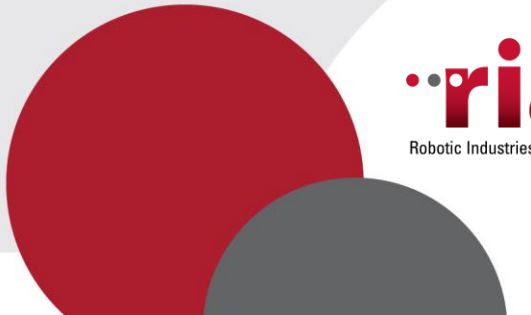
ROS-Industrial and Open-Source Solutions Making a Difference on the Factory Floor

Matthew M. Robinson
ROS-Industrial Americas
Program Manager
Southwest Research Institute

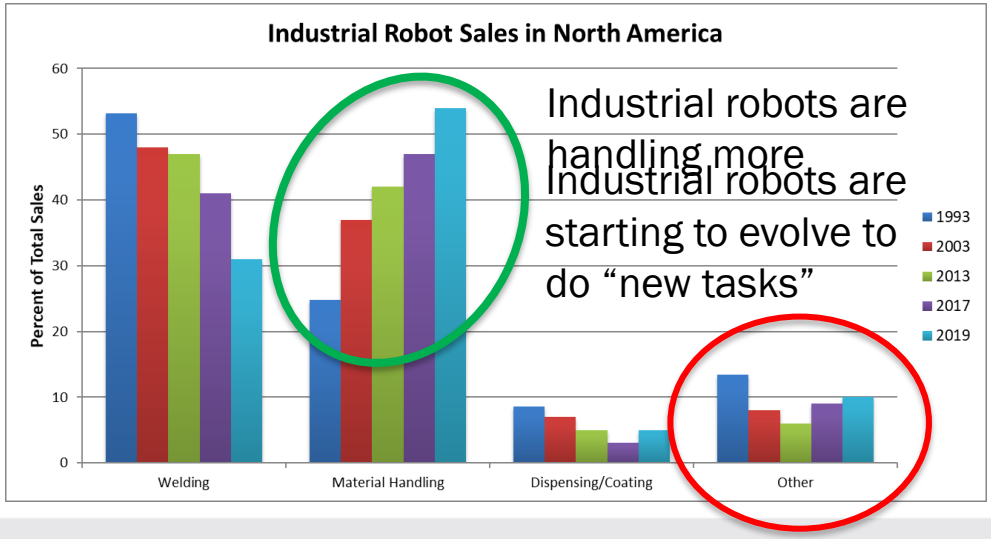


ria
Robotic Industries Association

Robotics Week

Industrial Robotics

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



Source: RIA Yearly Statistics, robotics.org

A Disruption in Software for Automation

Enter ROS – Robot Operating System

- Open Source
- Established to prevent re-inventing the wheel
- Maintained by Open Robotics
- Reusable Software Components
- >1,000,000 user downloads/mo

