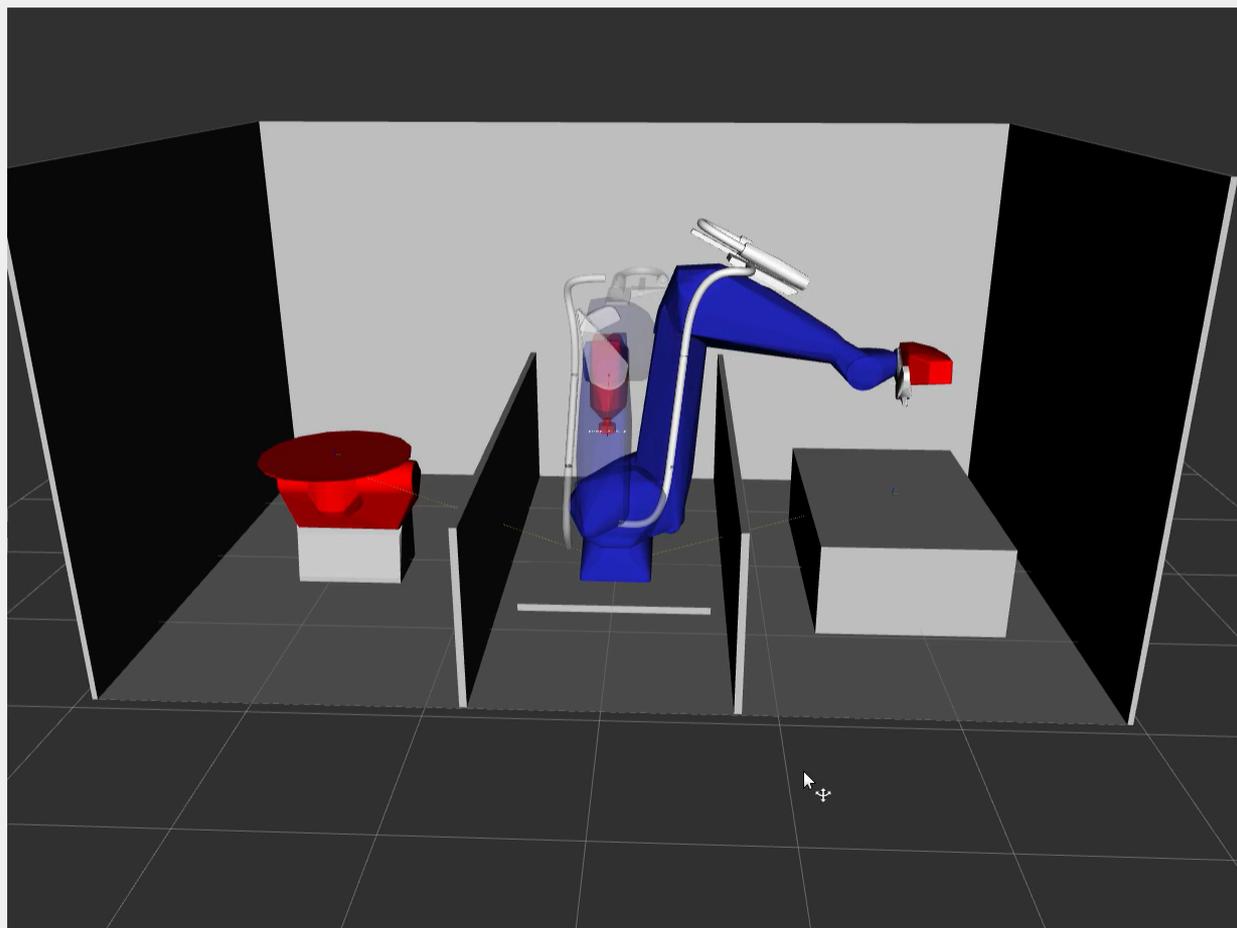
Back Halt

20%

Play Playback Speed 1.00 x 71.00 71.00

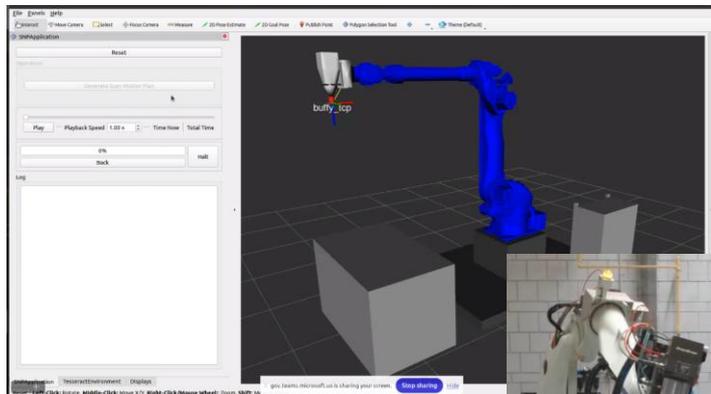
Log

```
[ Approve Scan Motion Plan Creation ] -> RUNNING
[ Approve Scan Motion Plan Creation ] -> SUCCESS
[ Generate Scan Motion Plan ] -> RUNNING
[ Generate Scan Motion Plan ] -> SUCCESS
[ Approve Scan Execution ] -> RUNNING
[ Approve Scan Execution ] -> SUCCESS
[ Enable Robot ] -> RUNNING
[ Enable Robot ] -> SUCCESS
[ Execute Scan Approach Motion ] -> RUNNING
[ Execute Scan Approach Motion ] -> SUCCESS
[ Start Reconstruction ] -> RUNNING
[ Start Reconstruction ] -> SUCCESS
[ Execute Scan Motion ] -> RUNNING
```



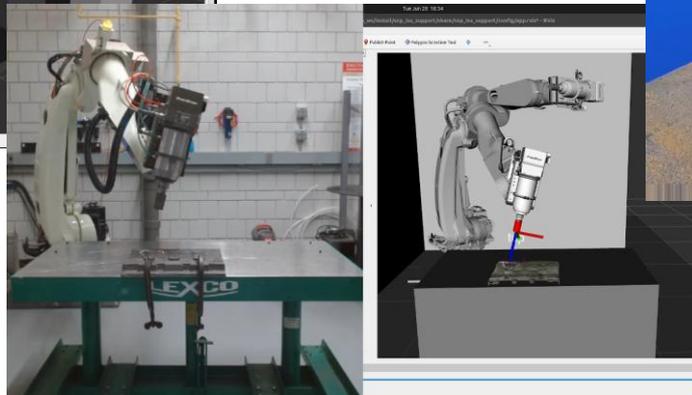
# Deployed Across Three Sites

## Same Software – 3 Sites



SwRI

ISU



Fisher Cast Steel

