Lessons Learned in Deploying ROS2 in Industrial Applications

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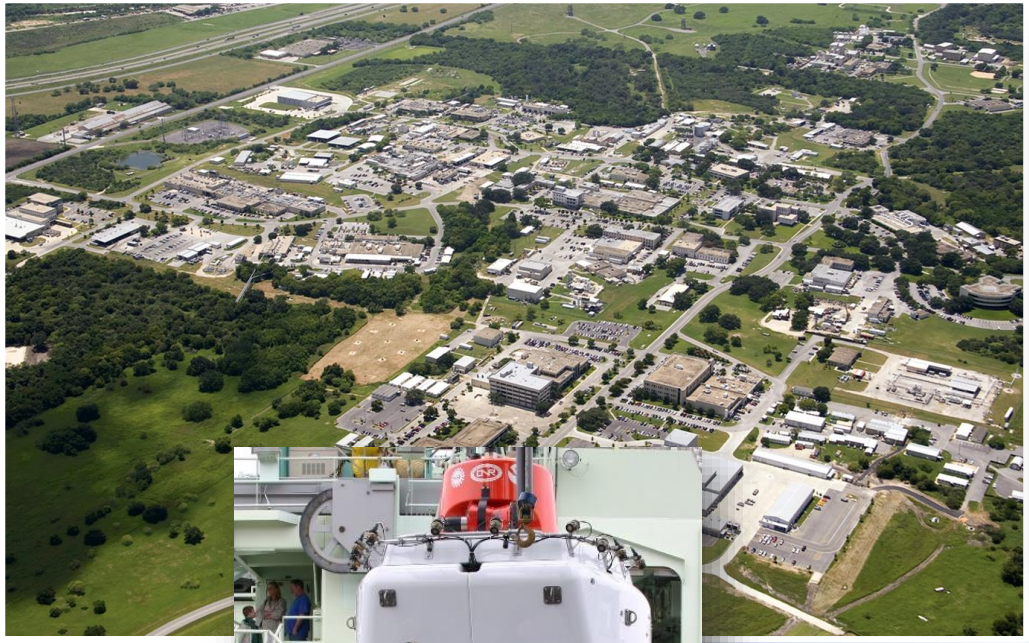
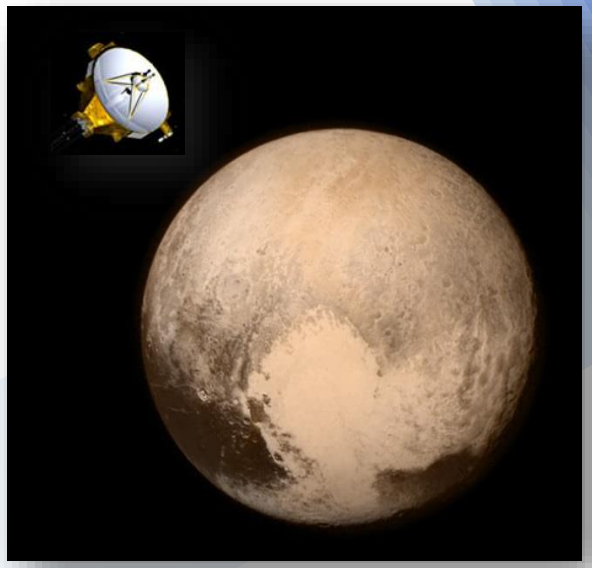
ASSOCIATION FOR ADVANCING AUTOMATION

AUTOMATE FORWARD

SwRI: Deep Sea to Deep Space



Alvin submersible



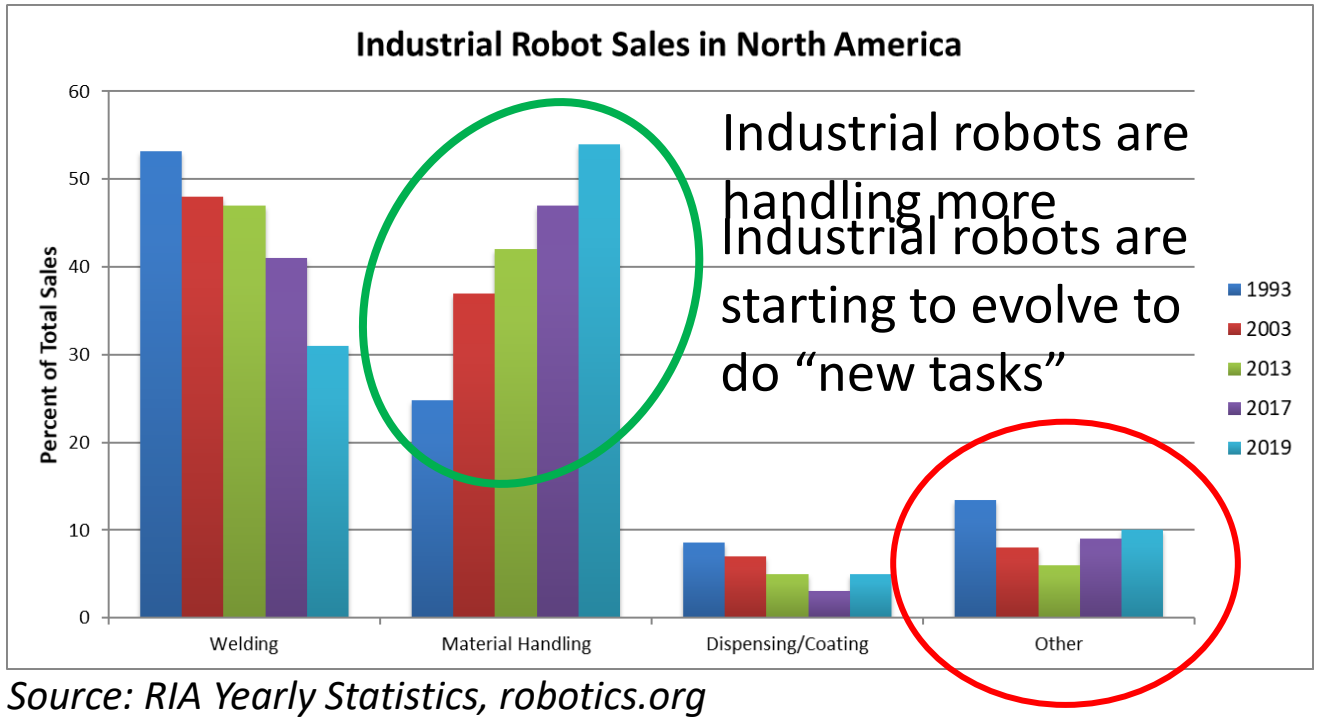
New Horizons, Pluto

Southwest Research Institute Characteristics

- Est. 1947
- San Antonio, Texas, USA
- Independent, Not for profit
- Applied RDT&E Services
- Natural Science and Eng.
- FY 2019 Revenue: $674M

Industrial Robotics

- Silos/Vendor Lock
- Historical reliance on large-scale end-users



Source: RIA Yearly Statistics, robotics.org

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ROS Releases and Journey to Industry

2008

- PR2 and ROS start at a research platform for universities and research institutes

