



ANNUAL NEWSLETTER

2016 Year in Review



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Letter from RIC-Americas

Dear ROS-Industrial Consortium (RIC) Members,

As we mark the end of our fourth year on March 1st, I look back with gratitude for the support of our members and open-source contributors. In these four years we have grown from a bootstrapped special interest group of ROS users who were experimenting with the use of ROS for manufacturing, to a global network of Consortia with administrators in North America, Europe, and (recently) the Asia Pacific Regions. Our membership has grown to 48 members globally, with many more expected as all regions continue to expand. We started with a few repositories that provided drivers to connect common industrial robots with ROS, and now have more than 60 repositories that support capabilities including sensor drivers, heterogeneous sensor calibration, Cartesian path planning, integrated development environments, and Focused Technical Project (FTP) application code. In this, our Annual Newsletter, we will highlight the activities, accomplishments, current projects, and future projects of the Consortium.

Highlights:

We are honored by the continued collaboration with Fraunhofer IPA, Manager of the ROS-I Consortium Europe, and their scientific advisors at TU Delft. Growth in Europe continues to be strong; EU sponsored projects using and contributing to ROS-I continue to flourish, and a new ROS-I focused development program has been awarded (page 3).

The Advanced Remanufacturing Technology Center in Singapore is the latest addition to the Consortium family. With a strong showing at the ROS-I Asia Pacific Workshop in July, and recent launch of RIC-APAC, we are excited to see what the powerhouse Asia Pacific region will bring to ROS-I (page 4).

The Open Source Robotics Foundation, developers and curators of the ROS core, released the ROS 2.0 Beta messaging system in December 2016. We are hopeful that ROS 2.0 will usher in a new era of robust, reliable, and realtime ROS capabilities. Read about their accomplishments in the last 9 years, and their plans for ROS 2.0 on page 5.

The Consortium in North America continued to conduct ROS-I training classes, with one held in April 2016 and a second scheduled for February 2017. We've updated the curriculum to Kinetic for this class. Read more on page 6.

The recently contested Robotics in Manufacturing Environments (RIME) institute was awarded to a team of more than 200 collaborators led by Carnegie Mellon University. Learn more about the award and the benefits for ROS-Industrial on page 7.

Remember the Scan-N-Plan framework FTP that was discussed at the 2016 Consortium Annual Meeting? That is pretty much what will be created under funding from a recently awarded AFRL project that will result in Advanced Automation for Agile Aerospace Applications (A5). Read more about this ROS-I based project on page 8.

Team Delft swept the two Amazon Picking Challenge events in June 2016 with an entry running a combination of ROS-I and

custom deep learning software with Yaskawa Motoman hardware. Their achievements are a spectacular testament to the power of open source software enabling researchers to focus on the challenging problems by building on top of freely available code for "solved" problems of the past (page 9).

The Robotic Blending Milestone 4 Project is fully funded with plans to demonstrate blending of more complex surfaces and edges at the Automate 2017 show in Chicago the first week of April. Read more about this enduring ROS-I project on page 10.

Championed by 3M, the Consortium is also implementing an industry-standard state machine called PackML in ROS. We anticipate that it will become the default template for all ROS-I applications in the future (page 11).

Another take-away from the RIC-Americas meeting last year, was the need for better developer tools. The Consortium has answered this call with two new tools: QT Creator Plug-in for ROS, and CAD-to-ROS workspace setup tool (pages 12-13).

Finally, we invite you to collaborate with us on one of the upcoming Focused Technical projects this coming year. We've proposed three ideas based on industry input: Collaborative Robotic Nut Plate Installation Milestone 1, CAD-to-ROS Task 4; Sensor Configuration and Calibration Setup, and the Robot AI Training Kit (pages 14-15).

We are grateful to our project sponsors, which include:

- Airforce Research Lab ManTech: A5 Program
- EU Seventh Framework Programme:
 - Factory-in-a-Day, Grant 609206
 - SMERobotics, Grant 287787
- Fraunhofer IPA: RIC-EU Manager
- German Federal Ministry of Economics and Technology: ReApp, Grant 01MA13001A
- Google Summer of Code Projects:
 - ROS Interface for Impedance/Force Control
 - Workspace Analysis and Base Placement
- H2020-European Commission:
 - ROSIN, Grant no. 732287
 - ScalABLE 4.0, Grant no. 723658
- NSF/US Ignite: Industrial Cloud Robotics across Software Defined Networks, NSF Grant 1531065
- RIC-Americas FTP Sponsors: 3M, The Boeing Company, Caterpillar, and GKN Aerospace
- Singapore A*STAR Initiative: ROS-Industrial Consortium Asia Pacific
- Southwest Research Institute® (SwRI®): RIC-Americas Manager



Happy 2017!

A handwritten signature in black ink that reads "Paul Hvass".

Paul Hvass
RIC-Americas Program Manager
paul.hvass@swri.org

Image courtesy of SwRI

Letter from RIC-Europe

ROS-Industrial is faring well in Europe, with a Consortium now over two years old and counting more than 20 organizations among its ranks. It has been very gratifying for me to nurture this growth by acting as an ambassador of open source for manufacturing and automation, and I am happy to report on a fast-improving perception toward it also outside its traditional realm of research and service robotics. This is happening thanks to an ever-increasing number of industrial application examples highlighting its potential, such as those demonstrated at the excellent RIC-NA members meeting that I had the pleasure to attend last March at Southwest Research Institute. It is possibly also due to dissemination work informing our audience on how to address non-technical aspects of open source, such as licensing and compliance processes, safety regulations and its business potential. I was glad to collaborate with experts in these fields and have them interact with our Consortium and Community members at multiple events during 2016. Specifically, in April 2016 we hosted a two-day workshop at Fraunhofer IPA targeted on these matters and titled Open-Source Software in Robotics and Automation: Best Practices and Legal Aspects. The event, of which you can find coverage on rosindustrial.org, covered regulatory and legal aspects to take into account in terms of safety standards, licensing and compliance processes. The feedback from attendees was extremely good, so we covered these themes again during the 2016 edition of the ROS-Industrial Conference, hosted also at IPA in November, which further expanded on them alongside more technically focused topics. The Conference was hosted during a three-day event which included a training session in collaboration with FH Aachen and RIC-EU members PPM AS and IT+Robotics srl, gathering a combined total of more than 60 attendees.

Speaking of events, I am now preparing, together with our RIC-EU partner and scientific advisor TU Delft, a significant ROS-Industrial presence at the next edition of RoboBusiness Europe (The Hague, the Netherlands, April 19-21, 2017). Attendees will enjoy ROS-I themed talks and demos at the exhibit showcasing the value of open source in industrial automation.

I am happy to report that two flagship research projects heavily leveraging ROS-Industrial are nearing completion, with Factory in a Day (www.factory-in-a-day.eu) now in its fourth and final year, and ReApp (www.reapp-projekt.de/) in its final months. I would like to thank the EU Commission and the German Federal Ministry for Economic Affairs and Energy for funding the projects, which are in the process of contributing further open-source software to the community. I am also glad to announce the start in 2017 of two new four-year publicly funded projects for the improvement and further development of the ROS-Industrial infrastructure and for its application to real factory-floor use cases. More information will be available soon at rosindustrial.org.

Let me finally rejoice with you on the expansion of the ROS-Industrial initiative in the Asia-Pacific region, thanks to excellent collaboration between RIC-NA, RIC-EU and especially our new partners at the Singapore-based Advanced Remanufacturing and Technology Centre - A*Star and Nanyang Technological University, which hosted a very successful ROS-Industrial workshop in July 2016.

I look forward to a year full of activities for our now-worldwide initiative!



Regards,
Dr. Mirko Bordignon
ROS-Industrial Europe
Consortium Manager,
Fraunhofer IPA



Brian Gerkey's keynote, kicking off the 2016 ROS-Industrial conference.

Mirko Bordignon introducing the audience to the Best Practices and Legal Aspects workshop, held in Stuttgart in April 2016.



Attendees to the 2016 edition of the ROS-Industrial training, held in Stuttgart together with the Conference in November 2016.

