AeroDef Manufacturing®

November 16-18, 2021
Long Beach Convention Center, CA

Development of an Agile Platform for Aerospace Applications Leveraging Open-Source Tools

ADVANCED AUTOMATION FOR AGILE AEROSPACE APPLICATIONS

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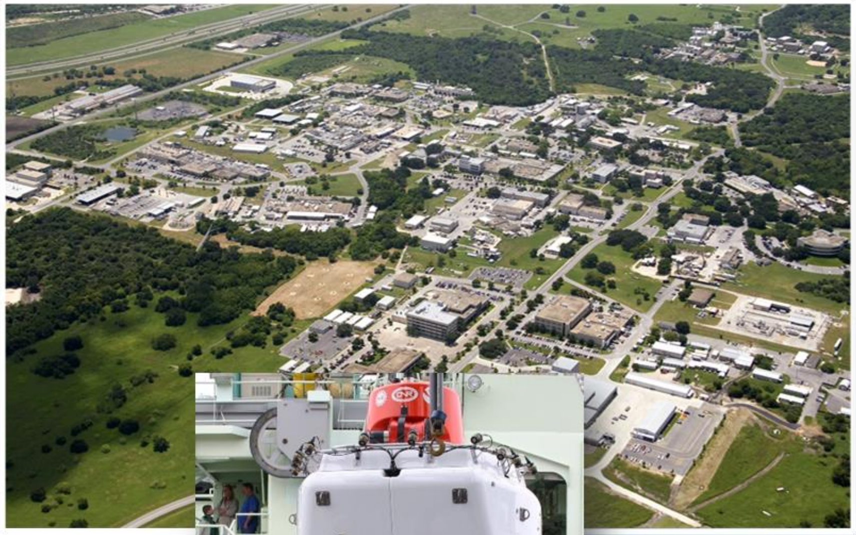
Matt Robinson

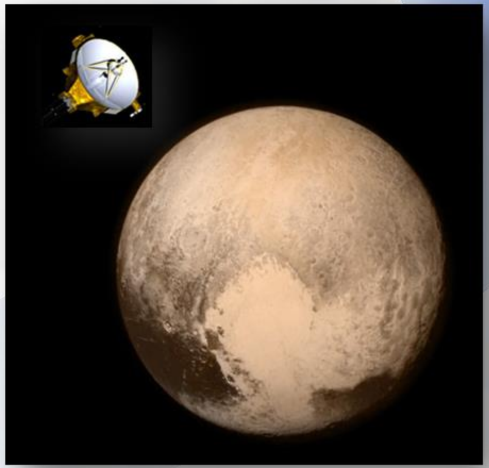
ROS industrial™

Overview

- SwRI Introduction
- SwRI Robotics & ROS-Industrial
- Approaches to Automation
- Scan and Plan
- Automation for Aerospace
- A5 Program
- Results and Challenges
- Future Work
- Relevance
- Questions

SwRI: Deep Sea to Deep Space





New Horizons, Pluto

Alvin submersible

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

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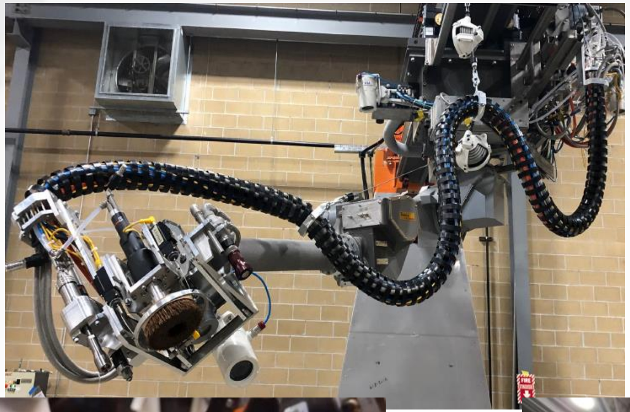
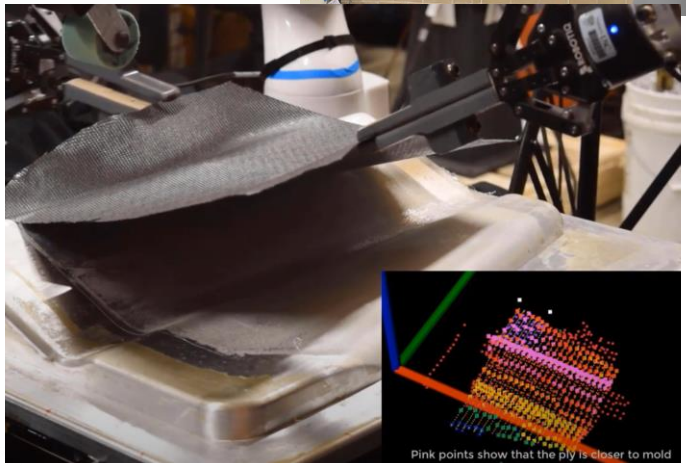
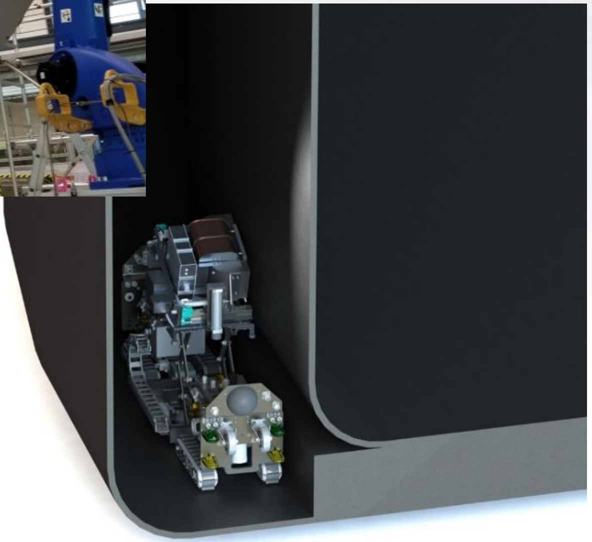
SwRI & Advanced Robotics in Manufacturing