Jan 2010

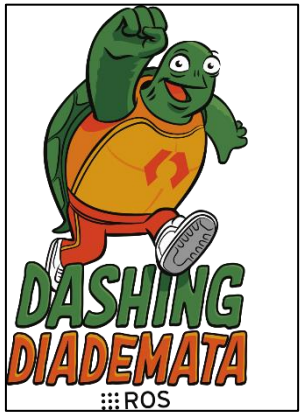
- ROS 1.0 is released with tutorials
- 12 releases between 2010-2018

Dec 2017

- First Beta release of ROS 2.0 for general use

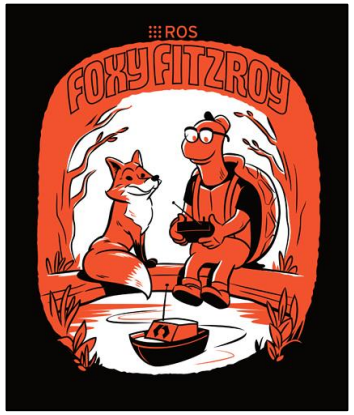
Dec 2018

- Actions support
- Navigation package



May 2019

- Multi-axis robot motion planning



Jun 2020

- Latest release

10 Year Development Cycle

ROS 2.0 Industrial Use

Start using for next generation platform development

Source: Open Robotics Presentation at ROSCON 2018 (Updated)

Goals for ROS 2.0

product-ready

Use **industry-standard middleware** (e.g., DDS)

Build in **security** from the beginning

Support **Linux**, macOS, and **Windows**

mission-critical

Support **real-time control**

Static analysis (e.g., MISRA)

Document design choices

Support safety certification

...but also familiar

Keep the core concepts from ROS 1

Distributed systems

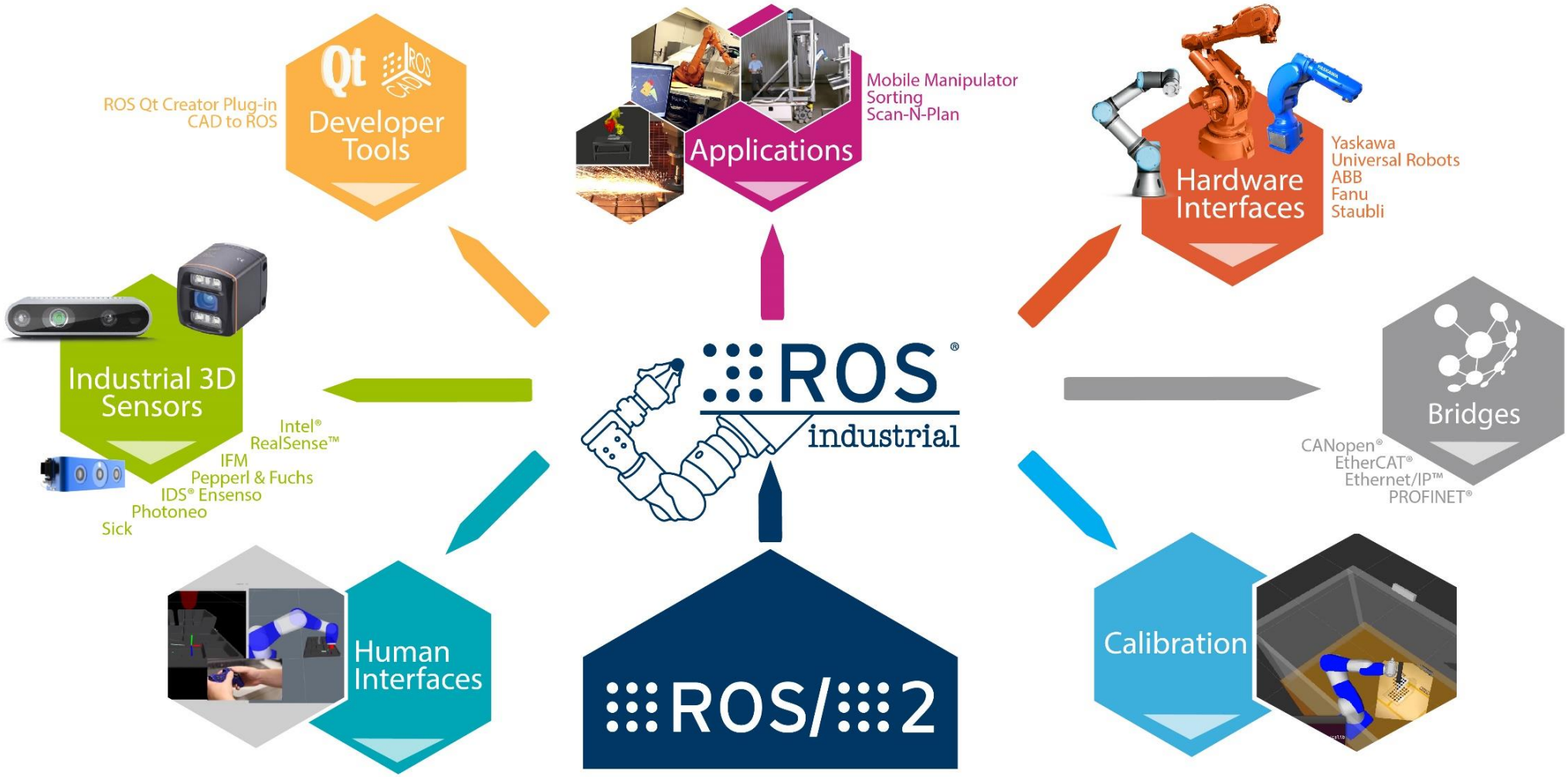
Federated development

Permissive open source license – allows for commercial hybrid model

Important for mass-scale industry adoption

Source: Open Robotics Presentation at ROSCON 2018 (Updated)

What is ROS-I?


ROS Qt Creator Plug-in
CAD to ROS
Developer Tools
Applications
Mobile Manipulator
Sorting
Scan-N-Plan
Hardware Interfaces
Yaskawa
Universal Robots
ABB
Fanu
Staubli
Industrial 3D Sensors
Intel® RealSense™
IFM
Pepperl & Fuchs
IDS® Ensenso
Photoneo
Sick
ROS industrial
Bridges
CANopen®
EtherCAT®
Ethernet/IP™
PROFINET®
Human Interfaces
ROS/2
Calibration

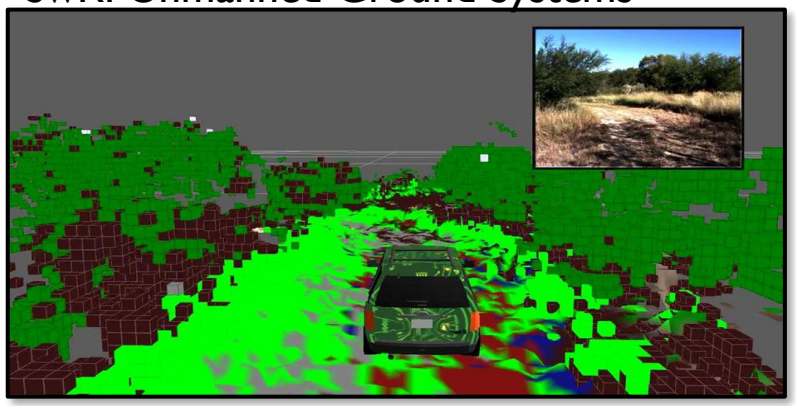
What Can ROS-I Do?