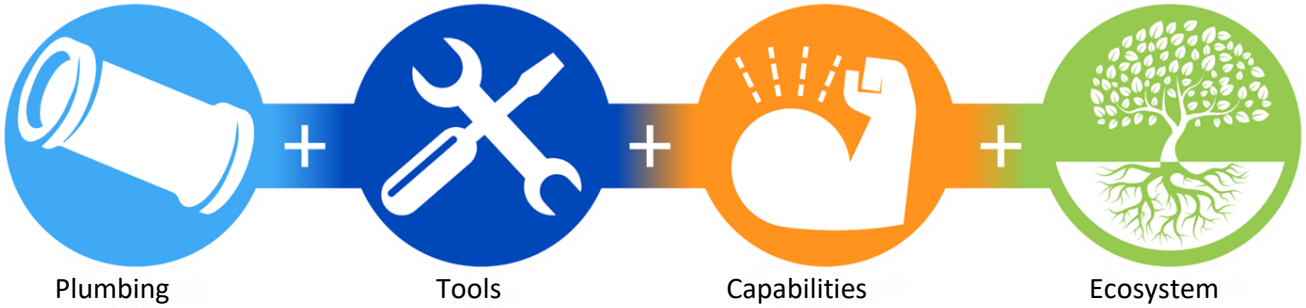
ROS

is…

A **Middleware** Framework

An International **Open-source** Project

A Library of **Free Software and Tools** for Robotic Development



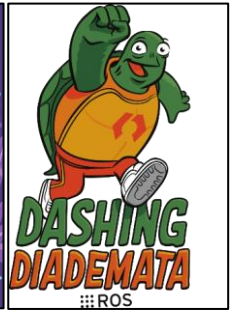
ROS Journey to Industry

2008

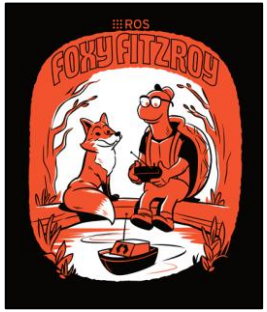
Jan 2010

Dec 2017

Dec 2018



May 2019



Jun 2020

10 Year Development Cycle

ROS 2.0 Targeted Industrial Use

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-Industrial?

ROS-Industrial Timeline

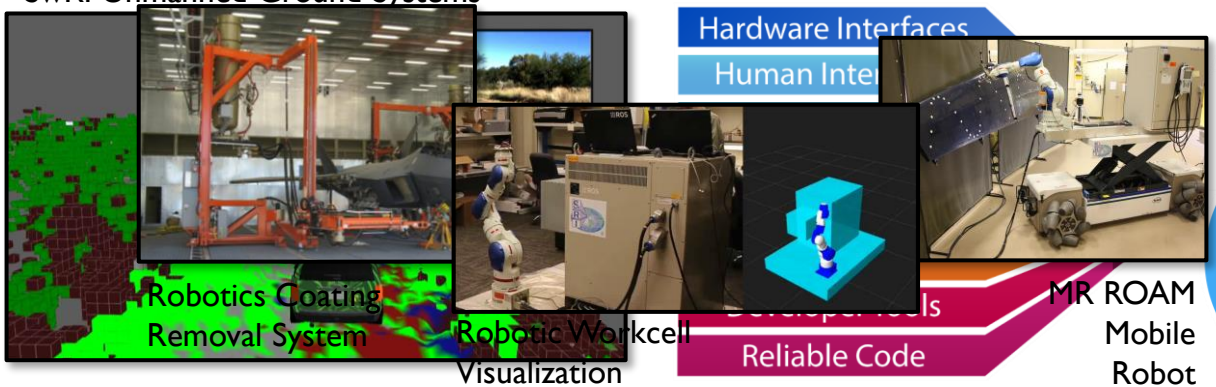
2010 SwRI Adopts ROS

2011 ROS-I Inception

2012 ROS-I Launch

2013-2016 ROS-I Consortium

SwRI Unmanned Ground Systems



Robotics Coating Removal System

Robotic Workcell Visualization

MR ROAM Mobile Robot

Enable Global Leverage of Regional Development

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 Development

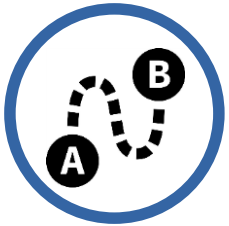
Environment Layer (MoveIt, Tesseract, Dart, etc.)

Messages, Topics

ROS 1 / ROS 2 / Middleware Layer

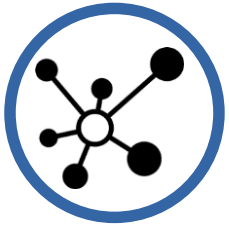
Independent of ROS

Collision Detection



Motion Planners

Kinematic Solvers



Connectivity Structure

Build ROS1 or ROS2, these are independent

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

What Can ROS-I Do?