Kickstarting ROS-Industrial for the Asia Pacific Region

Dear ROS-Industrial Consortium America Members, In July last year, the successful first ROS-Industrial Asia Pacific workshop in Singapore welcomed key international guests such as Brian Gerkey (OSRF), Morgan Quigley (OSRF), Paul Hvas (SwRI, RIC-NA), Mirko Bordinon (Fraunhofer IPA) and an overwhelming 130 attendees visiting ARTC in Singapore. This attracted many local and regional attendees, MNCs, LLEs and SMEs. The workshop comprised demonstrations at ARTC and NTUC along with presentations from international and local speakers

During the above event, an MOU was signed between SwRI, Advanced Remanufacturing and Technology Centre (ARTC) of A*STAR and the School of Mechanical and Aerospace Engineering of Nanyang Technological University (NTU).

We supported the exhibition booth hosted by SwRI in ROSCON, Seoul, Korea, where for the first time a global ROS-Industrial Consortium was represented. This presence at ROSCON supports the ROS-Industrial efforts with the aim to network with parties in the Asia Pacific Regions. The attendees came to the booth to discuss ROS-I roadmap, development work, job opportunities and of course what's happening with ROS-I Asia Pacific.

In early January this year, the first Global ROS-Industrial Community Meeting started the momentum for 2017. To read or view the video to learn more about the inspiring presentations, please visit the blog post [1].

Another ROS-Industrial Asia Pacific Workshop before ICRA 2017 is tentatively set for 25th and 26th May. Another key exciting item expected to come to Asia Pacific and hosted by ROS-I Asia Pacific is ROS-I training which is a hot topic for the region at the moment.

We are currently leading the PackML collaboration project with 3M, SwRI and PlusOne Robotics toward a common goal, which is to be able to use ROS as a state machine interacting with PACKML. Read about this exciting project on Page 11.

We look forward to 2017 as an exciting year ahead comprising events and workshops showcasing via demonstrations the advantages of using ROS-I as an enabler toward solving the software gap to support industrial automation.

We hope to see you all in Singapore in late May!



Min Ling Chan
Senior Project Manager,
Robotics Development
Advanced Remanufacturing and
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Nicholas Yeo
Technical Director
Advanced Remanufacturing
and Technology Centre (ARTC),
A*STAR

<http://rosindustrial.org/news/2017/1/1/first-global-ros-i-community-web-meeting>

Letter from Tully Foote, OSRF

This year marks the occasion of ROS turning 9 years old [2]! Through these years ROS has grown into a strong worldwide community. It's a community with a large variety of interests: from academic researchers to robotic product developers as well as the many robot users. Academic use of ROS continues to grow. Citations of the first ROS paper "ROS: An Open-Source Robot Operating System" have grown to 2,871.

To get a better sense of what's happening in the ROS community, if you have not already done so, I highly recommend reviewing the ROSCon 2016 program. You can also find all the video recordings in this gallery. ROSCon 2016 was another great event bringing ROS community members together to share how they're using ROS to solve their challenges. As the goal of ROSCon is to share information between the entire community we record the talks and make them available online. We've sold out our venues the last two years and are looking forward to another ROSCon next fall!

Part of understanding our growing community is to try to measure it. For the last 6 years we've been generating metrics reports. These reports can give a sense of aggregate what's happening in the ROS community. Our most recent report is from July 2016. David Lu has put together plots of several of the metrics across the last 6 years which can be quite informative.

This year we wanted to dig a little deeper into the code metrics, so we downloaded the source of all packages listed in the Indigo Igloo rosdistro and ran some analysis.

- The total line count is over 14 million lines of code
- There have been 2,477 authors
- And 181,509 commits
- Averaging 73.3 commits per author
- Git commits record 24 different time zones (out of 39 possible).

Analyzing the repository for significant lines of code using SLOCCCount shows:

- 4,077,199 significant lines of code.

- This represents an estimated 1,236 person-years of development.
- For a sense of scale, that is an average of 137 developers contributing full time over the last 9 years!

This only represents the packages publicly released into the Indigo rosdistro index.

Note that the tools only worked on Git repos so code from other source control systems was excluded. There are also a few projects which predate ROS but have ported to use ROS and their history is included.

We're looking forward to continuing growth through 2017 leading up to the 10-year anniversary of ROS. With the Beta 1 version of ROS 2.0 out, there will be space for new development. We're looking forward to our next release, Lunar Loggerhead, to coincide with Ubuntu's next release, Zesty Zapus. With both of these, the ROS community can continue to rely on the many libraries, tools, and capabilities they have come to know and enjoy, as well as begin to experiment with the new features in ROS 2.0 [3].

We write these anniversary posts to help give you a sense of how ROS has been doing over the past year, but we'd certainly encourage you to find out for yourself. Get involved. Write or edit a wiki page. Answer a question on ROS Answers. Come to ROSCon. And, when you're ready, think about helping to maintain ROS itself, or even contributing a brand new ROS package.

OSRF is doing great, but the long-term success of ROS depends on every member of the incredibly awesome ROS community. If you're already an active part of the ROS community, we can't thank you enough; and if you're not, think about how you can help ROS grow and thrive for the next nine years, and beyond.

Tully Foote
ROS Platform Manager,
Open Source Robotics Foundation



Every year, we're impressed and humbled by the enthusiastic support we get from the ROS community. This year was certainly no exception. After ROSCon 2015 sold out weeks in advance, we knew we had to find an even larger venue for this year's conference in Korea. The Conrad Hotel in Seoul turned out to be not quite big enough, however, as ROSCon 2016 sold out anyway. We hosted more than 450 attendees (a 20% increase over last year), 44% of whom came from the Asia Pacific region. This level of engagement is one of the reasons we decided to host ROSCon in Korea in the first place, and Asia as a whole is a big part of why ROS package downloads are up by 150% over the last year.