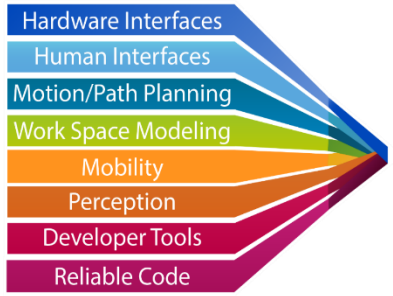
https://youtu.be/IxTJ473MY3Y

ROS-Industrial Timeline

2010 SwRI Adopts ROS → **2011** ROS-I Inception → **2012** ROS-I Launch → **2013-2016** ROS-I Consortium

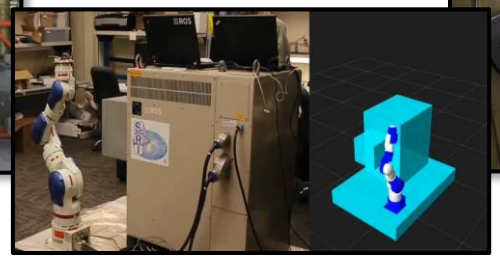
SwRI Unmanned Ground Systems



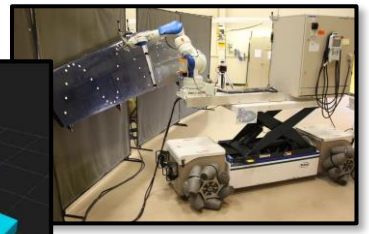


Enable Global Leverage of Regional Development

Robotics Coating Removal System



Robotic Workcell Visualization



MR ROAM Mobile Robot

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Tech Vision Supported by Industry

- **ROS-Industrial Consortium** acts as an ecosystem where different players – end-users, equipment providers, system integrators, institutes of research and training partners **come together to advance and proliferate Open Source robotics**

Strategy for Capability Development

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

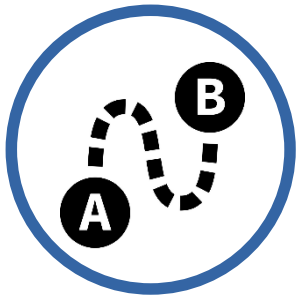
Messages, Topics

ROS 1 / ROS 2 / Middleware Layer

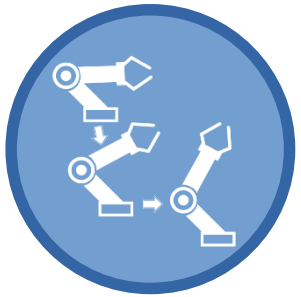
Build ROS1 or ROS2, these are independent

Independent of ROS

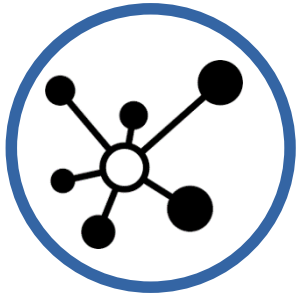
Collision Detection



Motion Planners



Kinematic Solvers



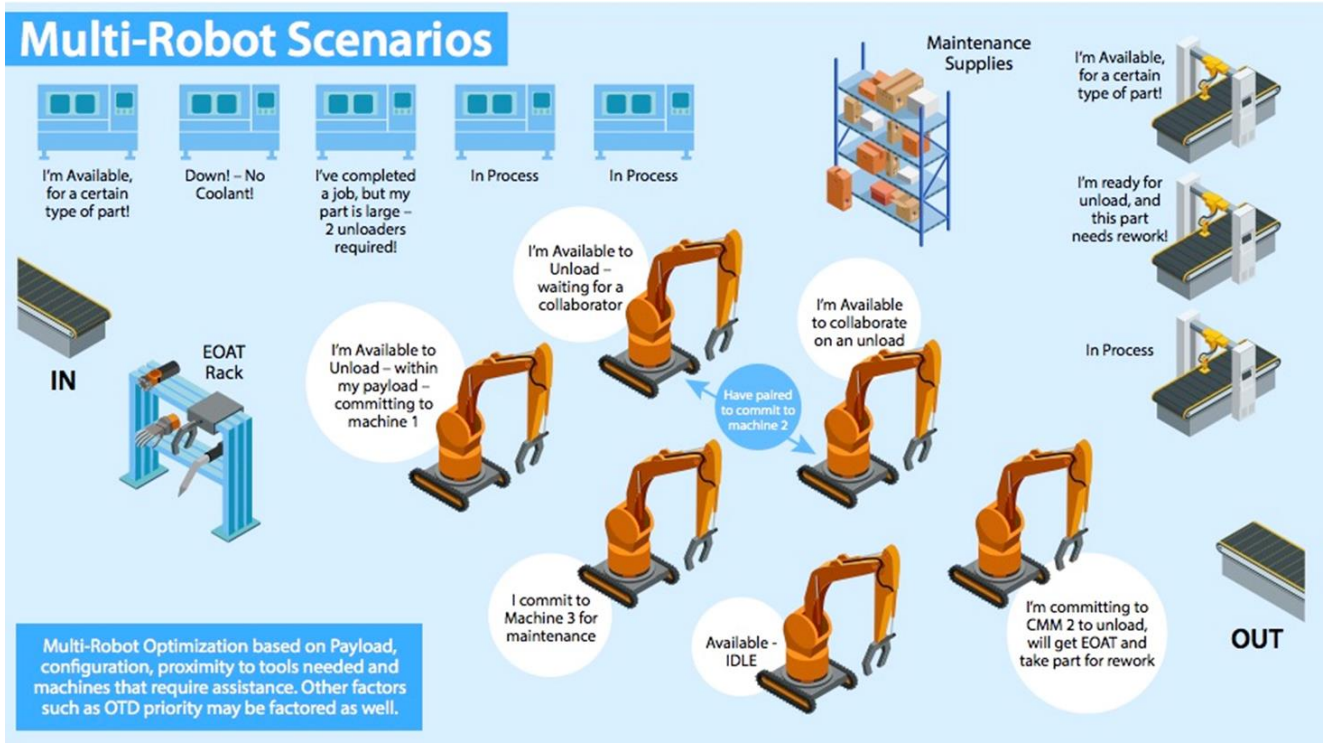
Connectivity Structure

Continue to support deployed end-user ROS1 systems with new capabilities as they are developed even if for a ROS2 solution

DDS – Why?