# Foundry Performance Observations

- Segmentation performance is sensitive to parameter settings that are not intuitive for non-expert users
  - Sensitive to type of casting and casting features
- Parts tested were ground in less than one minute and completed in one pass
- Computer time for this small casting is greater than processing time
- Offset by ability to set up multiple
- Develop means to tune for multi-set up in an intuitive manner – reduce computer/set up time
  - Standard templates
  - Simpler menus

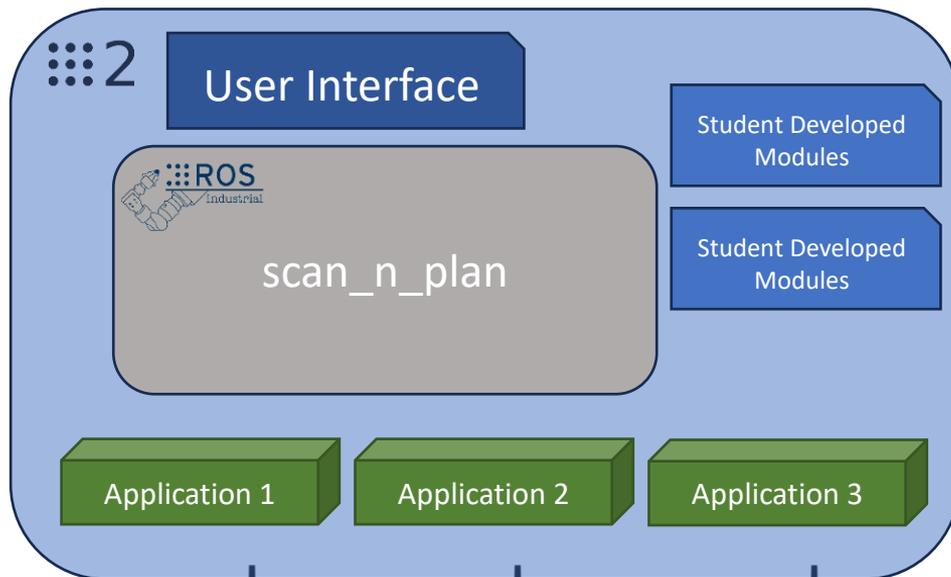
Tool Type	Casting size	Casting Shape
4" cup wheel	Small	Flat
		Convex
		Concave
	Medium	Flat
		Convex
		Concave
	Large	Flat
		Convex
		Concave
5" cup wheel	Small	Flat
		Convex
		Concave
	Medium	Flat
		Convex
		Concave
	Large	Flat
		Convex
		Concave
6" cup wheel	Small	Flat
		Convex
		Concave
	Medium	Flat
		Convex
		Concave
	Large	Flat
		Convex
		Concave