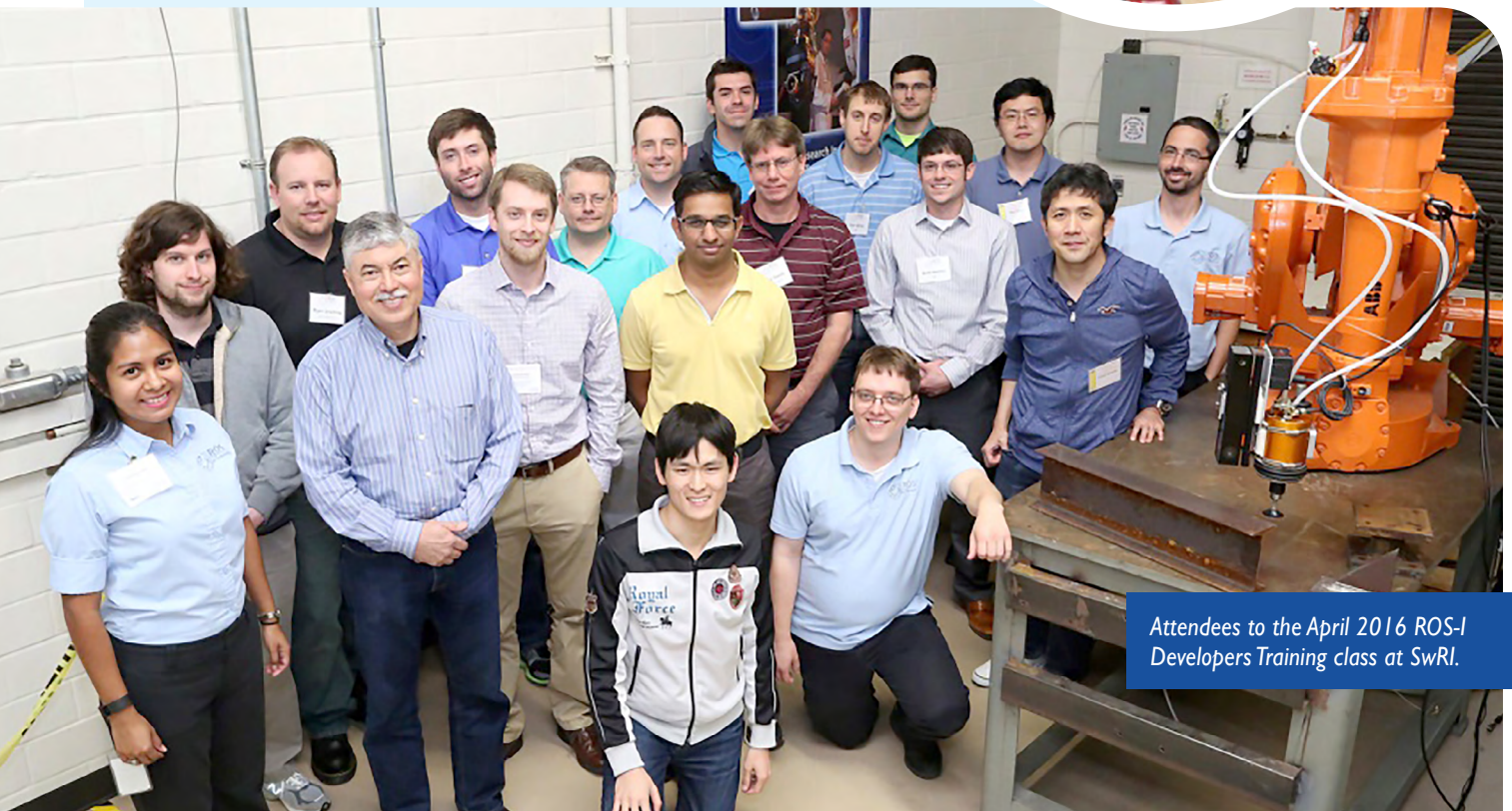
ROS-I Training Classes

Spring ROS-Industrial Basic Developers Training classes gave participants an opportunity to learn new skills through hands-on training. The ROS-Industrial Developers' Training Class was held April 6–8, 2016 at SwRI, in San Antonio, Texas, where the ROS-I Consortium Americas is based.

On April 6 the class reviewed ROS packages, parameters, topics, messages, launch files and URDFs. The first day ended with a tour of SwRI labs and campus where the participants were able to see several ROS applications as well as get a better idea of Southwest Research Institute facilities. The rest of training took developers through foundational robot manipulation (with an introduction to Descartes and other path planners) and perception with a multi-option lab day. Participants from 3M, ABB, Bastian, IDEXX, John Deere, JR Automation, Smart Robotics (Japan) and one student from the Make School attended. Check out the pictures.

Many thanks to Jonathan Meyer, Levi Armstrong, Shaun Edwards, and Christina Gomez from SwRI for this year's training.

In February 2017, SwRI is hosting a training class that will roll out the newest ROS Kinetic training curriculum. In addition to the version upgrades, the course has been refactored around a perception-driven manipulation project, so each lesson builds on skills learned in previous lessons. There is also new advanced training material (Session 5) that was added with sponsorship from The Boeing Company, which addresses topics including `roscod_lite` annotation, unit testing, `rqt` tools, `ros_lint`, and an introduction to STOMP motion planning.



Attendees to the April 2016 ROS-I Developers Training class at SwRI.

ROS-I and the New ARM Institute

In January 2017, the US Department of Defense awarded the 14th Manufacturing Innovation Institute (MII), which will focus on collaborative robotics, to the Advanced Robotics Manufacturing (ARM) team led by Carnegie Mellon University (CMU). As the Consortium Administrator, SwRI was among the 220-organization coalition supporting the new institute. Our congratulations to the ARM team!

The institute will be funded through a combination of \$80M federal dollars from OSD and \$173M matching local, state, and industry dollars over the next five years. Below, you will find a summary of the goals for RIME from proposer's day invitation website [4]:

"The motivation for the RIME-MII is to increase U.S. competitiveness in robotics applied primarily in manufacturing environments by 1.) encouraging the development and scale up for commercialization of critical enabling technologies such as human-robot/robot-robot collaboration; perception and sensing; robotic control: adaptation, learning, and repurposing; autonomy and mobility and, dexterous manipulation; 2.) establishing common standards and testing protocols allowing the integration of multiple robotics technologies; 3.) creating a robotic technology solution repository (to include modeling tools, databases, catalogue of technology demonstrations and concept sharing mechanisms); and 4.) providing workforce training and education programs to ensure the U.S. workforce can effectively collaborate with robots in a broad spectrum of manufacturing environments."

It is easy to observe that the objectives of RIME-MII align well with the goals and vision of ROS-Industrial software project and its supporting consortium, which include:

- Supporting advanced robotics capabilities for manufacturing
- Standardizing interfaces for cross-platform compatibility
- Modularizing and scaling components to larger systems
- Enabling a collaborative development environment
- Developing the workforce through training curriculum and hands-on classes
- Transferring technology via open-source license
- Providing affordability for small and medium enterprises

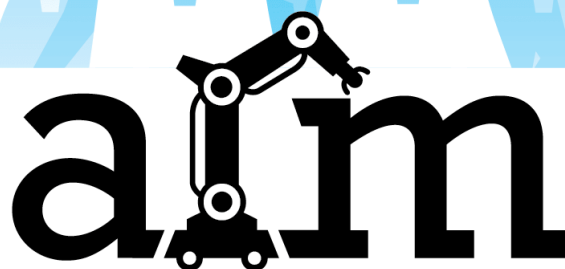
We are pleased to report that each of the competing teams sought to leverage ROS-Industrial as a conduit for open-source software development.

The relationship between the ROS-I Consortium and ARM Institute is still only roughly determined, and the members will need to ratify the detailed terms. We believe that the ROS-Industrial project stands to greatly benefit from the involvement of the broad manufacturing industry participating in the RIME MII.

The Consortium is grateful for the membership and participation of TARDEC. Dr. Greg Hudas (TARDEC), the government project manager for RIME, has expressed this: "ROS-I is vitally important to the success of the ARM Institute, and we look forward to its potential integration into ARM projects that leverage open-source software for advanced manufacturing."

We are excited to join the ROS-Industrial community. ARM and its many partners, both in industry and academia, share the view of open-source software development being the most effective strategy for distributed collaboration. We look forward to working together with the ROS-Industrial community to manage, promote, and maintain the open-source technology generated from ARM projects.

Howie Choset,
CTO, ARM
Professor, Robotics Institute at
Carnegie Mellon University



Advanced Robotics Manufacturing Institute

⁴ <https://www.dodmantech.com/Institutes/Robotics-MII>

A5 Project Award

A team from National Center for Defense Manufacturing and Machining (NCDMM), The Boeing Company, and Southwest Research Institute (SwRI) was awarded a contract to help the U.S. Air Force develop software and technology to make advanced robotics reusable for a variety of aerospace manufacturing and maintenance processes.

NCDMM will manage the four-year program. Boeing will provide process development and tooling expertise. SwRI will develop software using the open-source Robot Operating System Industrial (ROS-I) platform and will integrate all the subsystems on a large mobile manipulator robotic platform.

The Air Force Research Laboratory (AFRL) challenged the team to develop and demonstrate a mobile multi-process robotic solution through the Advanced Automation for Agile Aerospace Applications (A5) program.

“One of our primary goals is to promote the adaptability and flexibility of robotic systems,” said Rick Meyers, program manager in Automation and Robotics at the Air Force Research Laboratory Materials and Manufacturing Directorate. “This team will help to develop technology that enables the same system to be used in many different applications – including manufacturing and sustainment operations.”

Added Paul Hvass, a program manager in SwRI’s Manufacturing Technologies Department, “We want to make it easier to use a piece of machinery to transition from one manufacturing or maintenance task to another quickly and cost efficiently, without needing engineering or programming rework between tasks.”

“We are excited to move forward with this program,” said Jim Fisher, director of operations at NCDMM. “The Air Force has put forth an ambitious and compelling challenge, and the NCDMM, along with our project partners, anticipates successful demonstration of capabilities that meet or exceed the AFRL expectations.”

Boeing’s technology center in South Carolina will provide equipment focused on agile automation development including mobile robotic platforms, robotic manipulators, machine shop, and production aircraft materials for development and testing.

“Many operations in aerospace production and sustainment are good candidates for automation to increase safety, productivity, and quality,” said Max Amin-Javaheri, a director for Boeing Research and Technology’s Advanced Production and Inspection group. “A5 will expand opportunities for lower rate production environments and sustainment operations – areas that are typically very challenging to economically automate.”

Traditional manufacturing automation tends to rely on purpose-built machines, typically dedicated to a specific aircraft or component. Those machines demand large initial capital outlays and significant operating expenses; adaptation is costly and innovation is slow.

The A5 program aims to upend that paradigm using ROS-Industrial to develop flexible technology that can be used across different manufacturing processes and environments. Phase I will develop adaptive robotic capabilities in aircraft sanding, Phase II will apply those capabilities to composite aircraft repair, and Phase III will develop nondestructive capabilities using the same mobile platform.

“Using ROS-Industrial, we can dramatically reduce the amount of manual programming and intervention needed to implement advanced automation,” Hvass said.