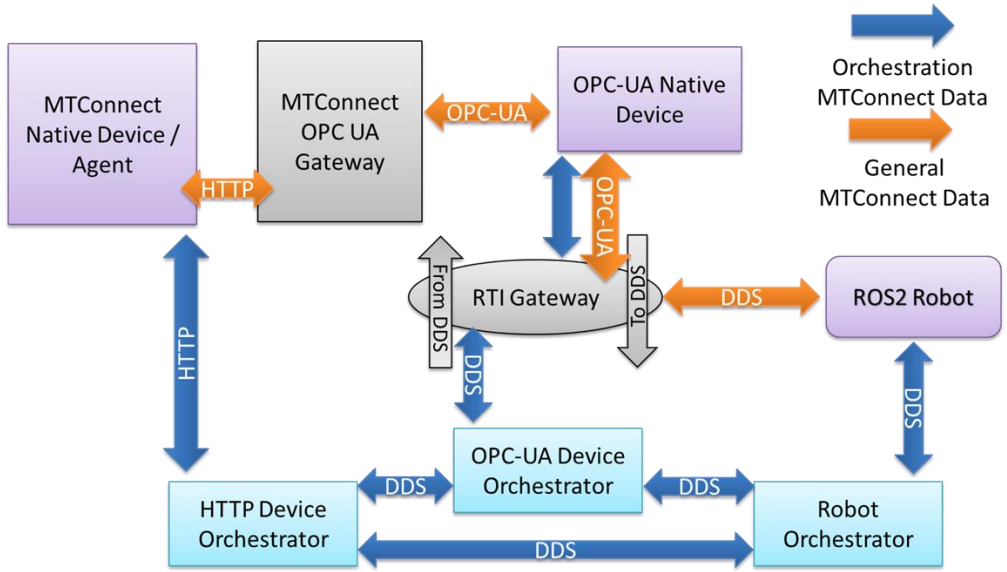
- ROS1 had a custom transport messaging layer
- Using an end-to-end middleware, like DDS, means less code to maintain
- Behavior and specifications well documented
- Provides publish-subscribe transport (similar to ROS1)
- Default discovery system eliminates the need for ROS master and enables a truly distributed system
- Long history of use, and a well supported standard
- Provides significant flexibility with regards to system design and interoperability

Driving Dynamic Interoperability



ARM Institute 18-01 Seamless Multi-Robot, Multi-Machine Interoperability – Siemens, RTI, SwRI, Yaskawa, KEBA, Schlumberger

Orchestrator originally implemented in ROS, implemented directly in the DDS environment improved performance of the application



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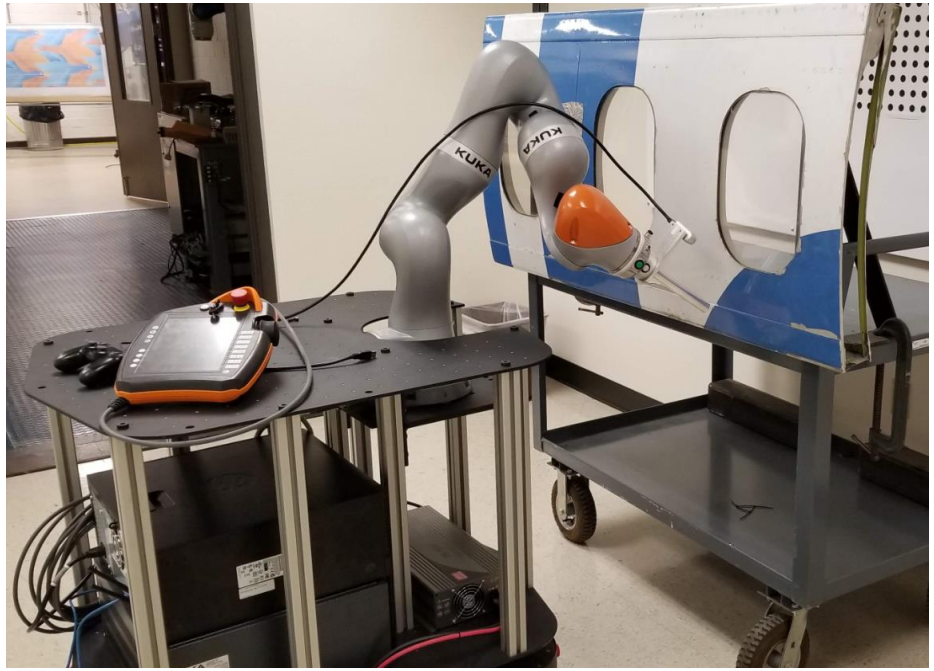
Deploying ROS2 into Production

- Leverage stated benefits of ROS2 to build production system
  - Launched initial effort in early 2019; Phase II in commissioning phase – 8 total systems
- At the time little ROS2 interface packages
  - Robots & sensor drivers
- Leveraged bridge and ported key components that were required
  - Leveraged the middleware agnostic strategy
  - Ported motion planning pipeline Tesseract to ROS2 (pure CMake)
- Put the first mobile manipulation ROS2 systems into production

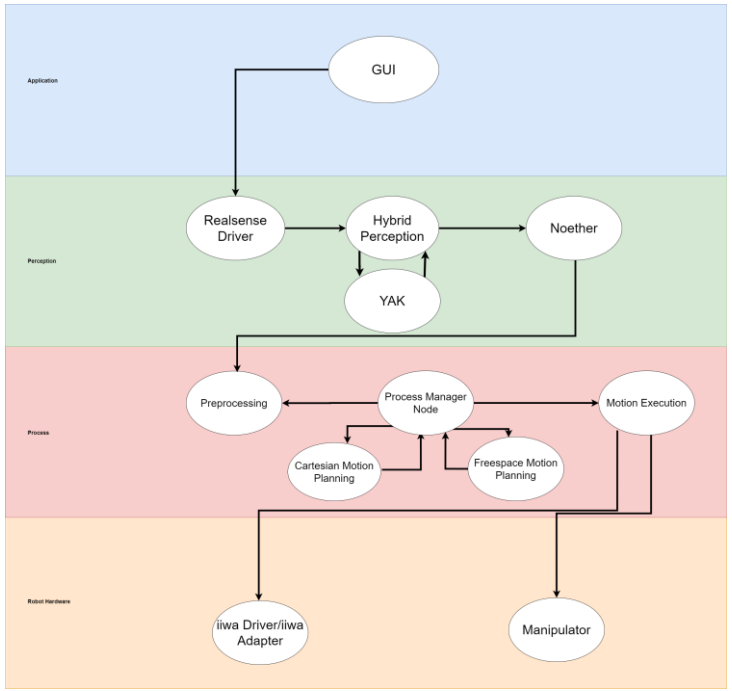


Created demo system based on first ROS2 production system

Reference: Lessons from a ROS2 Collaborative Industrial Scan-N-Plan Application, Building Out a ROS2 Mobile Scan-N-Plan Demonstration

Lessons Learned Deploying ROS2 into Production

- DDS experience gained/optimization
  - Certain implementations better at ensuring messages/services get where they need to
  - Others better at handling high frequency information
- Best Practices
  - Setting up nodes as component nodes improves node to node communication
  - Python launch scripts are useful to run scripts on launch (verify files installed in the right place) but there isn't an easy was to pass launch arguments to that script.
  - Complex task implementation and service architecture is difficult, each service has to exist on a different node.
  - Shared network with other ROS2 systems, requires unique ROS_DOMAIN_ID environment variable to avoid system cross-talk
    - common ROS_DOMAIN_ID makes communication between systems easy, an advantage provided by using DDS
- Improving performance utilizing the bridge
  - Actions are still a challenge over the bridge – run action server in ROS1 and call it from ROS2 then you need to custom make the reverse action bridge to assign every value in the action message on either side