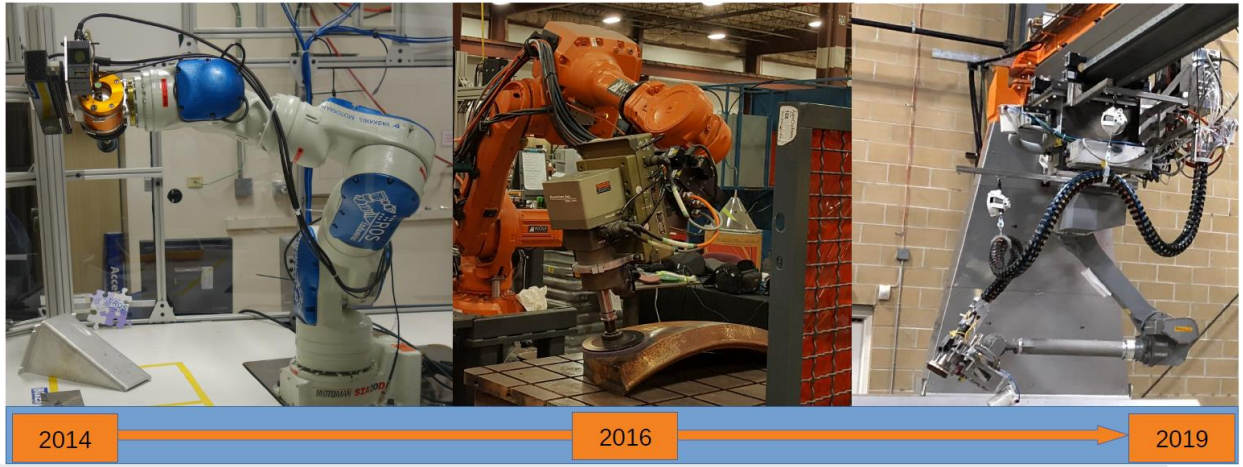
Getting Systems into Production

- Enabling foundation
- The right partners
- Plan – concept through sustainment

Source: https://github.com/swri-robotics/euler;
Basition Solutions, ProMat 2017

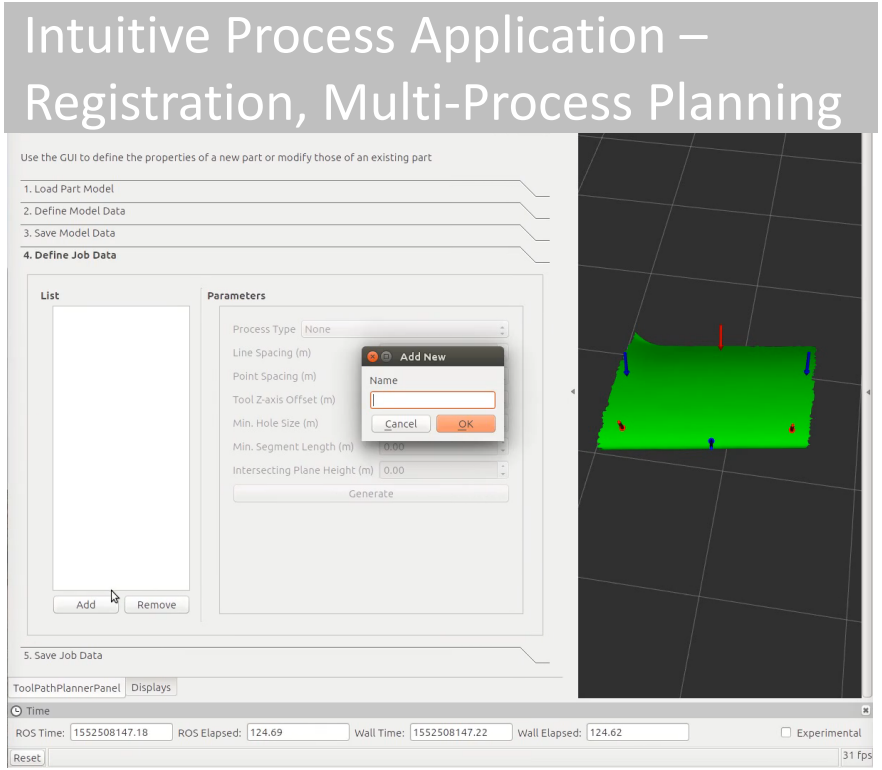
Evolution of Scan-N-Plan

- Build up of capability since 2014
- Leverage consortium developed capability
- Foundation for production deployment