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Featuring

COMPOSITES MANUFACTURING

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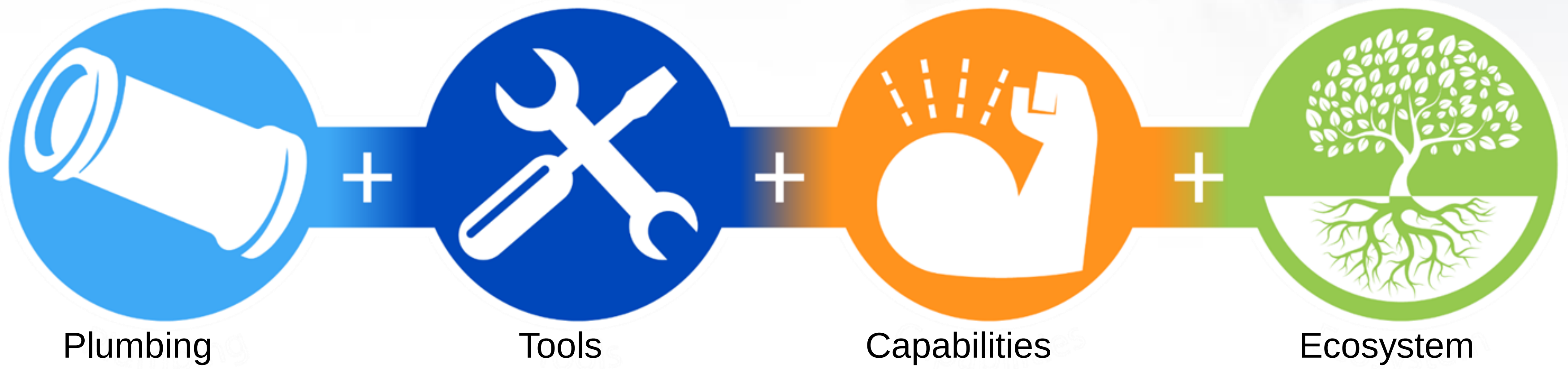
A Disruption in Software for Automation

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



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

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Technical Vision Supported by Industry

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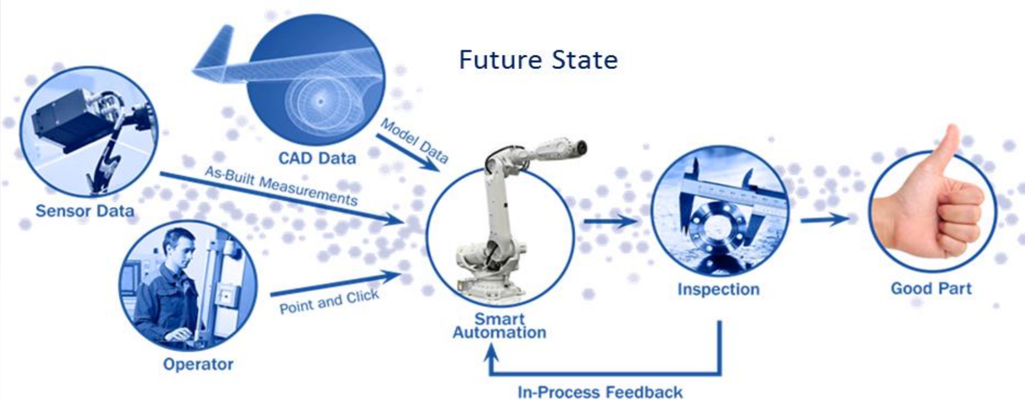
Automation for Aerospace

- Why?
  - Improved human safety
  - Improved quality for manufacturing processes
  - Improved productivity
  - Cost reduction
- Challenges
  - Large-scale components or assembled aircraft
  - Purpose-built automation is too expensive
  - High mix, low volume
  - Limited CAD and as-built model data

Continue to Evolve Automation



- Enables real-time adjustment to as-built condition
- Eliminates manual programming – operator just specifies tasks
- Enables process feedback and adaption via automated inspection
- “Smart” Automation

- Increased agility – able to do new things quickly
- Improved autonomy
- Intelligence that is adaptable
- Adjust in real-time to changing and/or perceived changes to the operational condition

A5 Program

Advanced Automation for Agile Aerospace Applications

- Advanced Automation for Agile Aerospace Applications
- Funded by Air Force Research Laboratory (AFRL)
- Team
  - National Center for Defense Manufacturing and Machining (prime)
  - Boeing
  - Southwest Research Institute
  - Robins AFB (end-user, technology champion)
- **Key goals**
  - **Take the automation to the part**
  - **No a-priori knowledge about the part or environment necessary**
  - **No need for expert robot programmers**
  - **Easily reconfigurable for new manufacturing processes**