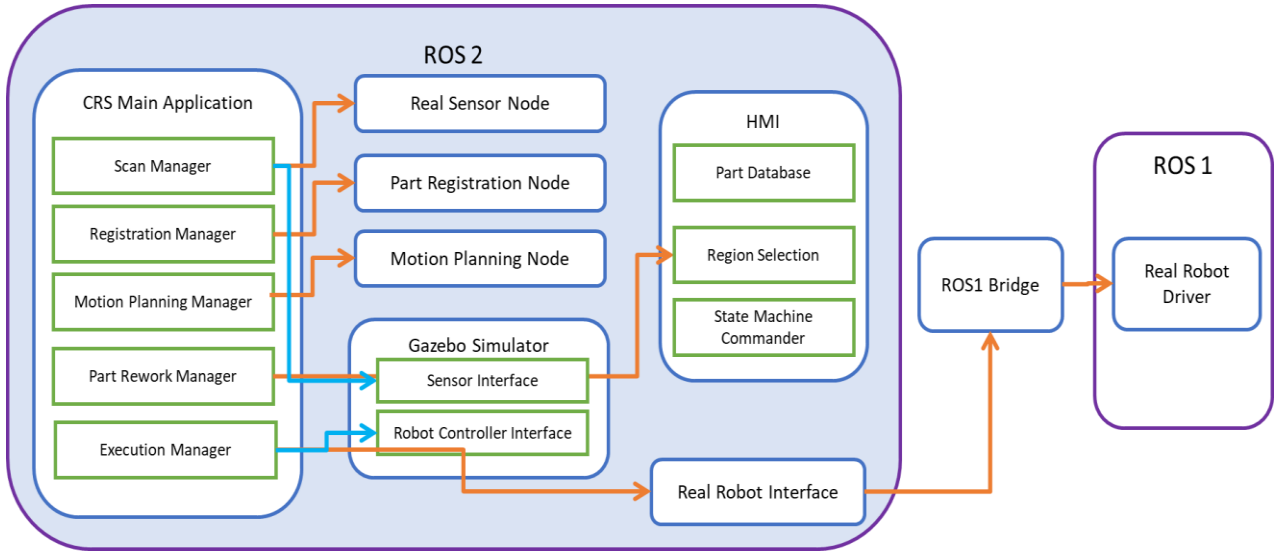
Source: https://rosindustrial.org/news/2020/7/8/developing-a-ros2-collaborative-industrial-scan-n-plan-application

ROS2 Collaborative Development

- In collaboration with Spirit AeroSystems, NIAR at Wichita State University and the ARM Institute
- Need at Spirit
  - Collaborative sanding application for composite parts
  - Reduce cost, rapid deployment on the floor, able to work close to humans intuitively
- Full open-source development of a Scan-N-Plan system in ROS2
  - Make available code, modules, and examples to enable reuse
  - Force-commanded constant velocity trajectory controller
  - Human marking detection and replanning

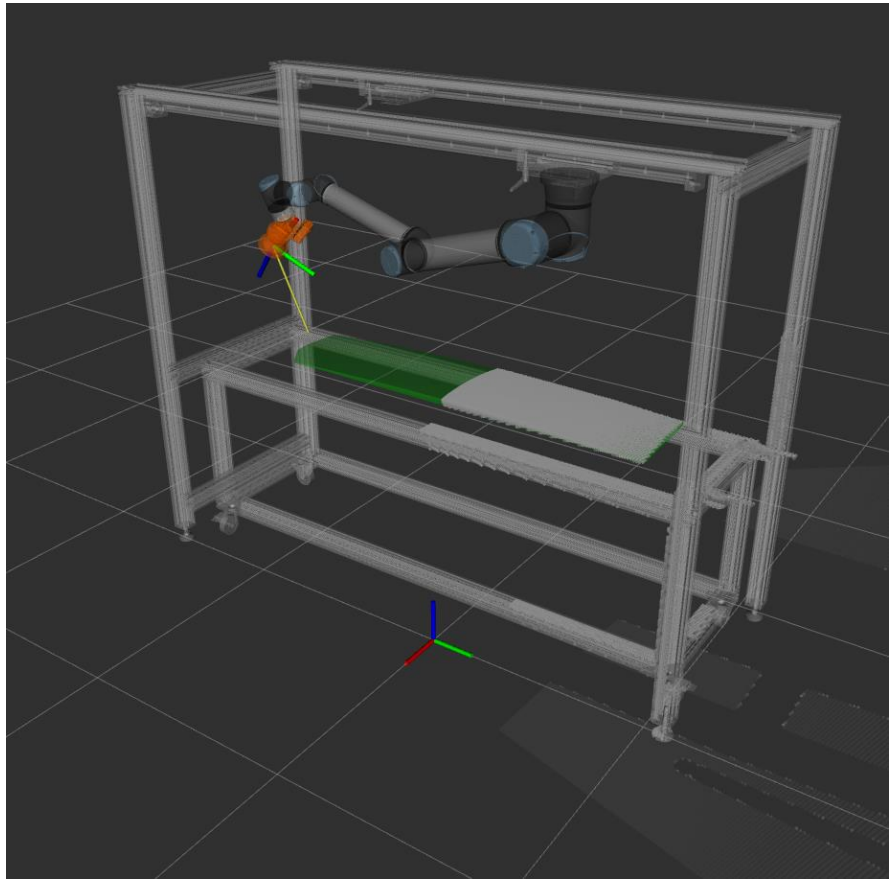
Build Out Complete Application

- Reduce cost, rapid deployment or the floor, able to work close to humans intuitively
- Leverage a deployment partner
- Leverage open-source software
- Make available in the form of a fully built application as a reference ROS2 example