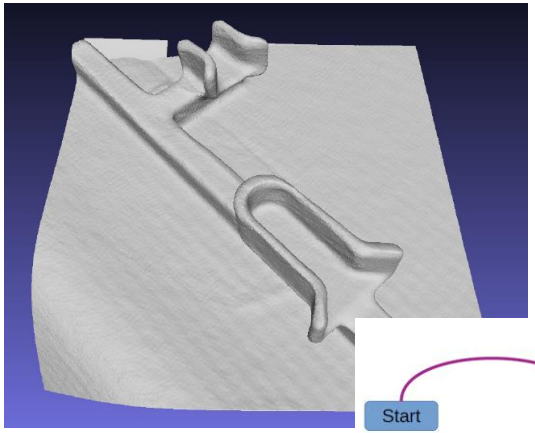
Aerospace Remanufacturing

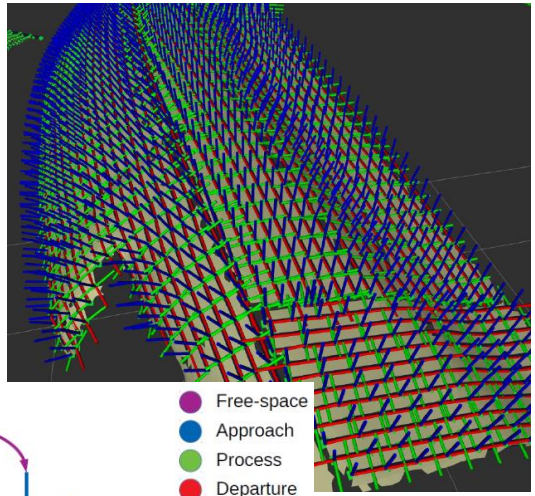
Intuitive Process Application – Registration, Multi-Process Planning

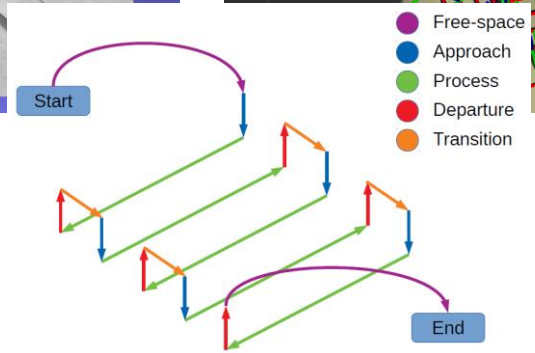


Open Source Leveraged

- ROS_SCXML
- YAK
- Noether
- Tesseract
  - Geometry
  - Motion Planning
  - Process Planning

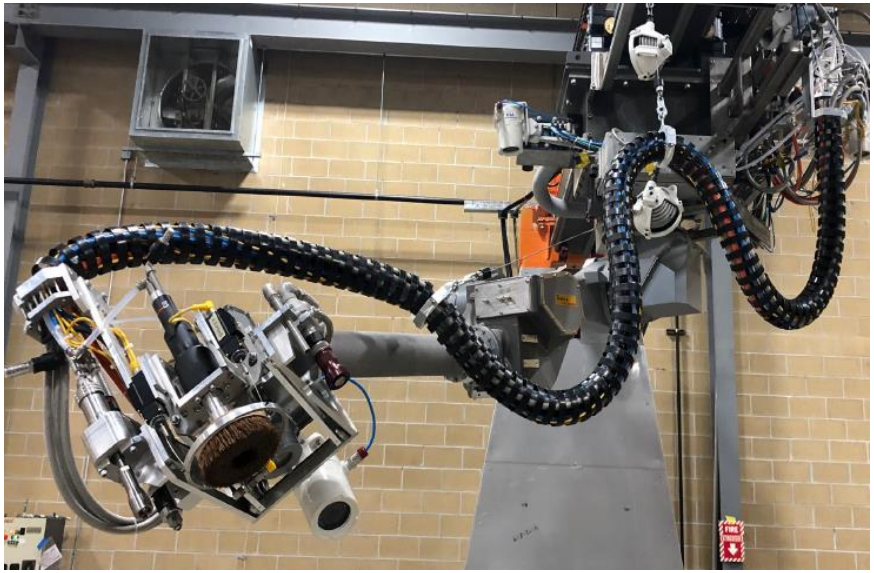






Lessons Learned

- Modeling System Constraints
  - Festooning
  - DC Joint Exclusion Zones
  - Configuration
  - Limit Robot Extension
  - Numerical Rounding
  - Error Recovery