As the primary framework, ROS-Industrial allows the team to quickly integrate the advanced capabilities of ROS with industrial hardware to enable robotic programs that perceive the aircraft, automatically plan tasks and associated robot motion, and reliably execute those plans. SwRI maintains the ROS-Industrial software repository and manages the ROS-Industrial Consortium with over 40 members in academia and industry-member groups around the world.

“The A5 program will draw upon the vast resources and ingenuity of the ROS community,” said Clay Flannigan, an assistant director in SwRI’s Manufacturing Technologies Department. “It is a diverse group of experts who are advancing secure and open-source robotics in academia and industry.”

An illustration depicts how a robotic arm commonly used in advanced manufacturing can be adapted to perform multiple functions such as under-wing sanding or composite repair on military aircraft.

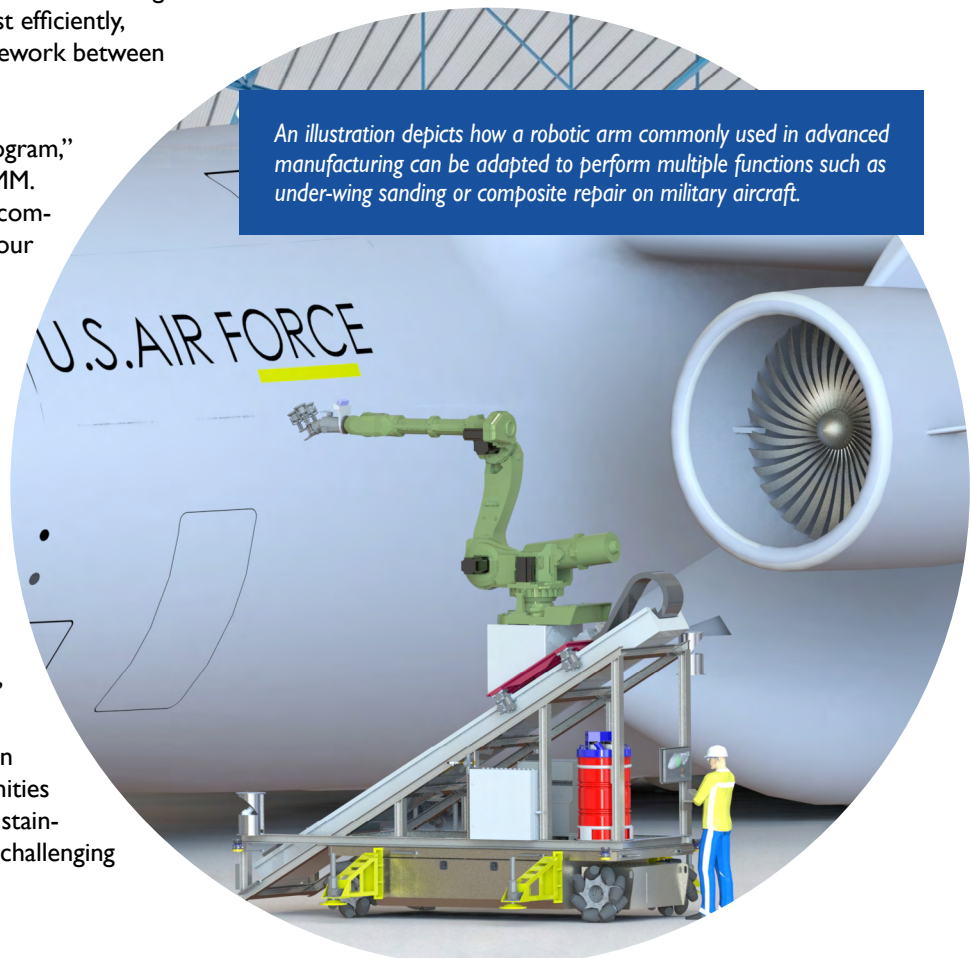


Image courtesy of SwRI

Amazon Picking Challenge Win

In June, we celebrated with Team Delft, who won the Amazon Picking Challenge using a Yaskawa Motoman robot that was controlled by ROS-Industrial software in conjunction with their deep learning perception system. Hosted in Leipzig, Germany, in concert with RoboCup 2016, the Challenge was a global event that brought fierce competition including teams from USA (MIT), Japan (PFN), and Germany (NimbRo). The Challenge aims to automate the "first and last miles of logistics." Teams were challenged to program their robots to pick objects from totes and put them on shelves (stow task) and also to pick objects from stocked shelves and put them into containers (pick task). The variety of the objects and the unstructured environment make these difficult tasks. Team Delft included mechanical engineers, vision experts and roboticists from the TU Delft Robotics Institute and Delft Robotics. The Robotics Institute is also the Scientific Advisor to the ROS-Industrial Consortium Europe.



A celebratory Team Delft after their win at the Challenge.



Team Delft's robot presenting its 1st place trophy for a winning performance at the 2016 Amazon Picking Challenge, held in Leipzig, Germany.



Team Delft's robot scans a shelf for items to pick.

Robotic Blending Milestone 4 Progress

Project Sponsors: 3M, Caterpillar, GKN Aerospace

Performers: SwRI, Wolf Robotics, TU Delft

Many fabrication processes, including additive manufacturing, casting, machining, and welding, produce parts with surface finish defects (e.g., build striations, pitting, mill-lines, or weld spatter) and edge burrs/flashing. Many processes are available to remove these defects including manual sanding, grinding, bead blasting, or vibratory polishing. In high-volume applications, manual processing can lead to ergonomic or safety hazards. Also, inconsistency from operator to operator can lead to variations in product quality, excessive use of consumables, or inefficiencies. The Robotic Blending Milestone 4 Focused Technical Project is creating automation technology that combines the flexibility of a manual process with the repeatability and safety of the robotic system.

The objectives of the Milestone 4 FTP include:

Edge Processing: Deburring/chamfering 3D edges that occur where two surfaces meet.

1. Industrial-grade Sensors: Replace the Kinect with an Ensenso industrial grade 3D camera.
2. More Robust Surface Segmentation: Add support for blending complex contoured surfaces and around large holes.
3. Recognition of hand-drawn regions for processing.
4. Closed-loop Inspection and Retouch: Integrating the process planning and quality assurance steps so that parts are finished with a closed, sensor-driven loop.
5. Technology Transfer: Meetings and demonstrations at sponsor-designated sites to support knowledge sharing among project participants and performers.