# Taking it further...



- Introduce software practices into universities
- Learn foundational tools
- Work with real end users
- Create something that works
- Students leave with skills and interest in foundry relevant tech and deployment





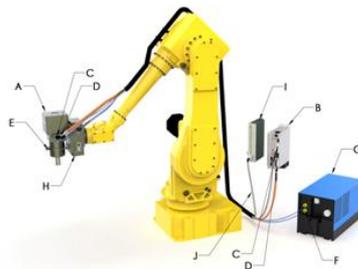
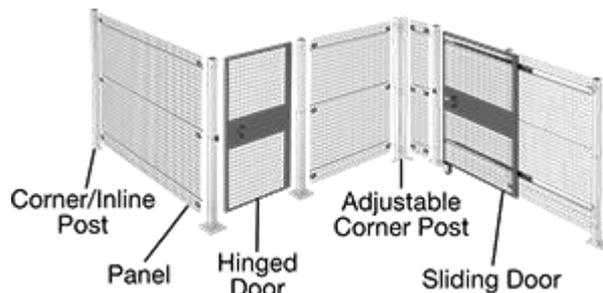
# Replication of wins

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- For integrators
  - Job shop package
    - Preconfigured Industrial PC
    - Camera
    - Documentation
- For savvy foundries
  - A cookbook – start with base model
    - Components
    - Companies
    - Contacts
  - Website
    - Documentation
    - Selection Guide
- Base Model:
  - Robot, fencing, process equipment, welding table with manual clamps
  - Base model 2: everything in 1 with adding a turn table
  - Base Model 3: Everything in 2 with adding solid walls or soundproof enclosure
  - Custom: Anything goes, brings in an integrator partner to help.

# Foundry Robotics Cookbook

- List of recommended components
  - Sourcing
  - Contact
- Integrator/Foundry
  - Receives robot package
  - Preconfigured PC and Camera
  - Able to select options for commission and test/verification



Item	Description
A	SERVO SPINDLE
B	SERVO AMPLIFIER
C	14.0M SERVO FEEDBACK CABLE
D	14.0M SERVO POWER CABLE
E	MOUNTING KIT
F	MILLER COOLMATE FITTING KIT
G	MILLER COOLMATE 3
H	ACTIVE COMPLIANT TOOL
I	ACTIVE COMPLIANT TOOL CONTROLLER
J	14.0M ACTIVE COMPLIANCE CONTROL CABLE

# What is next?

- Capability validation sprint with partner foundry – operator driven!



- Pilot the base model with a replication site
- Solicit feedback on method to enable foundries/integration partners to grab the specific components and get to work quickly
- Virtual test drive and commission
- Support structure – “help button” for all the pieces

# Take aways

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- Much like Android, robotics software can be broken down into usable components and run on any color hardware
- New techs able to “plug-in”
- Spread the support cost over a large community
- Large community = greater innovation
- Pathway for student development & student TALENT to get into foundries
- Operator and operations focused strategy – easy like an app

# Thank you

- Reach out with questions
- Provide feedback
- What tools/capabilities are needed?