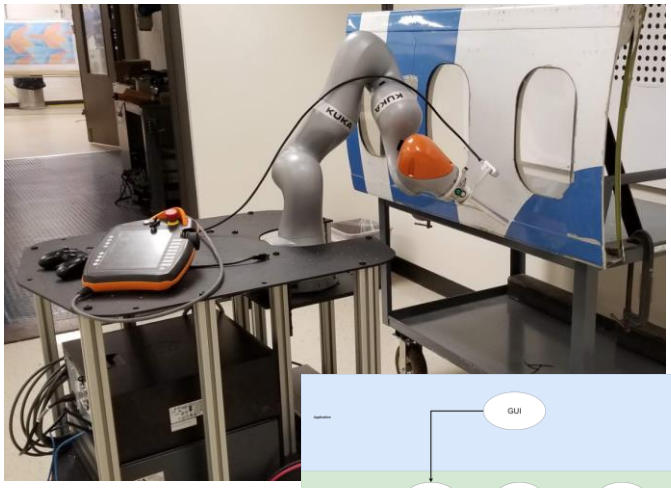


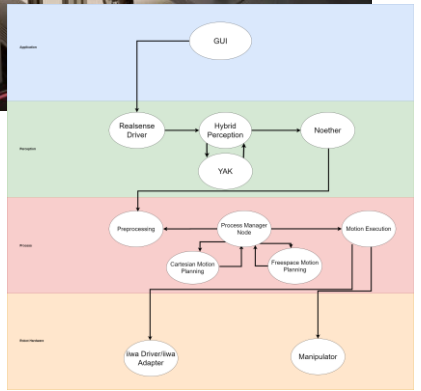
Deploying ROS2 into Production

- Leverage stated benefits of ROS2 to build production system
- Launched initial effort in early 2019
- At the time little ROS2 interface packages
  - Robots & sensor drivers
- Leveraged bridge and ported key components that were required
  - Leveraged the middleware agnostic strategy

And what happened…

- Ported motion planning pipeline Tesseract to ROS2 (pure CMake)
- Lessons learned in creating system-specific ROS2 packages
  - Greater flexibility, leverage ROS2 benefits (node lifecycle management
- DDS experience gained/optimization
- Created a demonstration system
- Put the first mobile manipulation ROS2 system into production





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

ROS2 Collaborative Development

- In collaboration with Spirit AeroSystems, NIAR at Wichita State University and the ARM Institute
- Collaborative sanding application for composite parts
- Full open-source development of a Scan-N-Plan system
  - Force-commanded constant velocity trajectory controller
  - Human marking detection and replanning

ARM
ADVANCED ROBOTICS FOR MANUFACTURING

SPIRIT AEROSYSTEMS

NIAR
WICHITA STATE UNIVERSITY
NATIONAL INSTITUTE FOR AVIATION RESEARCH

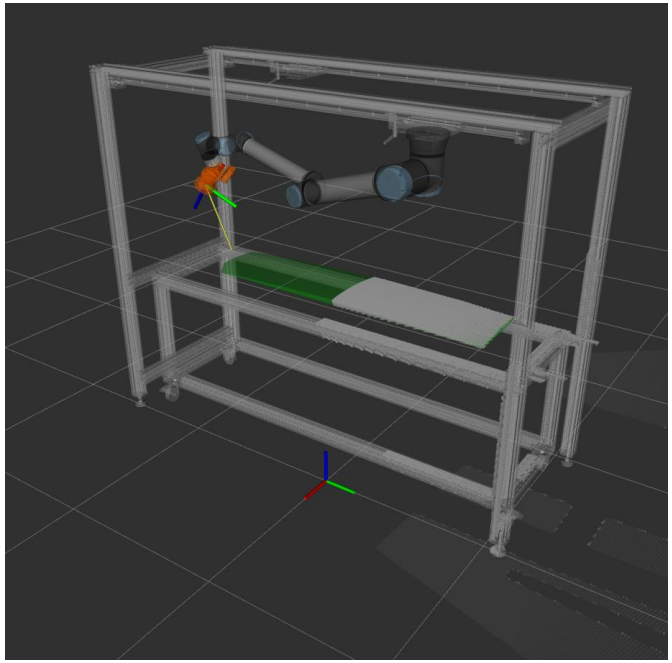
SwRI
SOUTHWEST RESEARCH INSTITUTE

Build out complete application

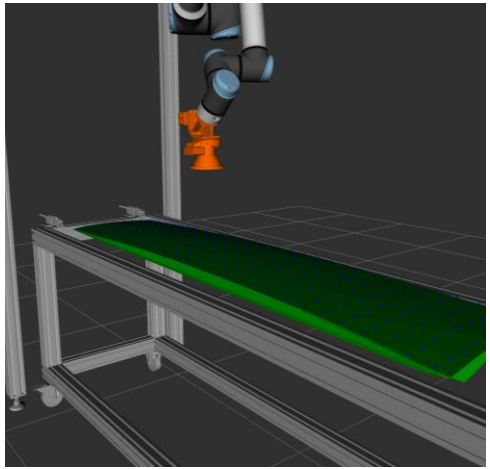
- Need at Spirit
  - Reduce cost, rapid deployment on the floor, able to work close to humans intuitively
- Leverage a deployment partner
- Leverage open-source software
- Make available code, modules, and examples to enable reuse