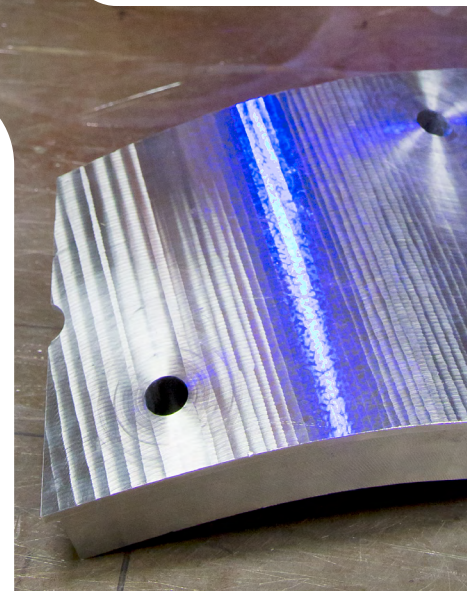
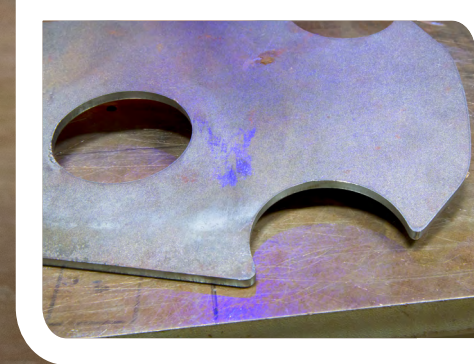
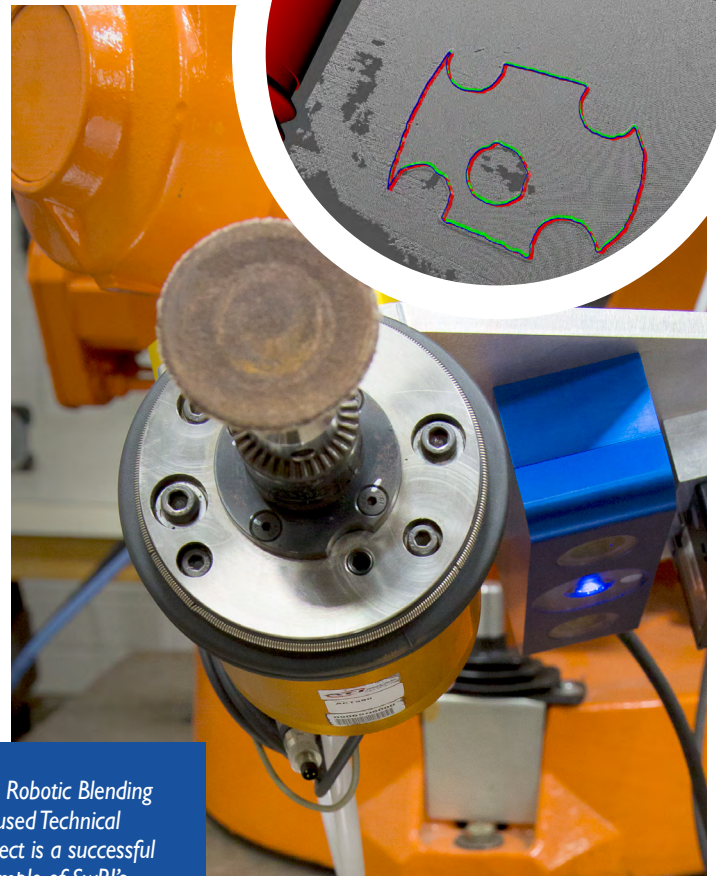
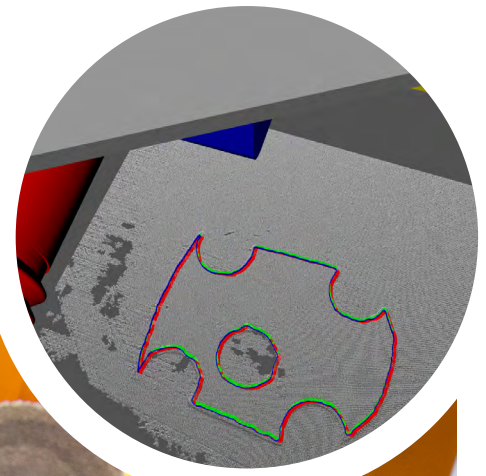
Progress: The project started in November 2016, and was fully funded in January 2017. Great progress has been made on edge processing, Ensenso integration, and more robust surface segmentation (refer to figures).

What is next?

Once Milestone 4 is complete, we believe the next step is to run individual pilot projects to mature the system on site at sponsor manufacturing sites. Wolf Robotics is the system integrator participating in the project, and we anticipate that they will lead projects to carry the torch forward into pilot operation.



The Robotic Blending Focused Technical Project is a successful example of SwRI's Scan-N-Plan process applied to removing machine tool marks from metallic parts and components to achieve a specific surface finish.



Collaborative Project: PackML State Machine for ROS-I

Consortium Participants/Collaborators: 3M, ARTC, SwRI, PlusOne Robotics

While ROS-Industrial is a foundational technology abstracting robot applications for industry, it is typically deployed on PC hardware (generally Linux based), which makes complete sense to the roboticist. To the manufacturing plant, however, the automation systems tend toward Programmable Logic Controller (PLC) hardware. Rockwell, Siemens, Mitsubishi and many other industrial vendors supply PLCs to factories all over the world. One challenge with PLC automation is developing complex manufacturing solutions that integrate hardware from multiple vendors.

Bringing together hardware from multiple vendors using a combination of new and legacy technologies (heterogeneous machines) with a standard control paradigm would simplify the problem. Fortunately, the ISA-88 standard includes a subset called PackML, which provides PLC programmers with a state machine (see figure below) and messaging protocol that allows disparate machines to work together. As more and more robots are integrated into manufacturing environments, it makes sense to extend the PackML standard into the ROS-I world.

ROS-I and PackML are a natural fit for each other. Both create a new way to solve old problems. Analogous to the way that ROS standardizes messaging, PackML has standard state definitions and standard messages to pass information about state transitions. Integration of robots into complex manufacturing environments will be made simpler with the new ROS-I/PackML library.

Project objectives:

- Prototype a ROS-I PackML state machine using an existing state machine library to get started.
- Test the prototype against a remote PLC with a standard PackML implementation and note needed improvements.
- Develop an open-source C++ library (think Boost) to implement the PackML state machine abstraction for use in ROS-I.
- Test the new ROS-I PackML library first with the remote PLC used for the prototype phase, and then integrate into existing ROS-I projects.

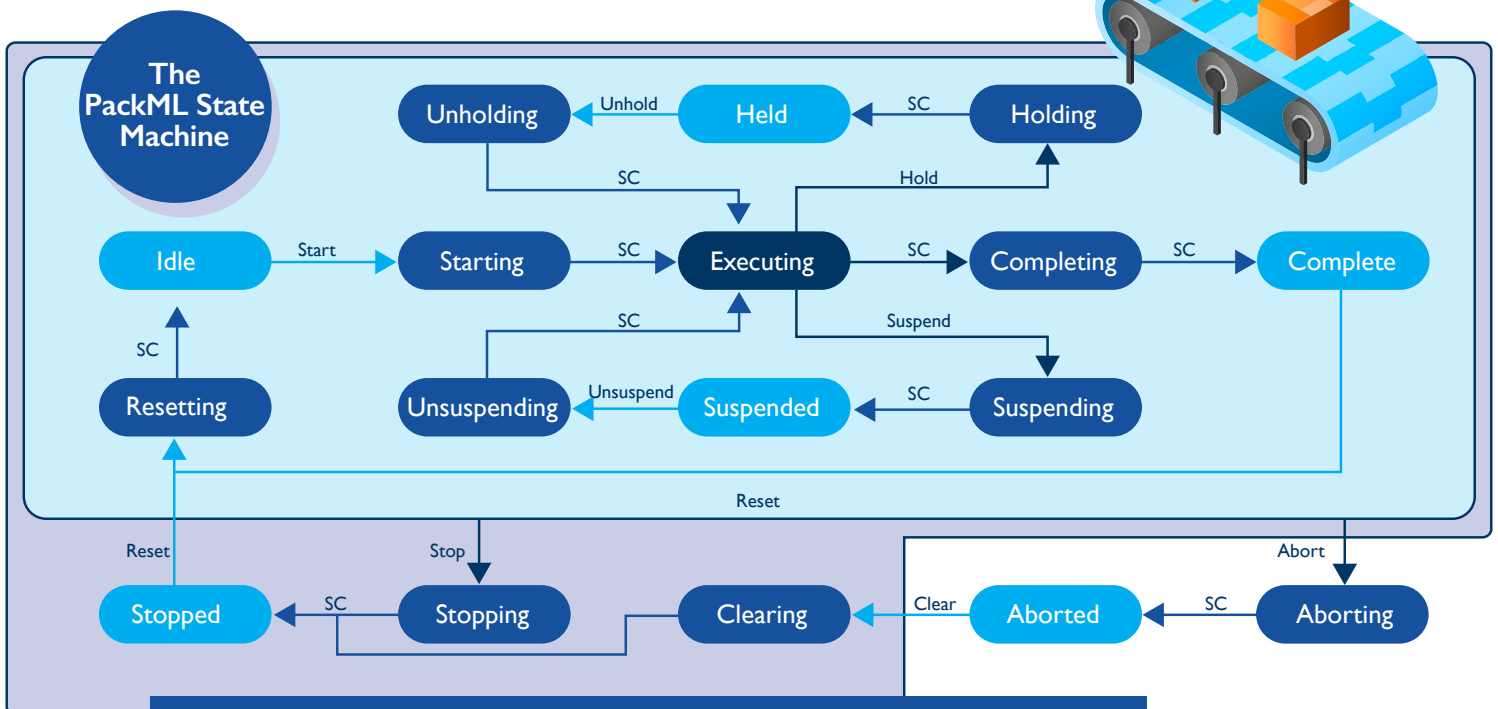
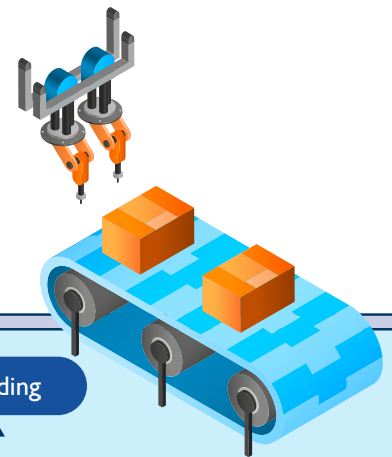
Design documentation and source code for the PackML project is being collected here:

https://github.com/ros-industrial-consortium/bohr_devel

To join future discussions about the PackML project for ROS-I, please email Min Ling Chan, Program Manager for the ROS-I Consortium Asia Pacific with your interest:

chanml@artc.a-star.edu.sg.