NCDMM
NATIONAL CENTER FOR DEFENSE MANUFACTURING AND MACHINING

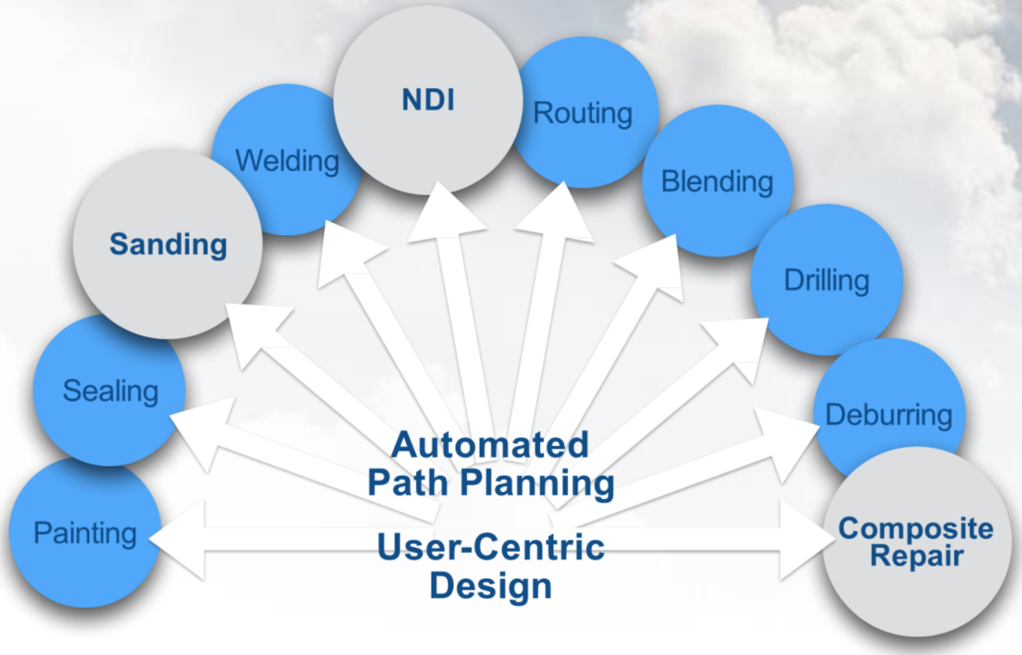
BOEING

SwRI

WARNER ROBINS ALC

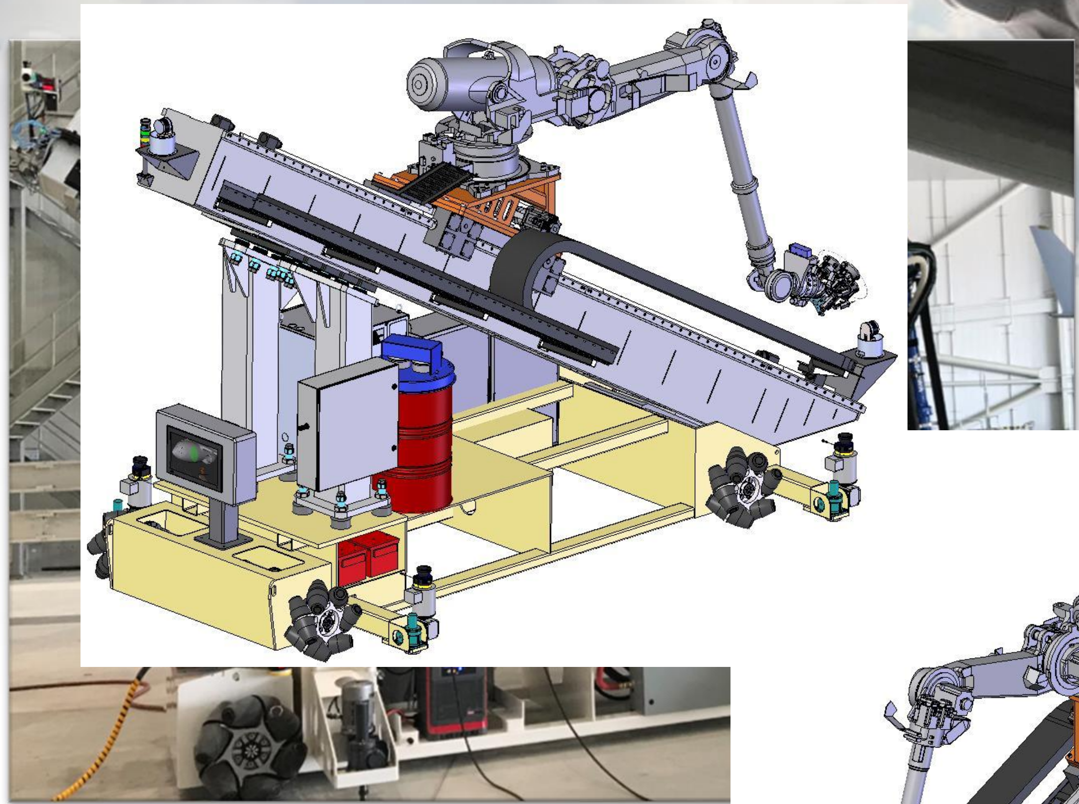
A5 Program

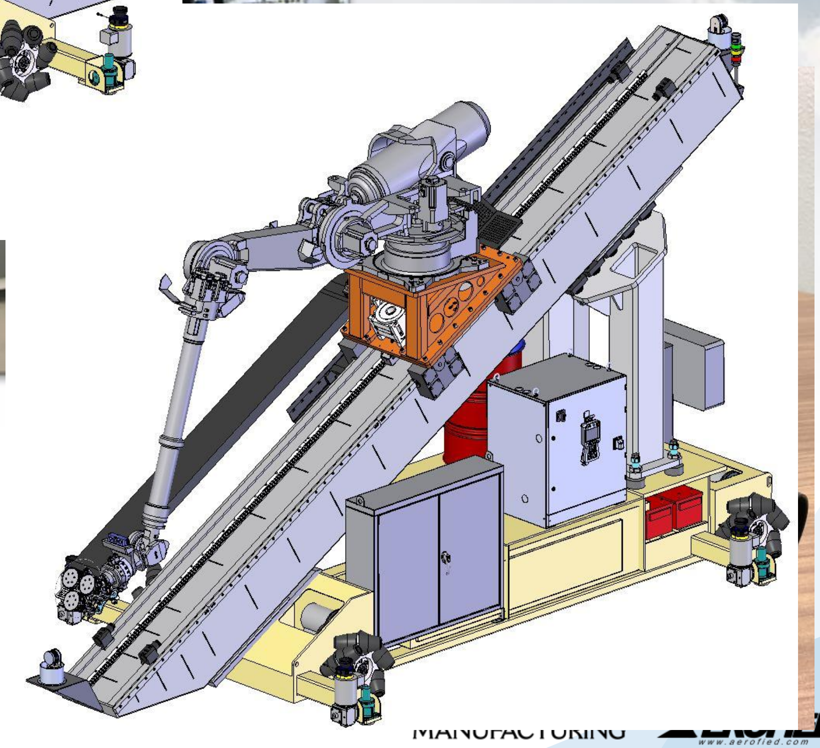
- Targeted towards aircraft sustainment
  - Platforms: C17, F15
- Tasks
  - Robotic system development
  - Development and demonstration of closed-loop sanding
  - Development of X-ray inspection and demonstration on in-service aircraft
  - Development and demonstration of third manufacturing process
  - Process improvement
  - Technology transfer to integrator



A5 Hardware

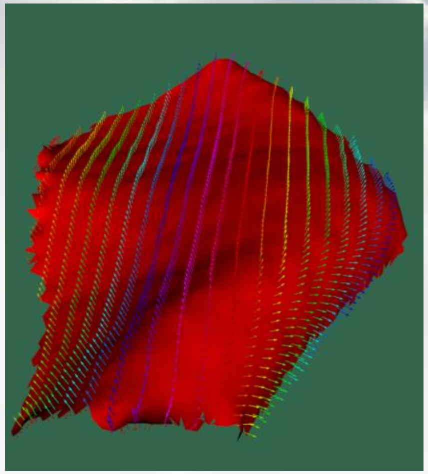
- Vetex mobile platform
  - Stability outriggers
- Yaskawa manipulator
  - 4m reach, 120kg payload
- Gudel rail
- 23’ (L) x 7.5’ (W) x 12.5’ (H)
- 22,500 lbs.
- Sensors
  - Wrist-mounted 3D sensor and color camera
  - Articulated LiDAR scanners with color cameras
  - Safety LiDAR scanners and bumper switches
- Operator HMI