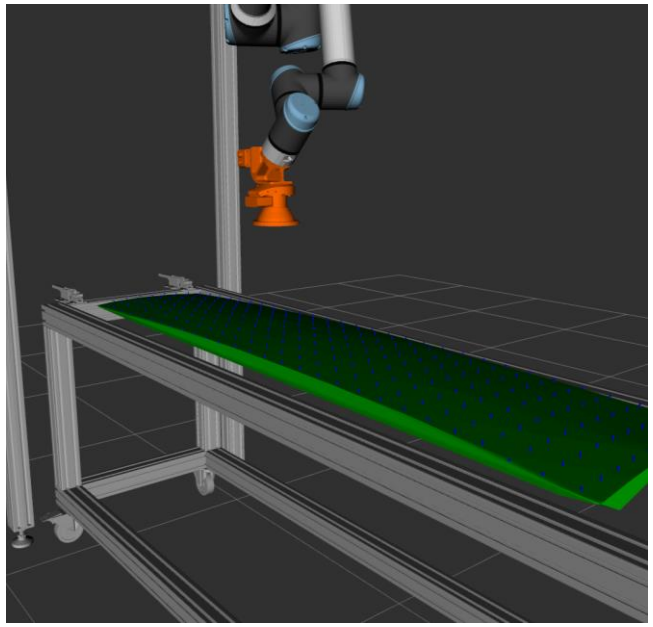


Full Functional Virtual Cell

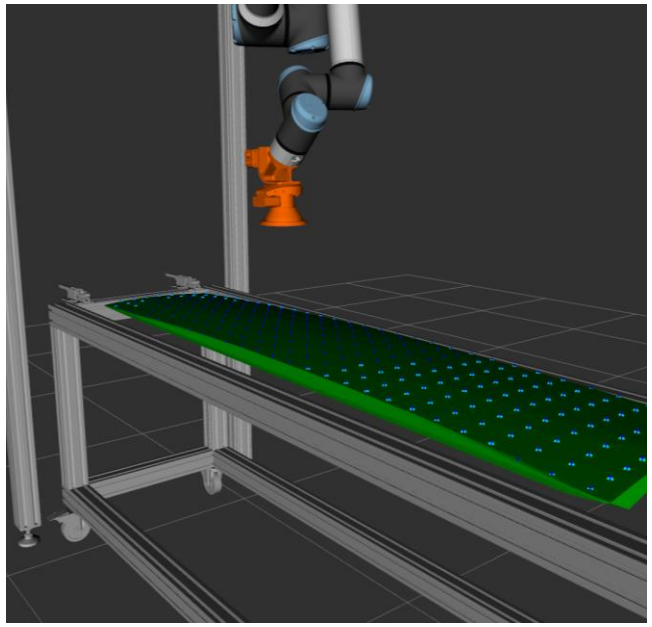
- Built in Gazebo
- Test localization
- Sensor simulation
- Reach analysis
- Robot base optimization
- Tool path and free motion planning



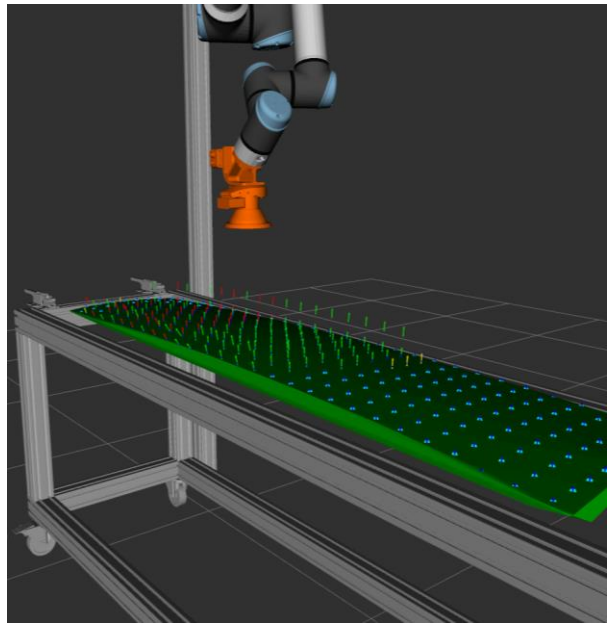
Interesting New Capabilities



Dark Blue –
Loaded toolpaths



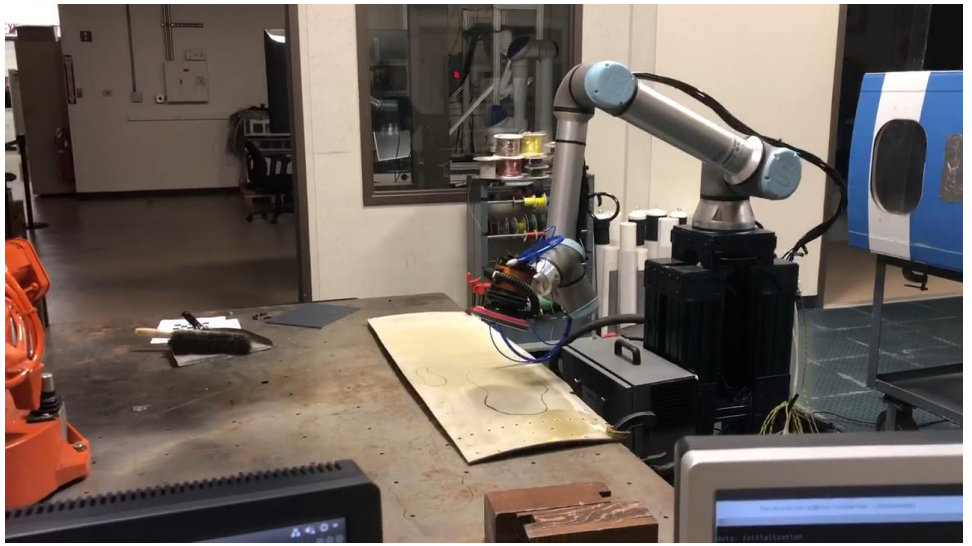
Light Blue –
Unreachable points

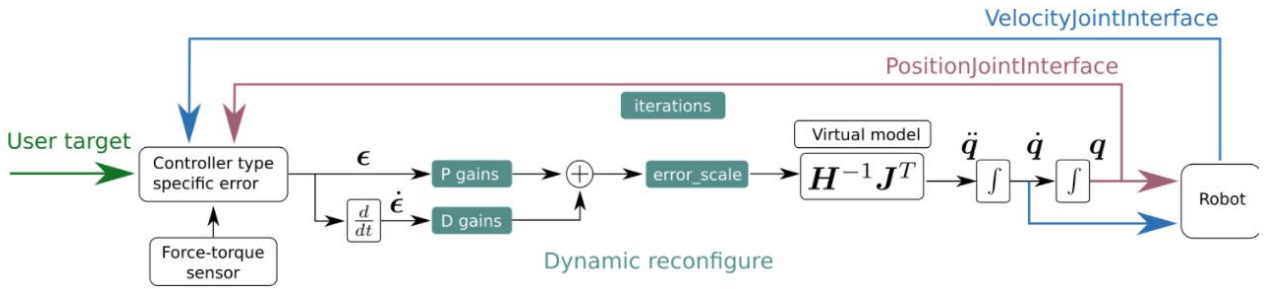


Green – Successfully planned
Yellow – Skipped due to length
Red – Failed collision checking

Compliance Controller

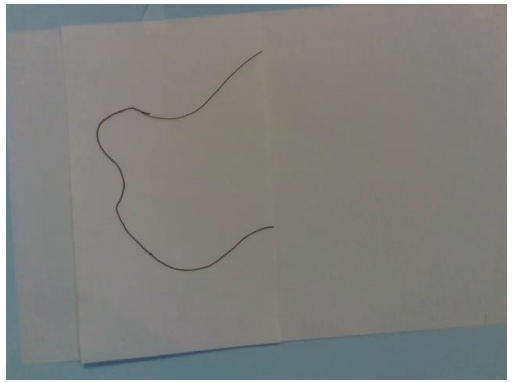
- In autonomous robot path planning often seeking to reach target poses
- In force-commanded operations you need to leave target pose to reach force
- Also need to maintain velocity while maintaining force
- Leveraged an open-source package to create a force-commanded velocity constant control
- Hardware agnostic