Thanks to Lex Sackett and Min Ling Chan for their contributions to this page.



The PackML state machine standard provides a prescriptive set of states, which have predefined meanings that are useful for nearly all automation, despite its packaging automation heritage. To implement unique states for a process, as would be desired for ROS implementations, a subordinate state machine can run, for example, within the "Executing" state.

Qt Creator Plug-in

Consistent feedback from the Consortium has focused on ROS-I ease of use. Specifically, developer tools have been difficult to configure, and even when such tools were used, much time was still spent jumping between terminal windows to source and launch ROS files. The ROS Qt Creator Plug-in was developed specifically for ROS to increase a developer's efficiency by simplifying tasks and creating a centralized location for ROS tools. Since it is built on top of the Qt Creator platform, users have access to all of its existing features like: syntax highlighting, editors (C++ , Python, etc.), code completion, version control (Git, Subversion, etc.), debuggers (GDB, CDB, LLDB, etc.) and much more.

The ROS Qt Creator Plug-in provides the following capabilities:

- Import/Create Catkin Workspaces
- Create Catkin Packages
- Custom Build and Run Configuration
 - catkin_make (Debug, Release, Release with Debug Info, Minimum Size Release)
 - roslaunch
 - rosrun
 - sourcing workspace

Note: The Qt Creator Plug-in supports multiple configurations to enable quick switching between configurations, and everything is saved.

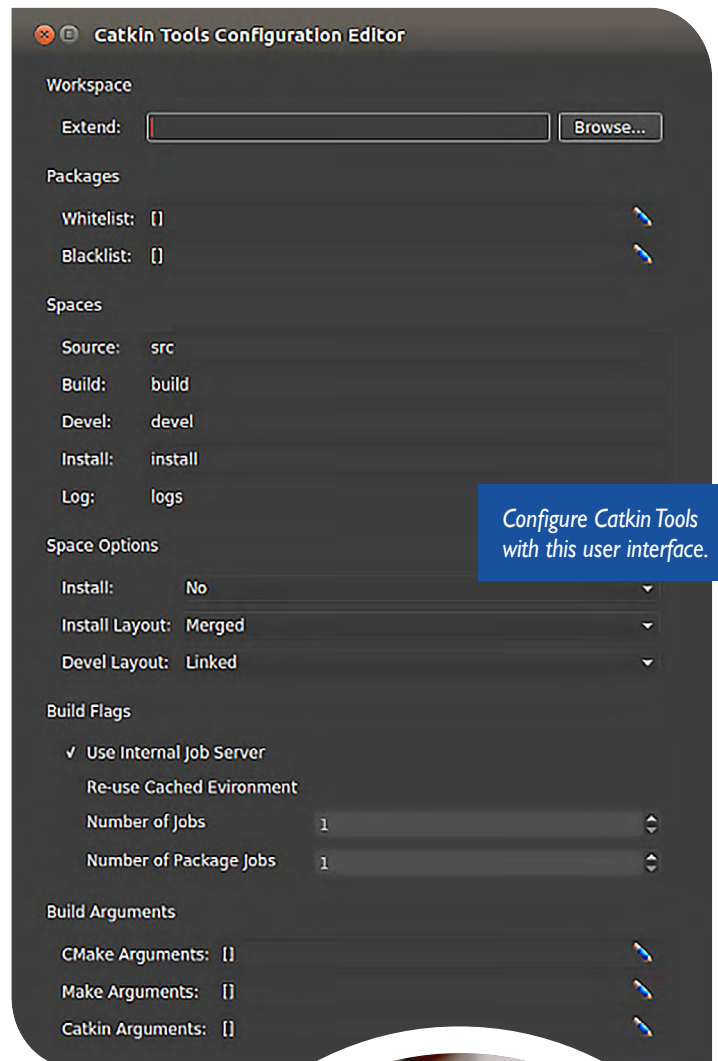
- Integrated Tabbed Terminal
- Templates
 - Industrial Robot Support Package
 - Basic Launch File
 - Basic URDF File
 - Basic Node File

Note: Users may create custom templates.

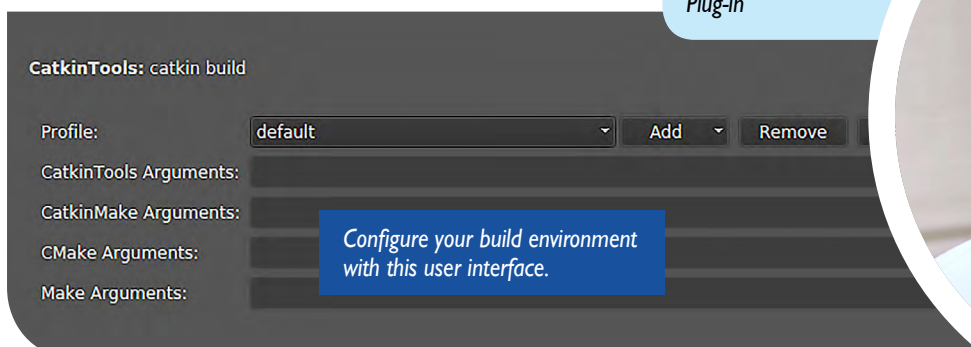
- More recent enhancements include:
 - Catkin Tools Integration
 - Build workspace
 - Create/Modify profiles with custom editor
 - Automatic workspace sourcing
 - Build progress bar updating
 - New code model manager: Automatically updated internal code model when changes occur
 - ROS clang config file for Qt Beautifier Plug-in
- Upcoming features in the work
 - Launch File Editor
 - ROSLint integration

- Provide build warnings without adding to CMakeLists.txt file
- ROS Settings UI
- Attach to un-started process run step to simplify ROS debugging

Check out two videos (https://github.com/ros-industrial/ros_qtc_plugin). The first is a short overview of the Qt Creator and its default capabilities. The second video is an overview of the ROS Qt Creator Plug-in developed by Levi Armstrong from Southwest Research Institute. We invite you to begin using the plug-in for your ROS development.



Levi Armstrong (SwRI)
Creator: Qt Creator
Plug-in



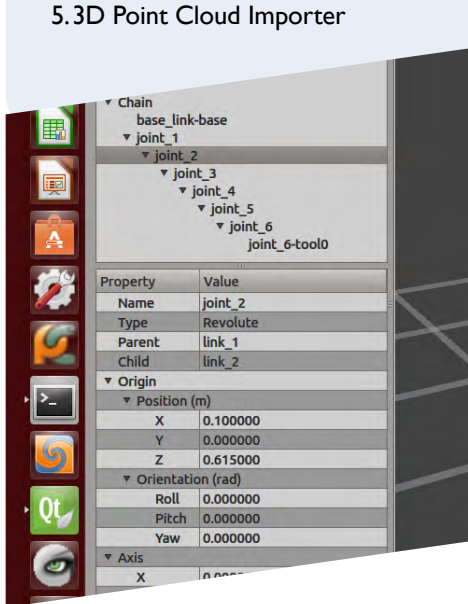
CAD-to-ROS Progress and Future Plans

A longstanding need, which will improve the efficiency of setting up a ROS project, is the ability to import model and process data from various CAD systems. A strong showing by the developer community led us to believe that much of the software development work would be contributed by collaborating consortium members, if technical leadership is provided to guide and curate the development. Furthermore, we wished to expand the future vision of CAD-to-ROS by building it into a 3D workbench framework. This will provide a common user experience for importing and configuring sensors, Cartesian process plans, motion plans, and point cloud data in the future. To assure incremental progress, we restructured the CAD-to-ROS project, reorganizing it into five tasks[5], each approximately four months duration:

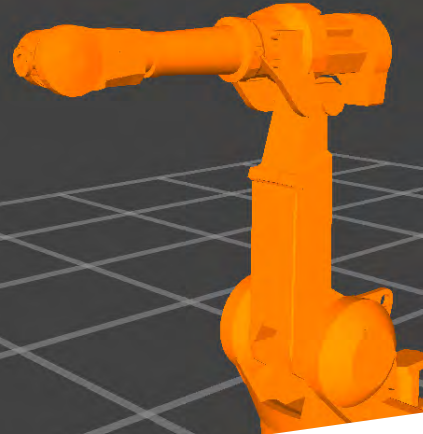
1. URDF GUI Editor
2. Process Planning
3. Workcell Planning
4. Sensor Configuration and Calibration Setup
5. 3D Point Cloud Importer

URDF GUI Editor

In spring 2016, The Boeing Company provided sponsorship for the administration of the first task of the CAD-to-ROS project, the URDF GUI Editor. In-kind software development support came from a team including 3M, ARTC, Fraunhofer IPA, Modbot, NIST, SwRI, Tracklabs, TU Delft, and UT Austin NRG. The alpha version of the code was tagged in May 2016 and provides a Qt-based graphical interface to URDF models supporting capabilities such as creating or importing a URDF, importing common CAD interchange formats like STEP and STL, adding or editing link and joint properties, drag/drop re-ordering of joints or links, automatic convex hull collision geometry creation, and exporting URDF or Xacro. Another convenient feature of the software, when compared to URDF text file editing, is that the model visualization is constantly updated so changes are instantly visible without reloading.



For this particular Consortium project, the Consortium has implemented a business model in which only contributors from the Consortium have access to the URDF editor tool. This is an opportunity to see how productive the community can be when motivated by a little self-interest! To access the project, please email: paul.hvass@swri.org



<https://github.com/ros-industrial-consortium/roadmapping>

Workcell Planning

For the Google Summer of Code Project (GSoC) 2016, with coordination from OSRF and the ROS-I Consortium, a toolkit called [Reuleaux](#) has been developed for the purpose of workspace analysis and base placement for a specified task. The workspace analysis is highly beneficial for any robotic system as it provides information about the reachability of the manipulator. The base placement system uses the workspace analysis tool and provides optimal base position for a specified task given predefined end effector positions.

Reachability Map

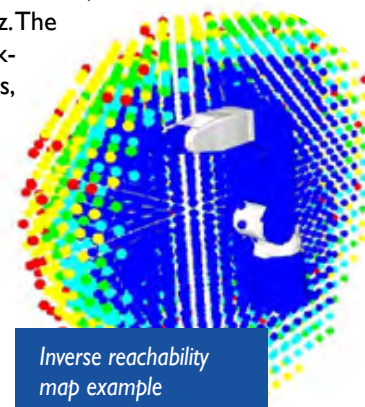
The first project goal was to develop a tool that can define reachability of any manipulator with existing robot definition such as URDF (Unified Robot Description Format). With a URDF of the robot and resolution based on user needs, the tool can provide multiple maps representing the information about the workspace such as a reachability map, capability map

and inverse reachability map. Several new ROS messages have been generated for workspace analysis which represent the coordinates of the workspace envelope, poses in the envelope and reachability of each pose.

Inverse Reachability Map

The purpose of the inverse reachability map is to find suitable base positions for a robot with given task poses. The inverse reachability map is a general inverse transformation of all the reachable poses of the reachability map of the robot. The inverse reachability map is dependent on the generated reachability map. With a visualization toolbox for Reuleaux, the workspace can be visualized in RViz. The visualization tool also displays the workspace with different structures (spheres, cones, cylinder and box), colors (based on reachability or solid colors) and reachability index (spheres with high/low reachability).

Thanks to Abhijit Makhil (Idaho State University) and Alex Goins (SwRI) for their contributions to this page.



Images courtesy of SwRI

Upcoming FTPs

Collaborative Robotic Nut Plate Installation Milestone 1

Rivets are the fastener of choice for commercial and military aircraft structural applications with thousands installed in each aircraft. The reluctance of the industry to change from rivets is based on the lower installed cost, lighter weight, and prohibitive cost for re-certification. Current Nut Plate installation (figures below) is accomplished through manual tasks of drilling holes and driving rivets. Thousands of nut plates are required in the construction of both military and commercial aircraft and represent hundreds of costly labor-hours to accomplish. As the aerospace industry looks for process changes that would drive down the manufacturing cost they recognize that cost-effective robotic riveting solutions have not yet been developed.

Objectives: (Milestone 1) This project is designed to significantly reduce the time needed for nut plate installation with robotic technology, and to transfer the tasks that pose a significant ergonomic threat from the human operator to a collaborative robot.

(Milestone 2 – Future Work) Development of a cost-effective riveting end effector for nut plate installation will be readily scalable to larger conventional rivet installation as well.

Technical Approach and Justification: This project will develop and demonstrate a collaborative robotic system to locate and install nut plates. To be successful, the project team will need to overcome technical gaps related to the development of collaborative robotic controls to perform a manufacturing process based on human instruction and a low-cost scalable robotic riveting end effector. In doing so, the project will advance collaborative robotics, perception/sensing, open-source software, dexterous manipulation, and manufacturing process integration technical thrust areas.

(Milestone 1) To install a nut plate, the robot-human interaction is envisioned to work in the following manner: The robot would be programmed to locate and drill the nut plate bolt hole along with drilling and countersinking the two rivet attaching holes, followed by the insertion of two 3/32 rivets. At this point, a call would be placed to the human to insert the nut plate onto the two rivets and position the bucking bar. Once this is accomplished,

the operator would command the robot to initiate the rivet impact sequence to complete the nut plate installation. The human would inspect the installation and initiate the cycle for the next nut plate in the series. Human-robot interaction for fault conditions would be tested.

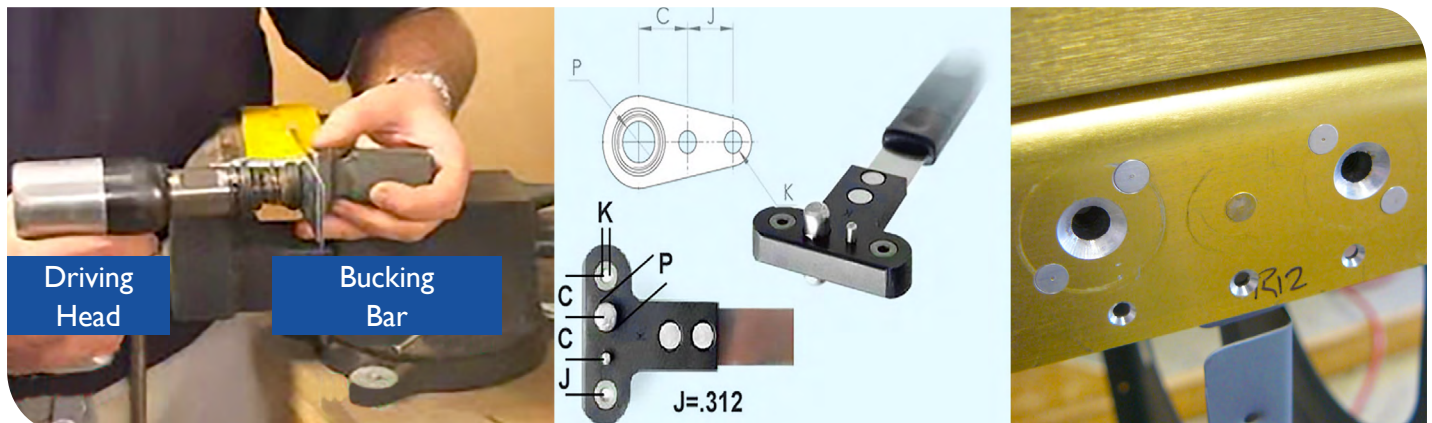
(Milestone 2 – Future Work) In today's aircraft assembly processes, the preferred tool to install the rivet is the rivet gun and a bucking bar. The end effector must apply a force to the work-piece sufficient to allow the impact of the rivet gun to upset the rivet, while not causing a negative impact on the robot. The rivet gun end effector concept must be scalable to accommodate a wide range of fastener sizes and materials. The design of the end effector will utilize established aerospace processes for locating the nut plate position in aircraft coordinates and drilling the appropriate attach holes and inserting the appropriate rivet. Developing the riveting function of the end effector will require force sensing capability along with recoil shock absorption. By controlling the impact pulse and the responding recoil reaction the desired feather touch experienced through human riveting should be achievable.