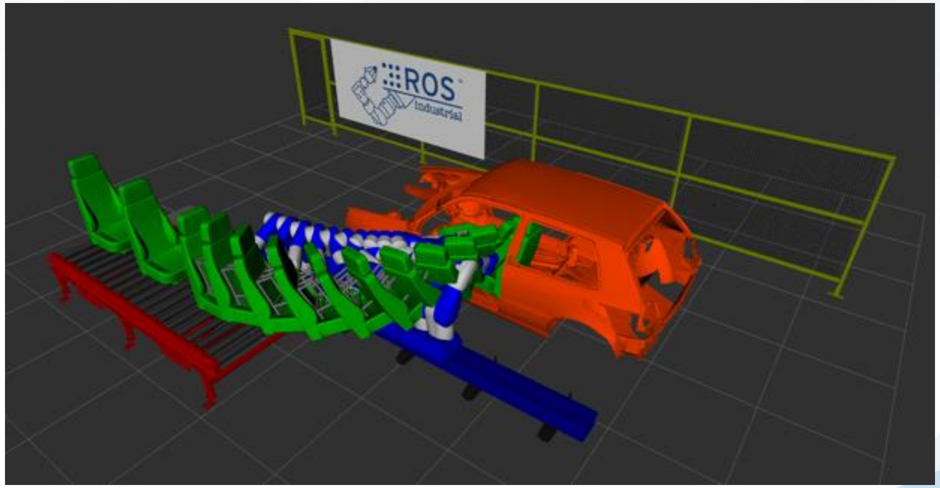


A5 Software

ROS industrial™

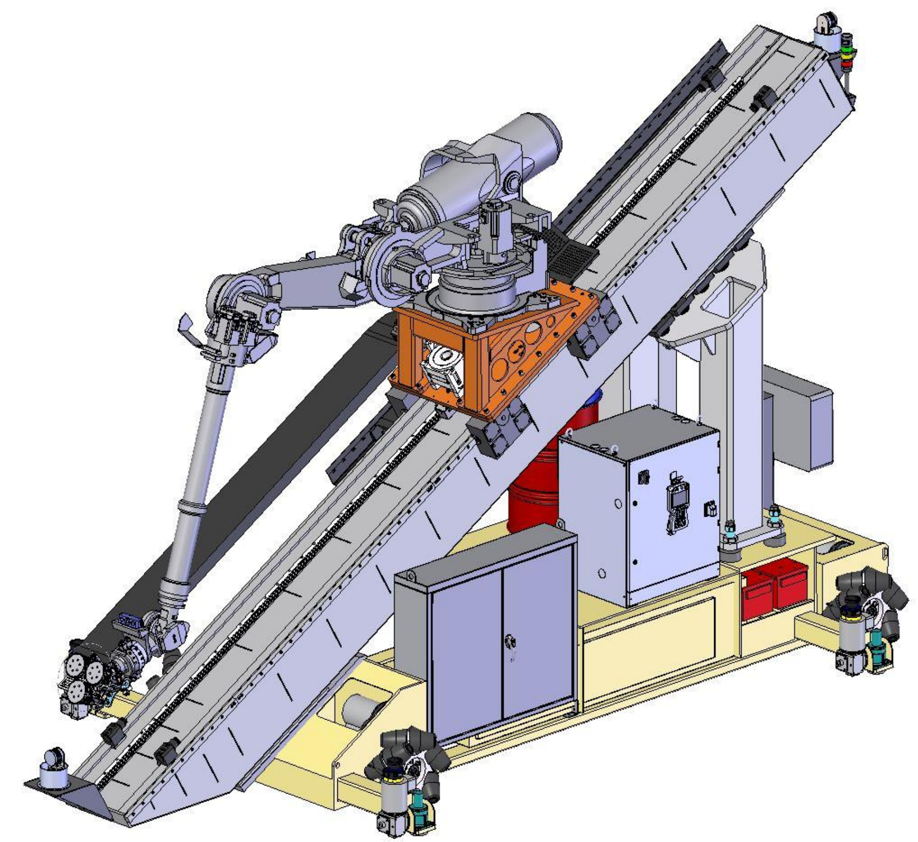


- Built on ROS
- Leverages many open-source tools
  - Surface reconstruction
  - Automated tool path planning
  - Automated collision-free motion planning
  - Communication to equipment, sensors, and robot
- Runs on a standard industrial PC
- Released as open-source*
  - https://github.com/orgs/a5-robotics
  - *Currently available only to ROS-Industrial Consortium members