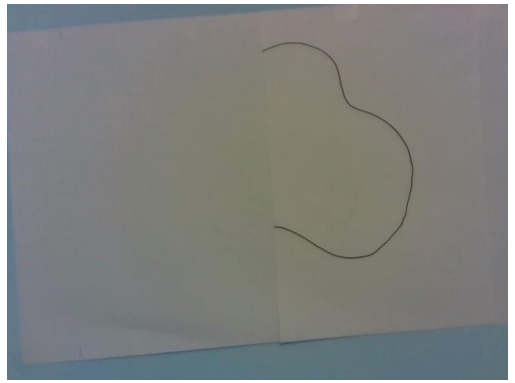


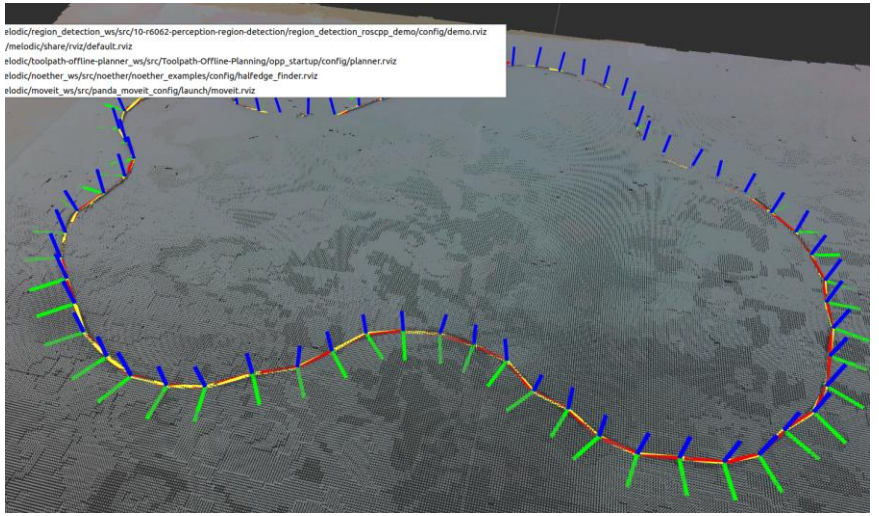


Planning in human drawn regions

- Inspectors mark up parts
- Required that system plan to resolve areas within bounds not meeting spec
- Developed library that leverages perception system to segment out area to be processed

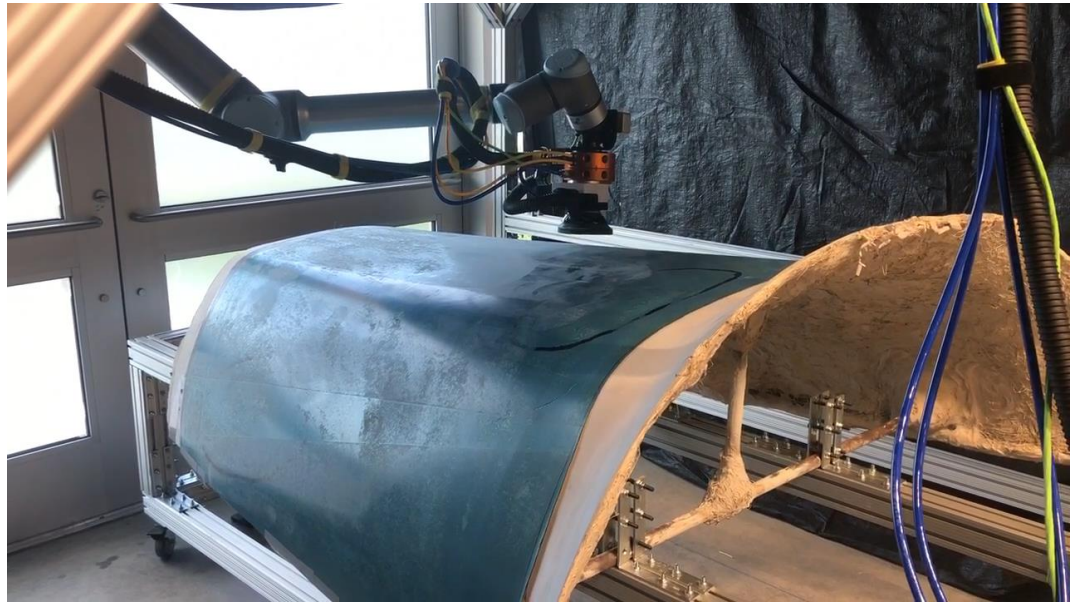






Integrated at NIAR

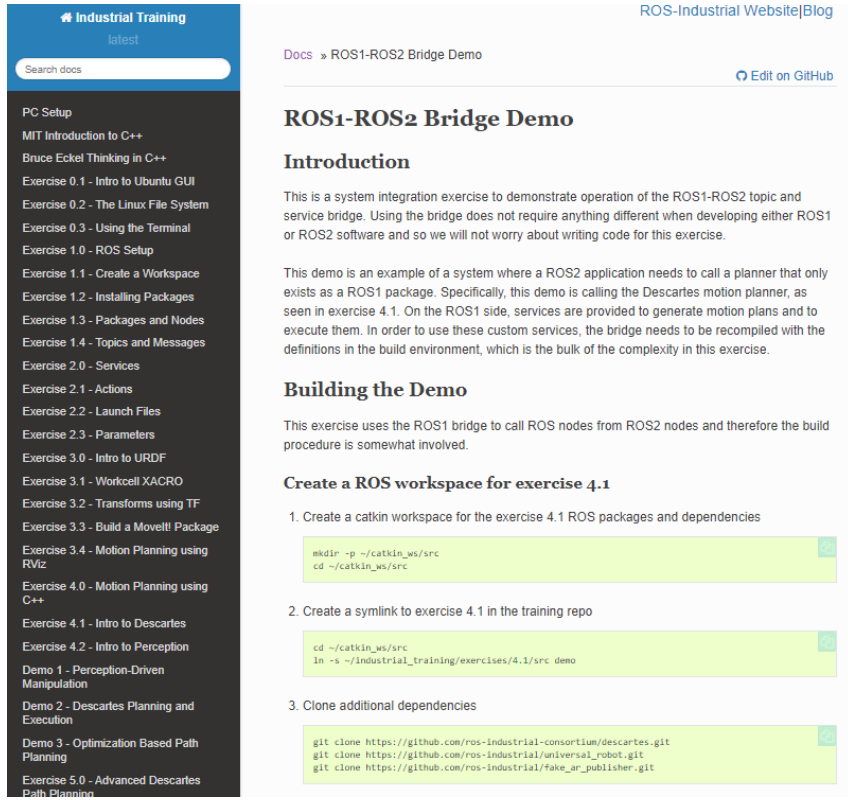
- Deploy on hardware at NIAR
- Integrate and verify software functionality
- Train NIAR and Spirit personnel on use
- Project demo October 2020 - https://youtu.be/Pj_NsO22Bws