The challenges of developing a cost-effective system for human/robot interface will be achieving a smooth predictable relationship between force and reaction across time that will duplicate the motion of a well-trained human technician. Digital mapping of human movements and recording the associated forces produced by the rivet gun will be characterized to develop a time force sequence that will allow the system to duplicate worker capabilities. Once the process of mapping the human riveting process is developed it can be scaled up to cover a broad range of rivet sizes.

A side benefit of developing automated nut plate riveting capabilities will be elimination of the human medical expenses associated with impact guns and elimination of the costs associated with the hand tools required to support today's process.

Technologies Involved: Collaborative robotics and robot-human processes, process simulation, robotic riveting, open-source software, process control, TV&V, and E&W upskill training.

Products: Process and equipment specification; development and final demonstration conducted at sponsor facilities in a production-relevant environment.



Upcoming FTPs

Sensor Configuration and Calibration Setup

On page 13 we discussed the progress toward two of the five milestones of the workspace modeling initiative known as CAD-to-ROS. Continuing along our roadmap (page 13), we propose to divide and conquer the final three milestones by distributing the development effort among our three Consortia:

- RIC-Americas: Sensor Configuration and Calibration Setup
- RIC-EU: Process Planning
- RIC-APAC: 3D Point Cloud Importer

RIC-Americas will tackle the Sensor Configuration and Calibration Setup task, which aims to make the existing Industrial Calibration library accessible to non-experts via a new front end user interface along with a database structure for common 2D and 3D sensors that are used for ROS-I projects. Specifically, we plan to create the following capabilities:

- Create a graphical library from which to drag and drop 2D and/or 3D imaging sensors and calibration targets into the 3D environment
 - Populate the library with existing sensor configuration packages
 - Populate the library with existing calibration target models

- Update sensor models to include field-of-view geometry
- Enable the perspective to snap to the sensor point of view
- Configure sensor parameters such as IP address, frame rate, and data window size with GUI controls
- Create intrinsic calibration sequences for individual sensors using a GUI interface
- Create extrinsic calibration sequences for multiple heterogeneous sensors, synchronized with robot motion and/or synchronized with calibration target motion using a GUI interface. Unique GUIs will be created for four typical use cases:
 - Single sensor mounted on the robot's wrist
 - Static stereo pair of sensors mounted a fixed distance apart
 - Static array of sensors mounted throughout the workcell and the calibration target mounted on the robot
 - Static array of sensors mounted throughout the workcell and calibration target mounted on a conveyor
- (Desired) Create extrinsic calibration sequences for a sensor using features of opportunity in the environment (i.e., without a calibration target)
- (Desired) Create a launch file editor and analyzer to enable graphical representation of launch file structure and dependencies
- (Desired) Integrate with **fetch** calibration [6] tools to calibrate kinematic chains aka robotic manipulators.

[*http://docs.fetchrobotics.com/calibration.html](http://docs.fetchrobotics.com/calibration.html)

Development of a Reactive Automated Mixed Palletizing Algorithm

The formation of shipping pallets (palletization) is a key process in any commercial operation that involves physical goods.

Palletization entails stacking boxes onto a pallet prior to shipping and may involve boxes of a single size (homogenous palletizing) or boxes of multiple sizes (mixed palletizing). Due to the fact that palletization can be a rote task, it is often performed by machines. Automated palletization works well in cases where pallet patterns are fixed and solutions can be found in cases where knowledge of box types is complete. However, the mixed palletizing problem is NP hard, so many of the planning solutions are heuristically driven and best run offline or prior to palletizing. Further, not all palletizing is performed with complete knowledge and some palletizing centers are unable to choose the order in which boxes are palletized.

We propose a Consortium Focused Technical Project to tackle the mixed palletizing problem by developing a Reactive Automated Mixed Palletizing (RAMP) algorithm. Rectangular packages of random size will arrive on a conveyor belt in a random order and need to be placed on pallets. The limited information constraint reformulates the problem from a planning problem to a reactive placement problem, where the goal would be to produce the best pallet possible, given the arriving boxes. Most of the academic literature surrounding this problem focuses on complete knowledge planning and optimality, leaving this niche less explored. The development of algorithms for reactive mixed palletizing is thus a problem of practical interest with value behind finding workable solutions.

Development will take place in a simulation environment in which a robot arm will place randomly arriving packages onto pallets. Should the algorithm simulated in this scenario meet requirements, a follow-on phase to develop and test a physical palletizing system will be proposed.

If you have interest in this project, please contact clay.flannigan@swri.org.

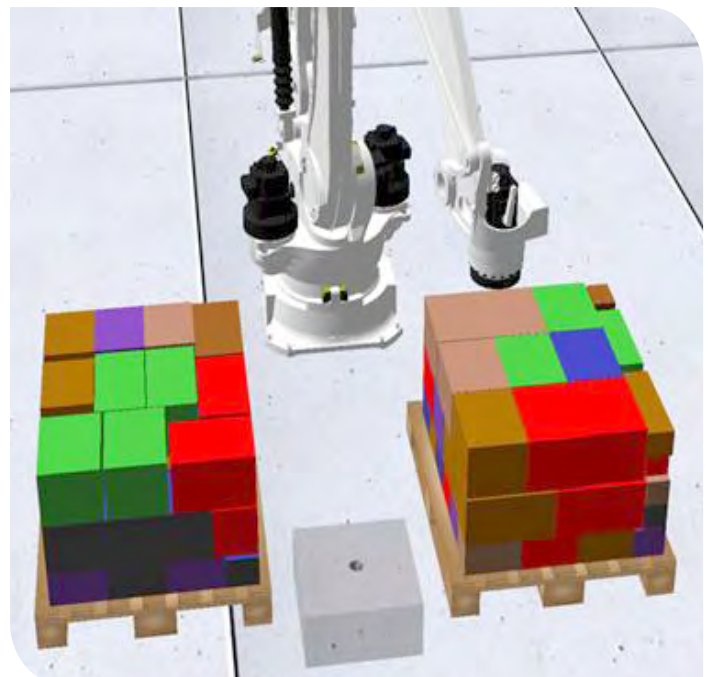


Image courtesy of SwRI



Current members of the worldwide ROS-I Consortium

Upcoming Events

RIC-Americas 2017 Annual Meeting

When: April 6–7, 2017 (Immediately following Automate 2017)
Where: Hyatt Regency McCormick Place, Chicago, IL, USA
Registration: Please see the [event page](#) on [rosindustrial.org](#)

How many people can we send?
 Full – 3 Associate – 2 Research – 1
 Each Additional – \$300

Agenda

Thursday Evening April 6, 2017:

- **Dinner (Provided):** A hosted dinner will be held near the McCormick Center the evening before the RIC meeting.

Friday April 7, 2017 (Members Only):

Some highlights of the annual members meeting include:

- **Consortium Updates:** Learn about the latest ROS-I community developments from the three leaders of our international Consortia, and planned Consortium activities for 2017.
- **Lunch Keynote:**
 - **Title:** Flexible Automation for Manufacturing in Heavy Industries
 - **Presenter:** Matthew Robinson, Automation Team Leader, Manufacturing Technology, Caterpillar Inc.
 - **Abstract:** Traditional automation solutions serving high-volume uniform product applications haven't translated well to high-mix low-lot applications in heavy industries. A new flexible approach is needed to enable new capabilities for traditional robotic equipment by leveraging modular, advanced perception-driven functionality. To realize this vision, the whole robotics community – including university

partners, applied researchers, industry, regulation, and integrators – needs to embrace open solutions. The Scan-N-Plan Robotic Blending Consortium project is an important first step on our advanced robotics journey to the benefit of shareholders, customers, and partners in the factory.

- **Technical Presentations:** Invited talks by ROS-I innovators.
- **Focused Technical Projects:** We will provide an update on current Consortium projects and upcoming 2017 projects.
- **Roadmapping:** The meeting will conclude with a general discussion on the technical roadmap which will set the agenda for the 2017 activities.

Future Events

- Apr. 19–21, 2017 [RIC-EU Annual Meeting](#) in conjunction with [RBE 2017](#), The Hague and Delft, the Netherlands
- May 15–17, 2017 [ROS-I Developers Training Class](#) SwRI, San Antonio, Texas
- May 25– June 3, 2017 [RIC-APAC Launch](#) in conjunction with [ICRA 2017](#) Singapore
- Sept. 21–22, 2017 [ROCon 2017](#) Vancouver, Canada



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