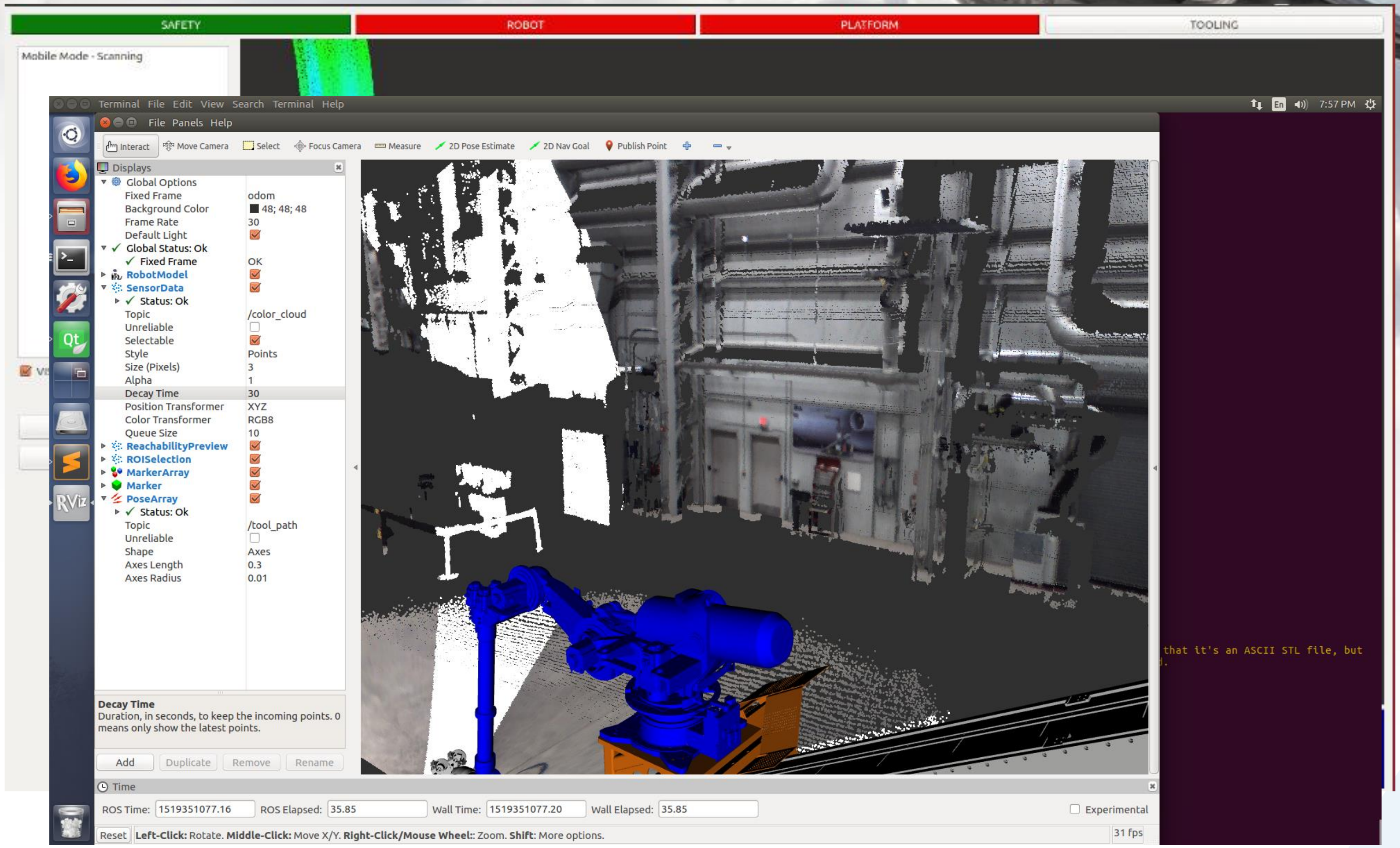
A5 System Operations

- Mobile Mode
- Scanning Mode
- Process Planning Mode
- Execution Mode



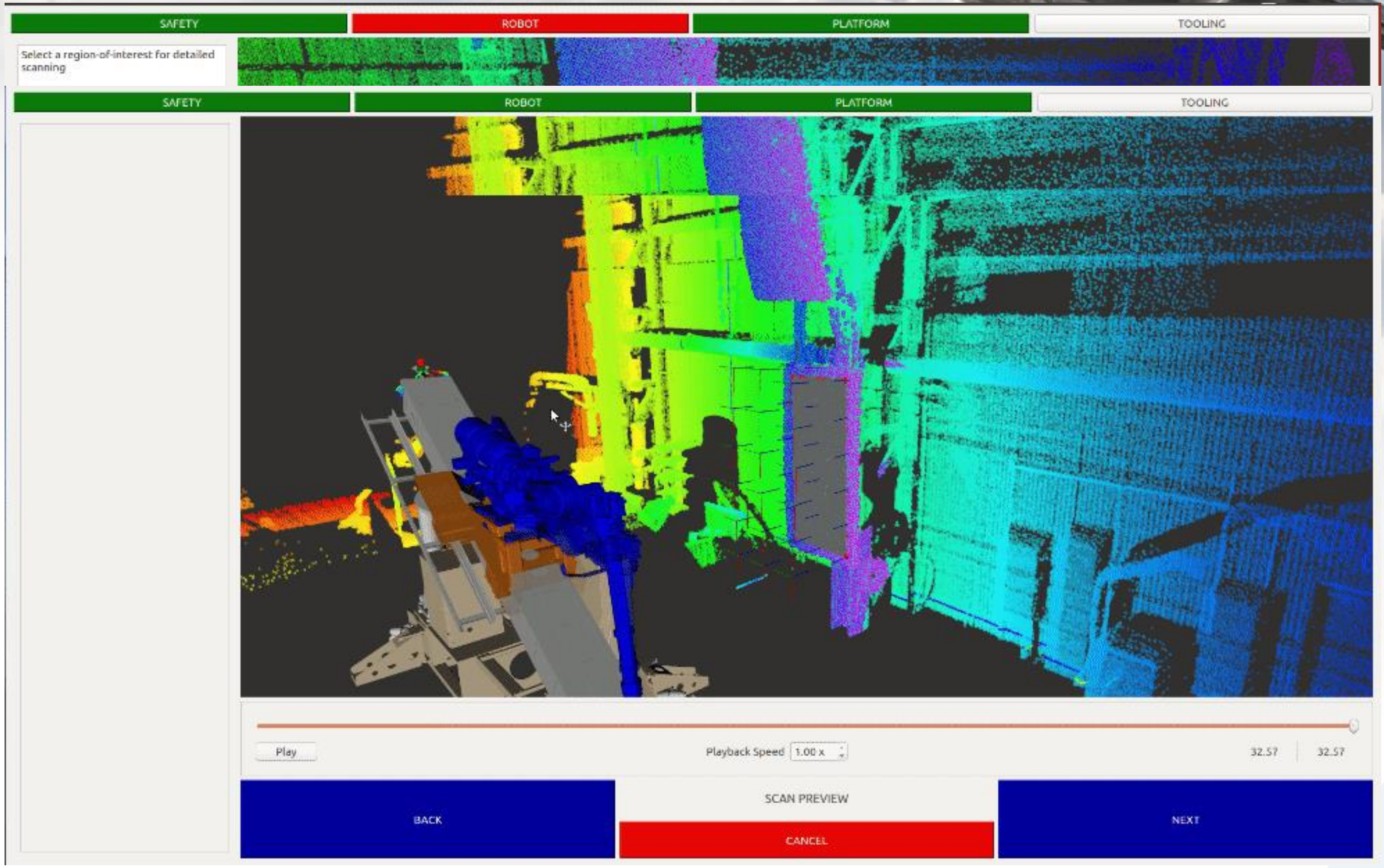
Mobile Mode

- Operator manually positions platform
- Visual reachability feedback from GUI
- Collection of coarse data for environment representation
- Colorized point cloud data
- Turn point cloud scan into collision object
- Extend outriggers for process stability