Full Functional Virtual Cell

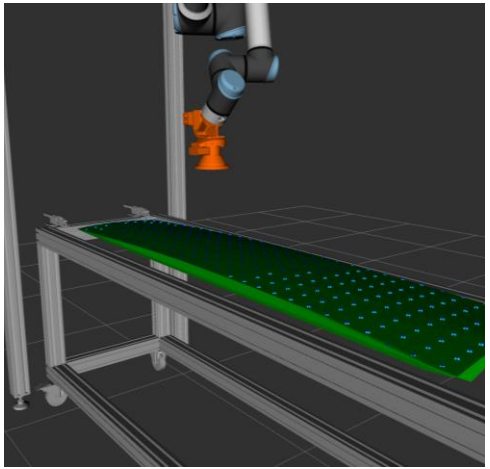
- Test localization
- Sensor simulation
- Reach analysis
- Robot base optimization
- Tool path and free motion planning



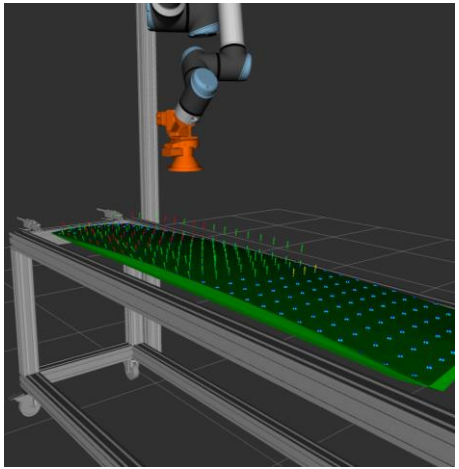
Interesting new capabilities



Dark Blue –
Loaded toolpaths



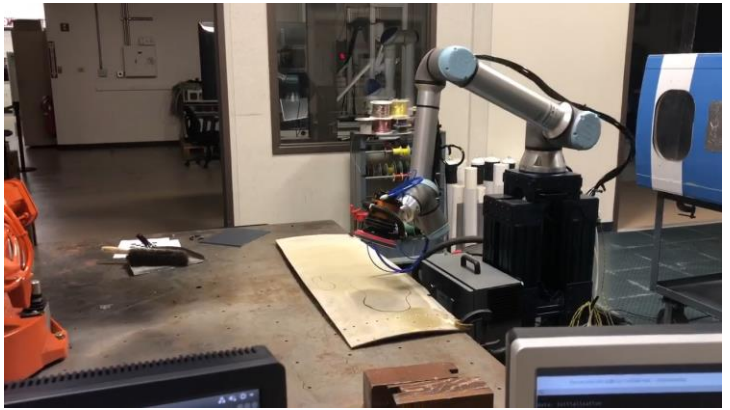
Light Blue –
Unreachable points

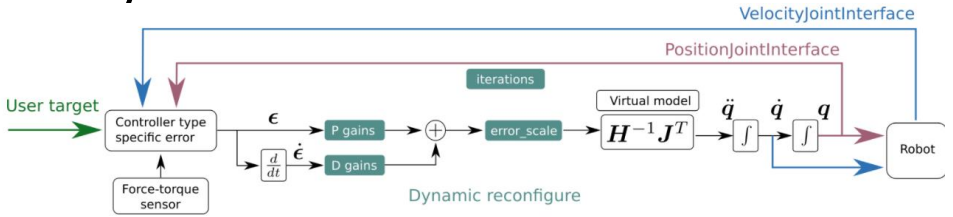


Green – Successfully planned
Yellow – Skipped due to length
Red – Failed collision checking