Demonstration Video

Training – A Journey

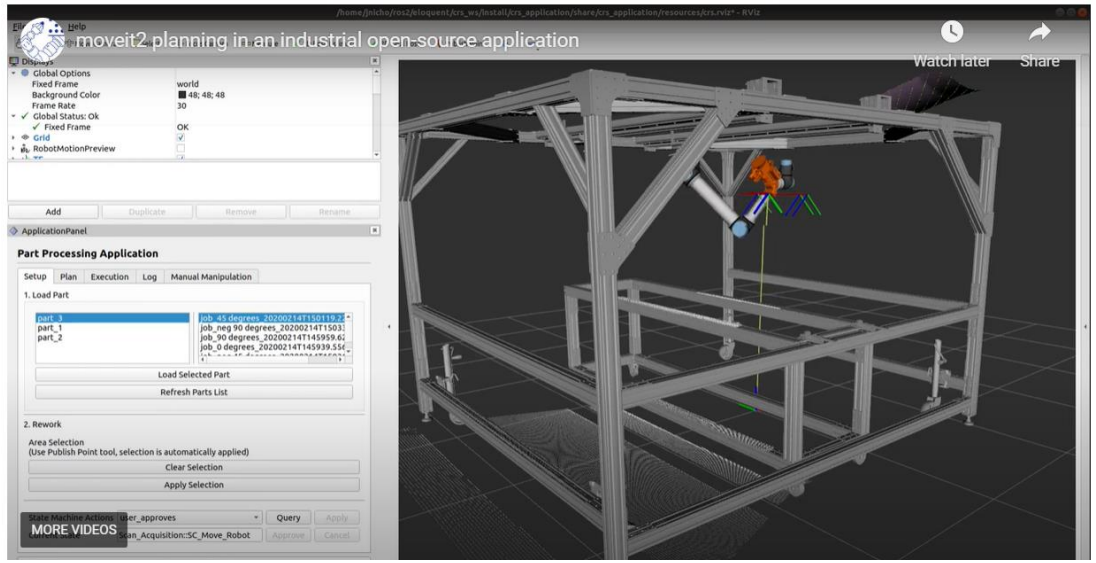
- A key component of ROS and ROS-Industrial has been training and documentation resources
- Currently transitioning ROS-I training to ROS2
  - Dependency porting still a work in progress
- Additional resources to support different roles
  - Manufacturing Engineers
  - Technicians
- Continue to work with open-source community to provide resources, in parallel encourage use
  - Use drives content creation/references/documentation



Source: https://industrial-training-master.readthedocs.io/en/latest/_source/session7/ROS1-ROS2-bridge.html

MoveIt2

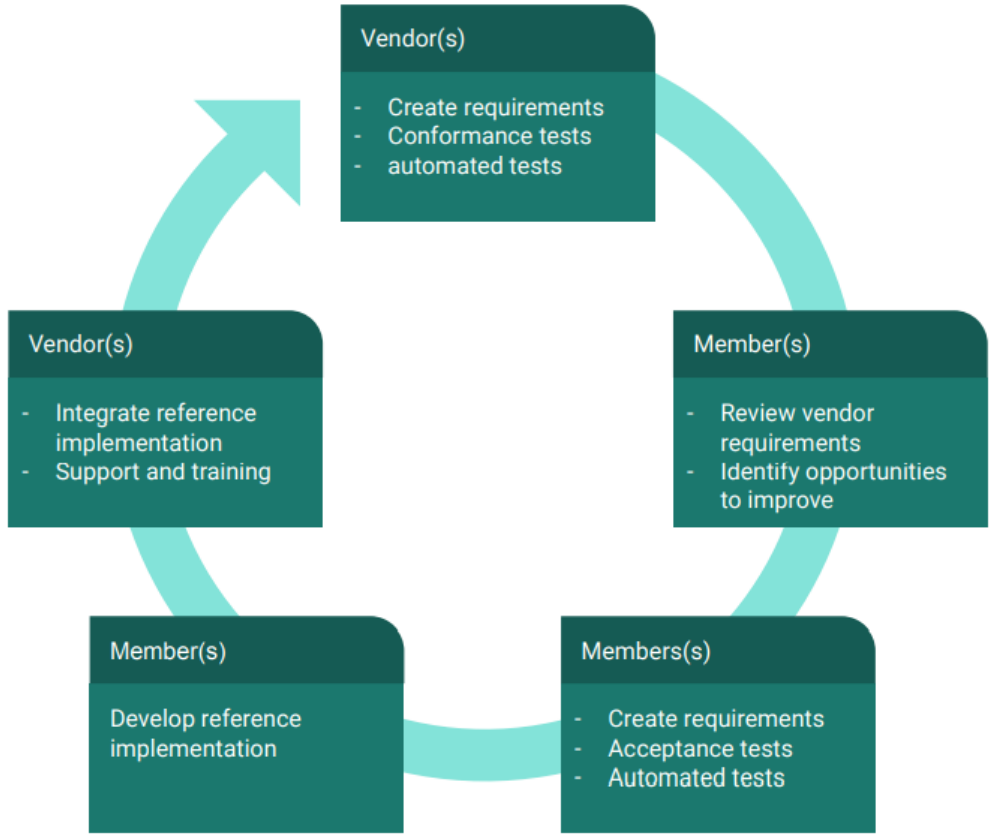
- Default open-source robotics manipulation platform and environment
- Out of Beta with the late 2020 ROS2 Foxy release
- Includes multi-platform support
- Major achievement to enable rich application development in ROS2
  - Pending porting of some key features for entry-level users
  - Moveit_setup_assistant
  - Able to use MoveIt Setup Assistant in ROS1
- Focus on realtime performance leveraging ROS2 native realtime support via DDS



Source: https://rosindustrial.org/news/2020/4/29/using-moveit2-on-a-industrial-open-source-application

Beginning of Interface Development

- PickNik, UR, and FZI Research collaboration on UR RO2 Interface
- Industrial OEMs reviewing their strategies for ROS2
- Hardware Interface WG
  - Goal: Create a standard for classes of interfaces to enable consistency in ROS2
  - Reference implementations to lower the barrier for OEMs to create and support interfaces



Source: Jeremy Adams, OCI, ROS-I Dec 2020 Community Meeting

Take Aways

- ROS2 is ready for use and offers advantage for industrial applications – better with each release!
- ROS2-based systems are delivering value on shop floors
- Increased use of ROS2 drives documentation, references, and hardware interface development
- As a community we can enable an ecosystem that enables focus on what makes a difference for each end-user
- Work with academia and industrial OEMs to understand the importance of open-source and ROS2 specifically

Resources for the Community

- ROS-Industrial
  - Home: rosindustrial.org
  - Documentation: wiki.ros.org/industrial
  - Code: https://github.com/ros-industrial; https://github.com/ros-industrial-consortium
  - Training: http://ros-industrial.github.io/industrial_training/
  - ROSin: http://rosin-project.eu/
- Upcoming Events (https://rosindustrial.org/events-summary/)

Thank You

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