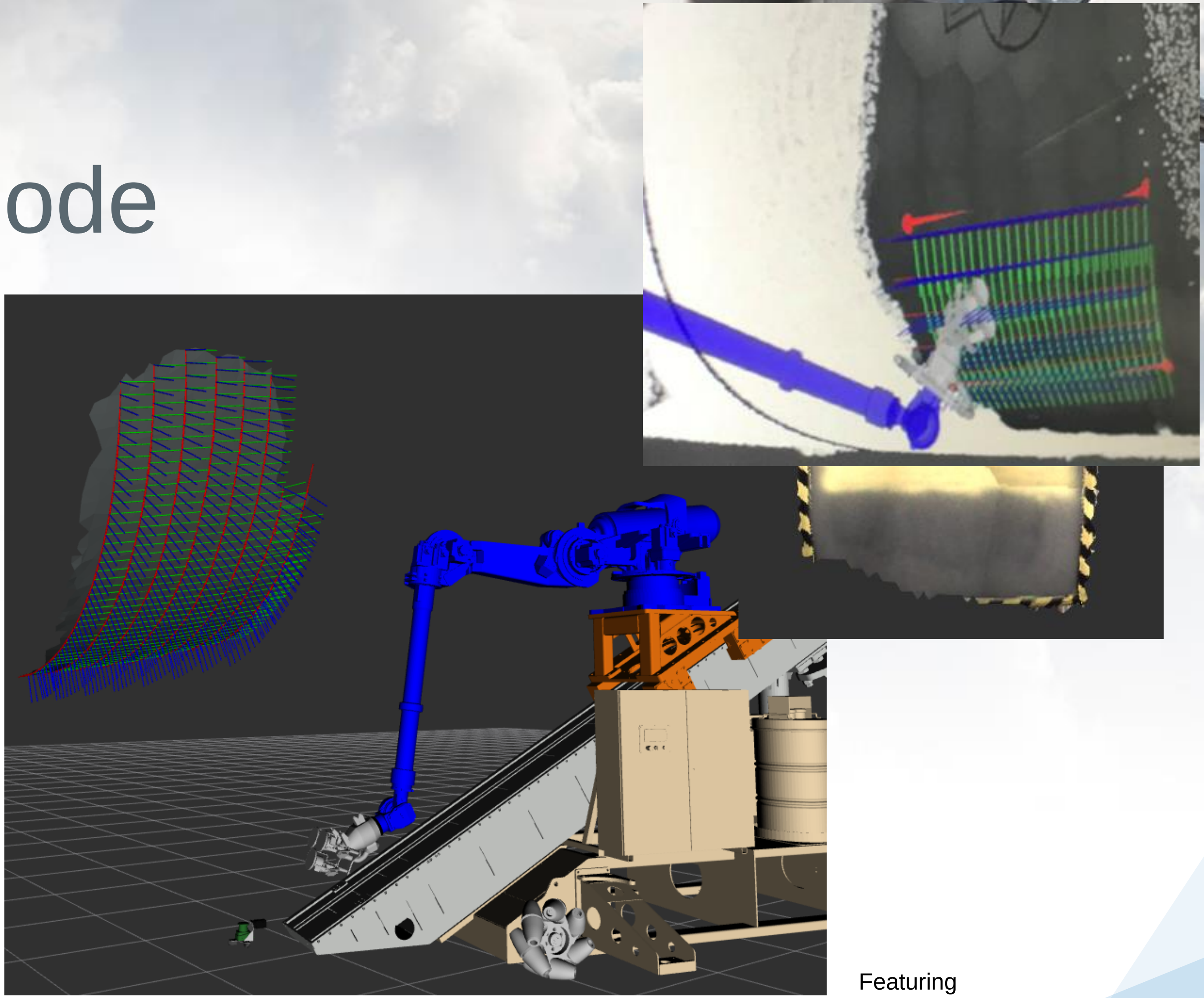
Scanning Mode

- Interactive robot instruction using GUI
- Surface reconstruction
- Automated tool path planning
- Automated motion planning
- Trajectory preview and operator approval
- Collection of higher accuracy data using wrist-mounted 3D sensor
- Surface reconstruction
- Collision environment update