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

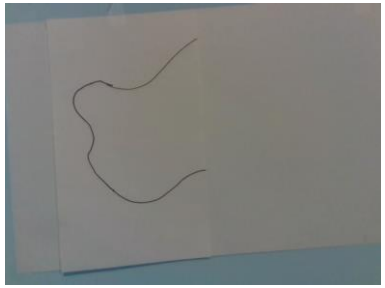


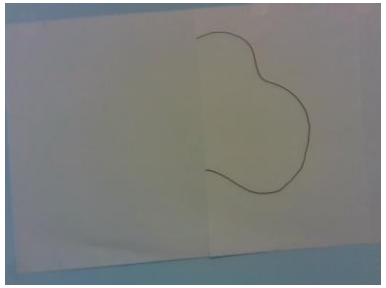


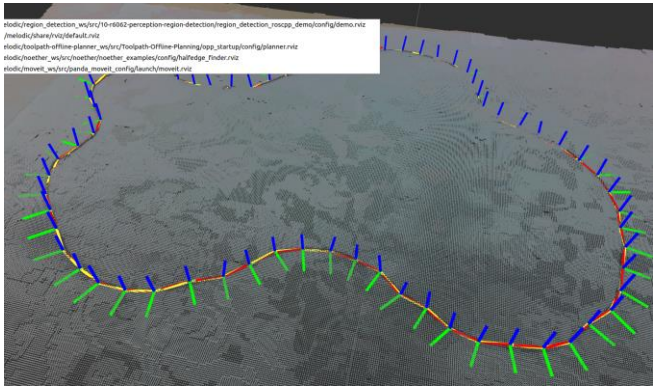
References: https://github.com/fzi-forschungszentrum-informatik/cartesian_controllers

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

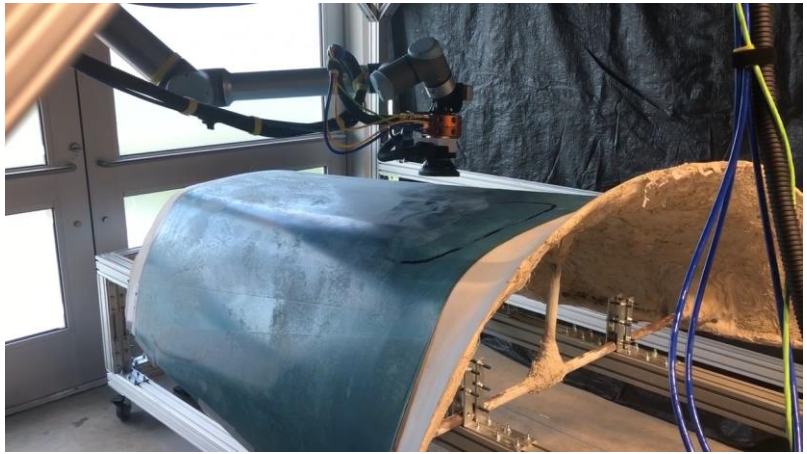






Integrated at NIAR

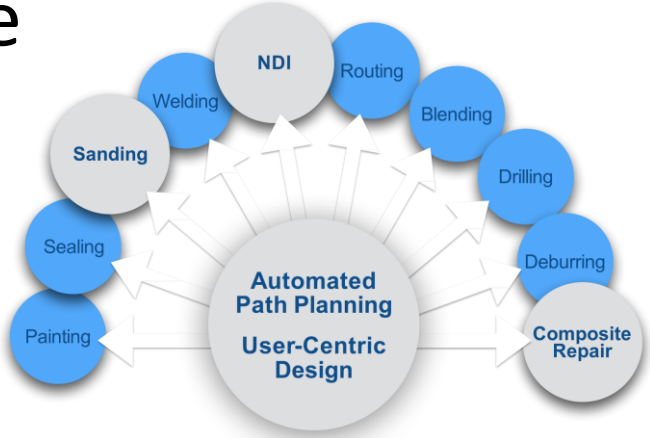
- Deploy on hardware at NIAR
- Integrate and verify software functionality
- Train NIAR and Spirit personnel on use
- Project demo slated for October 2020



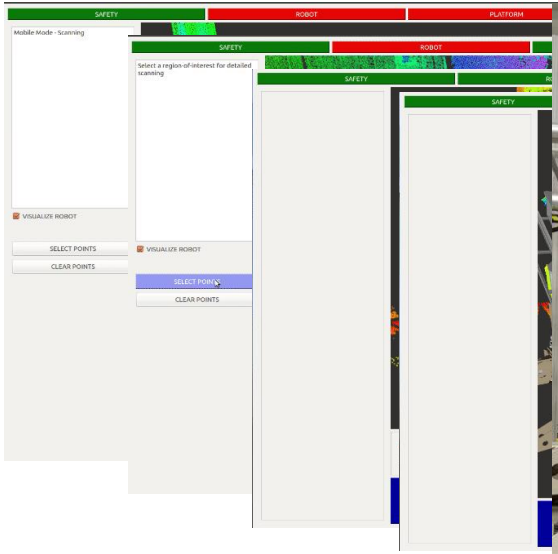
Repository: https://github.com/swri-robotics/collaborative-robotic-sanding