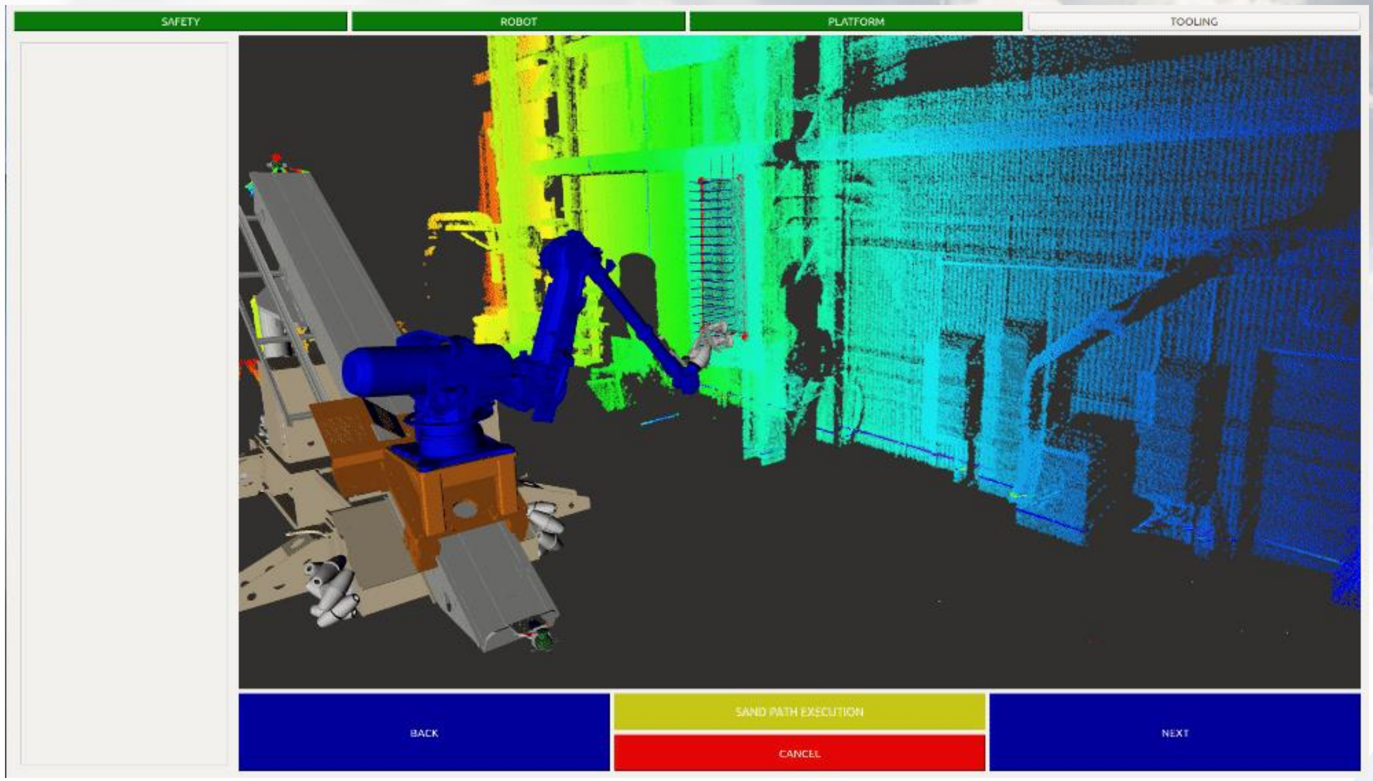
Process Planning Mode

- Interactive robot instruction
  - Colorized mesh
  - Selection cursor is tool model
- Operator specifies key process parameters
  - Feeds, speeds, offsets, pressure, force, etc.
- Automated tool path planning
- Automated motion planning
- Trajectory preview and operator approval

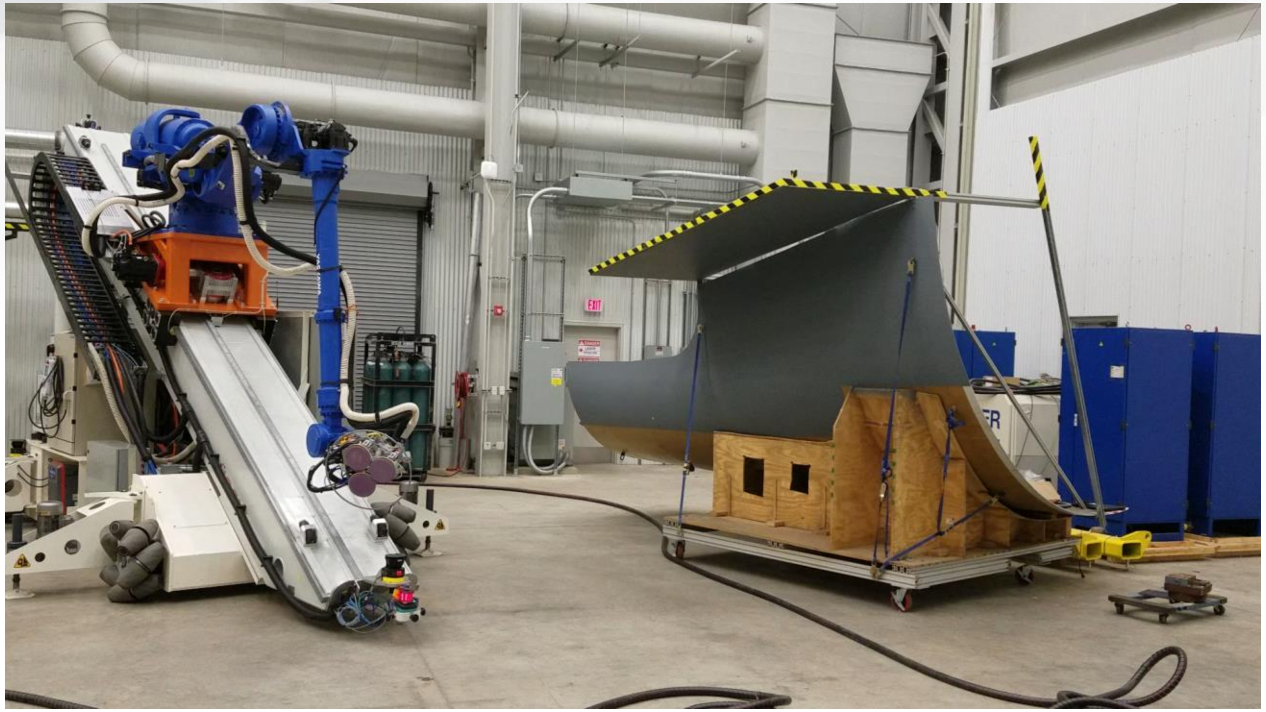


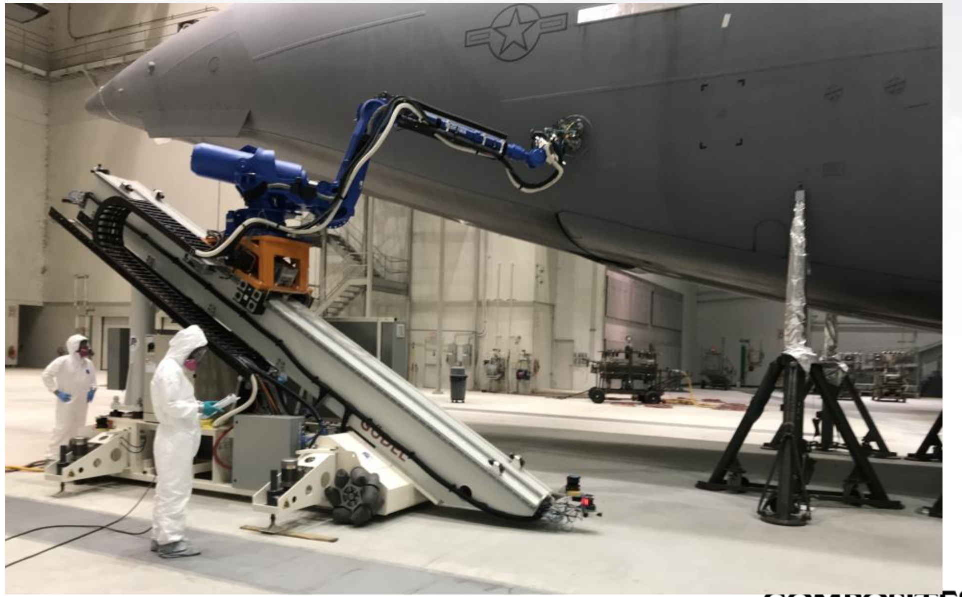
Execution Mode

- Robot performs specified process
- Collection of process data
- Communication with tool and auxiliary equipment
- Process feedback to operator



Results

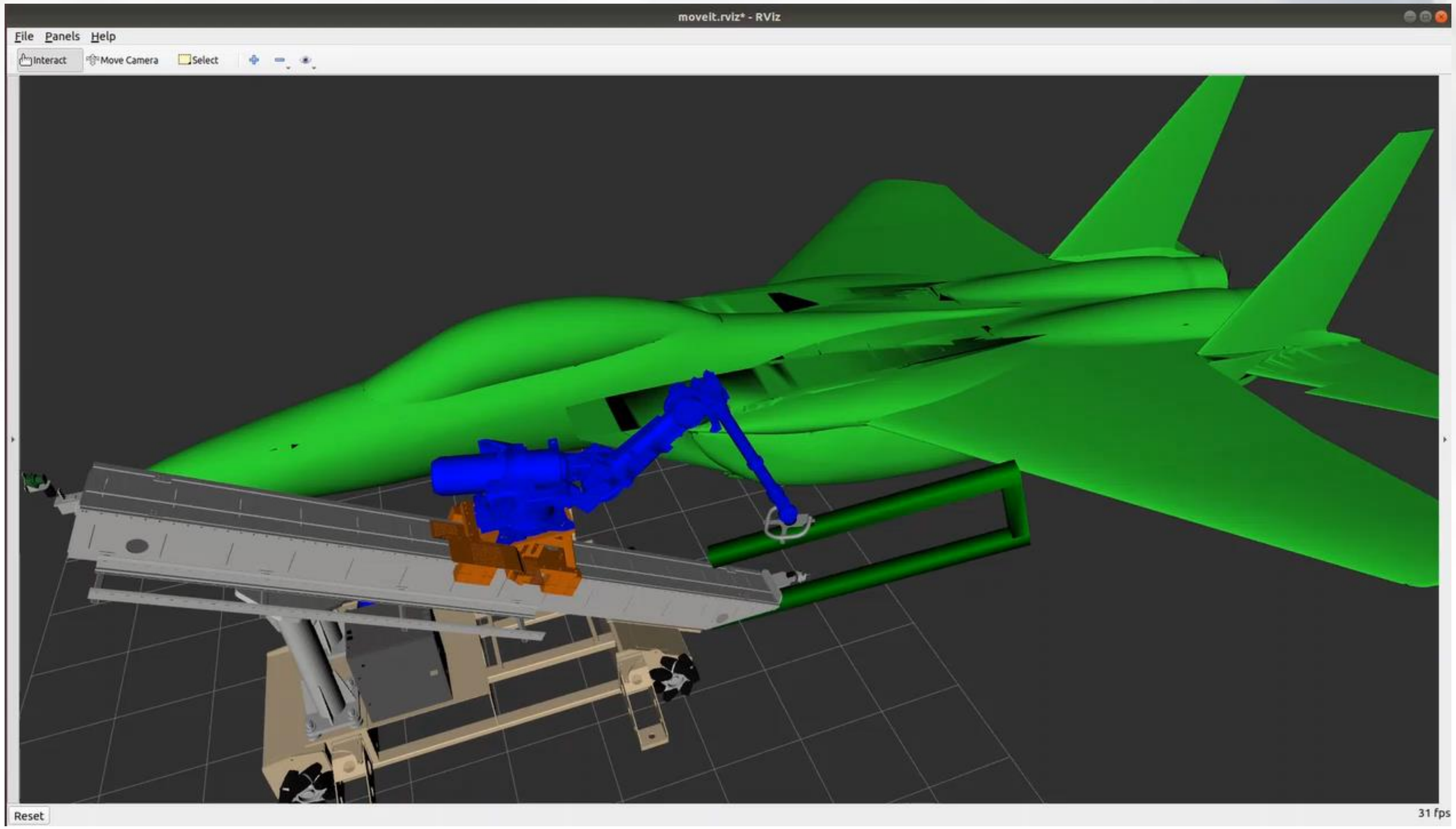




Results

- A5 Phase II (on-going)
  - X-ray NDI for F-15 inlet duct inspection
  - Updating to facilitate new process and workflow
  - Adding new capabilities
    - Constrained motion planning
    - CAD model alignment to sensor data
    - Support for new motion planners/frameworks

A5 – X Ray Inspection



Extensibility Results

- Leveraged A5 software as platform for paint applications
  - ARM Institute
    - https://arminstitute.org/project-highlight-mobile-autonomous-coating-application-for-aircraft-sustainment/
    - https://arminstitute.org/project-highlight-autonomous-coating-with-realtime-control-and-inspection/
- Demonstrated adaptability to new hardware
- Improved existing tools and developed new capabilities

Extensibility Results

Future Work

- Continue additional phases of A5 program
  - X-Ray NDI Physical Demonstration
  - Process Improvement & Solution Hardening
  - Technology transfer
- Leveraging A5 software framework for other applications
- Integration of new tools for surface reconstruction, tool path planning, and motion planning

Challenges

- Develop trust that the robot will behave “sanely” around valuable aircraft
- Surface reconstruction
- Operator Usability
- Wide-area sensor package calibration
- Cable management
- Production hardening
    - Overall processing time
    - Error logging/recovery

Conclusions

- Feasible agile automation strategy for aerospace applications
  - Take the automation to the part
  - No a-priori knowledge about the part or environment necessary
  - Can utilize CAD data
- No need for expert robot programmers
- Easily reconfigurable for new manufacturing processes
- Easily adaptable for different robot configurations
- Open-source software can be effectively leveraged for industrial applications

Questions?