Enabling Agility – A5

- Interest in systems that are able to do new things quickly
- Leverage mobility
- Enable port of software to different hardware configurations



A5 in action


SAFETY
ROBOT
PLATFORM
Mobile-Mode - Scanning
VISUALIZE ROBOT
SELECT POINTS
CLEAR POINTS
Select a region-of-interest for detailed scanning


EXIT

Agile solutions in progress

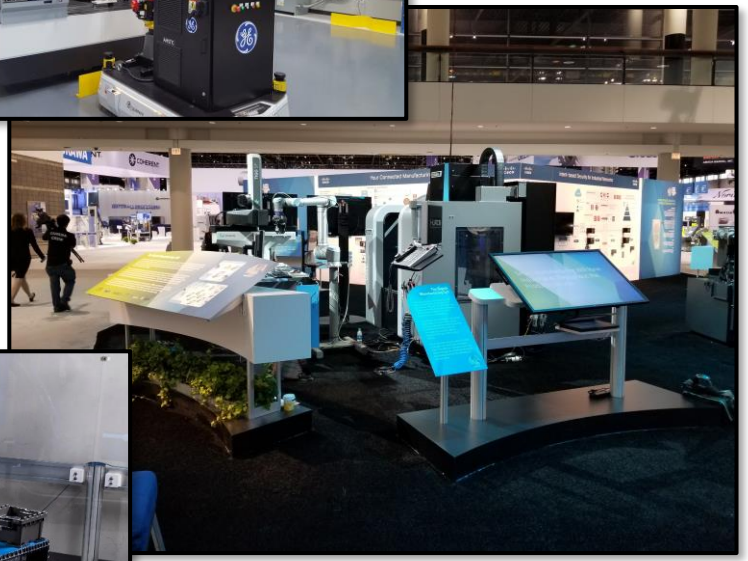
- A5 is in a phase 2 that will execute NDE on in-service aircraft
- Hardening in scope for live at service depots
- Active ARM Institute projects to “port” A5 to different configurations
- Open-source code leveraged by ROS-I members in their solution developments

Removing barriers on the floor

People and Machines Working Together

Enable Hardware to Work Together

Seamless Set Up and Production

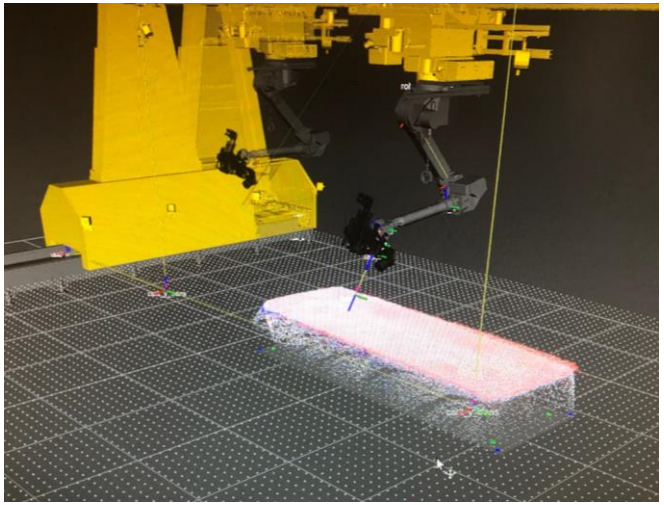


Repository: https://github.com/mtconnect/ros_mtconnect_2, https://arminstitute.org/projects/seamless-multi-robot-multi-mac-interoperability/

ria Robotic Industries Association | Robotics Week

Where we going with ROS & ROS-I?

- Grab and Go Capability
- Cross-Platform
- Assured Quality and Performance
- Non-expert Application Set Up
- Enable Solution Developer and End-User Value



GUI-Based Registration & Process Application

Take Aways

- ROS-based systems are delivering value on shop floors
- ROS2 is ready for use and offers advantage for industrial applications
- There are development partners to deploy advanced systems
- Leverage of reuseable blocks enables efficient deployment of future capability
- As a community we can have a resource to enable focus on what makes a difference for each end-user

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

Matthew M. Robinson
Program Manager ROS-Industrial Consortium Americas
Southwest Research Institute
San Antonio, TX 78248

210-522-5823

matt.Robinson@swri.org