FINAL PANEL PROJECT REPORT
PLUG AND PLAY COBOTICS
AGREEMENT # 2019-375-014

March 28, 2025

1.0 Project Overview

This project addresses two problems that limit the adoption of automation, specifically cobots for use in shipbuilding:

- Typical cobot integrations are "vertical," thus often adding welding equipment desired by the integrator, not allowing use of already installed equipment, and
- The proposed simplified approach reduces the cost and optimizes the already efficient skill set of shipyard mechanized welding equipment operators.

The results of the project will drastically improve the implementation of cobotics for welding and other processes by allowing the use of the already installed equipment with which welders are already proficient. Cobot applications that are set up in a dedicated workspace are not the focus of this project. This project is focused on cobot applications that can be anywhere in the greater workspaces of shipyards: plate processing, panel lines, inner-bottom assembly areas, and many others.

Cobot welding systems from integrators can cost in excess of $90K. That alone is a barrier to implementation for many shipyards. At the same time, integrated systems will often have welding equipment that is usually the preference of the integrator. The welding power supply will typically require a 480 Volt power cable that must be dragged across the area to the job at hand. A cobot, just the cobot, from the manufacturer may cost far less than half that, and can make use of the installed welding equipment, not needing a 480V cable, just the umbilical from the power supply to the cobot and wire feeder assembly.

The essence of this project is to streamline the use of the cobot as a motion system, similar to the many mechanized devices now in wide use. The superior ease of set up, path planning, and worker safety can be put to full advantage by the results of this effort.

At present a shipyard panel fabrication area has welding power supplies located under the structural supports of the overhead crane rails. They are connected to 480V buss ducts so that power cable length is minimized. Shipyard workers have been working with these set ups for years, and are completely adept at setting welding parameters, setting up mechanized tractors, hitting the start switch and making welds. This project will allow the cobot to be the next-generation motion system for welders, plasma cutters, and other devices.

The project goal is to demonstrate the use of a cobot as a general-purpose motion tool that is flexible enough to work with a variety of welding, cutting, and other metalworking equipment that is currently on site and used at shipyards.

The project objectives are to reduce the complexity currently required to set up a cobot to work with welding and metalworking equipment via a simplified interface that allows the use of the equipment's existing settings and procedures. The objectives are:

- Demonstrate ability to perform weld tasks through a simplified cobot interface:
    - That is easy to use, intuitive, and accepts weld settings that are already on the welding power supply
    - That works with multiple weld power supplies
- Demonstrate ability to perform metal cutting tasks:
    - That works with multiple plasma cutting tools

2.0 Project Results

This is the Final project report for the subject agreement. Technical efforts for the period of performance (3-22-24 through 3-28-25) include:

2.1 Task 1 – Project Initiation and Kickoff

Project team members participated in a kickoff meeting to review project scope and identify candidate applications and equipment for each process.

For welding, fillet welds on 3/8-in. thick plate and a groove weld qualification demonstration on 1-in. thick plate were selected. Base materials would conform to NAVSEA Technical Publication 248 (TP248) group S-1 and welded with .052-in. diameter E71T-1 filler wire. Shielding gas would be 100% CO_2. Single pass welding was selected, although the team commented that multipass welding and weave beads would be positive additions. A Miller Electric Continuum 500 power supply and Miller Electric Arc Reach wire feeder was selected for welding equipment.

For cutting, the team determined that thicknesses of 1/4- to 1/2-in. material would be used for demonstration of the cutting application. A Hypertherm 125 amperage plasma cutter at Ingalls, and a Miller Electric 125 amperage cutter at RTT were selected.

NSWCCD was consulted in follow on conversations to determine a path towards qualification for the semi-automatic GTAW process. Cross section macrographs, microhardness testing, tensile testing, and bend testing were selected as inspection methods for this effort.

2.2 Task 2 – Development of Plug and Play Cobotics Solutions

This task involved developing plug and play welding and cutting solutions. EWI was accountable for the development of the welding solution, and RTT handled development of the cutting solution.

2.2.1 Welding Solution

For the welding task, simplified path planning for weld starting and stopping was developed. Required communication hardware was created to interface with processing equipment. A cobot mounting solution was selected to secure the cobot to the work area. Lastly, an end effector mounting solution was chosen. All components were assembled, and the finalized welding solution is shown in Figure 1.

Figure 1. Welding Plug and Play Cobot Solution

For path planning development, EWI selected Smooth Robotics as a commercially available off the shelf (COTS) solution. Functionality features of this tool include:

- General: travel speed, blend, stick out
- Angles: work and travel angles and reference plane for angles
- Corners: settings for easily programming corner welds
- Weaving: Amplitude, Period, Arc motion, Dwell
- Ramping / Slope
- Move: up/down, Left/Right, Fast/Slow

The Smooth Robotics user interface is shown in Figure 2.

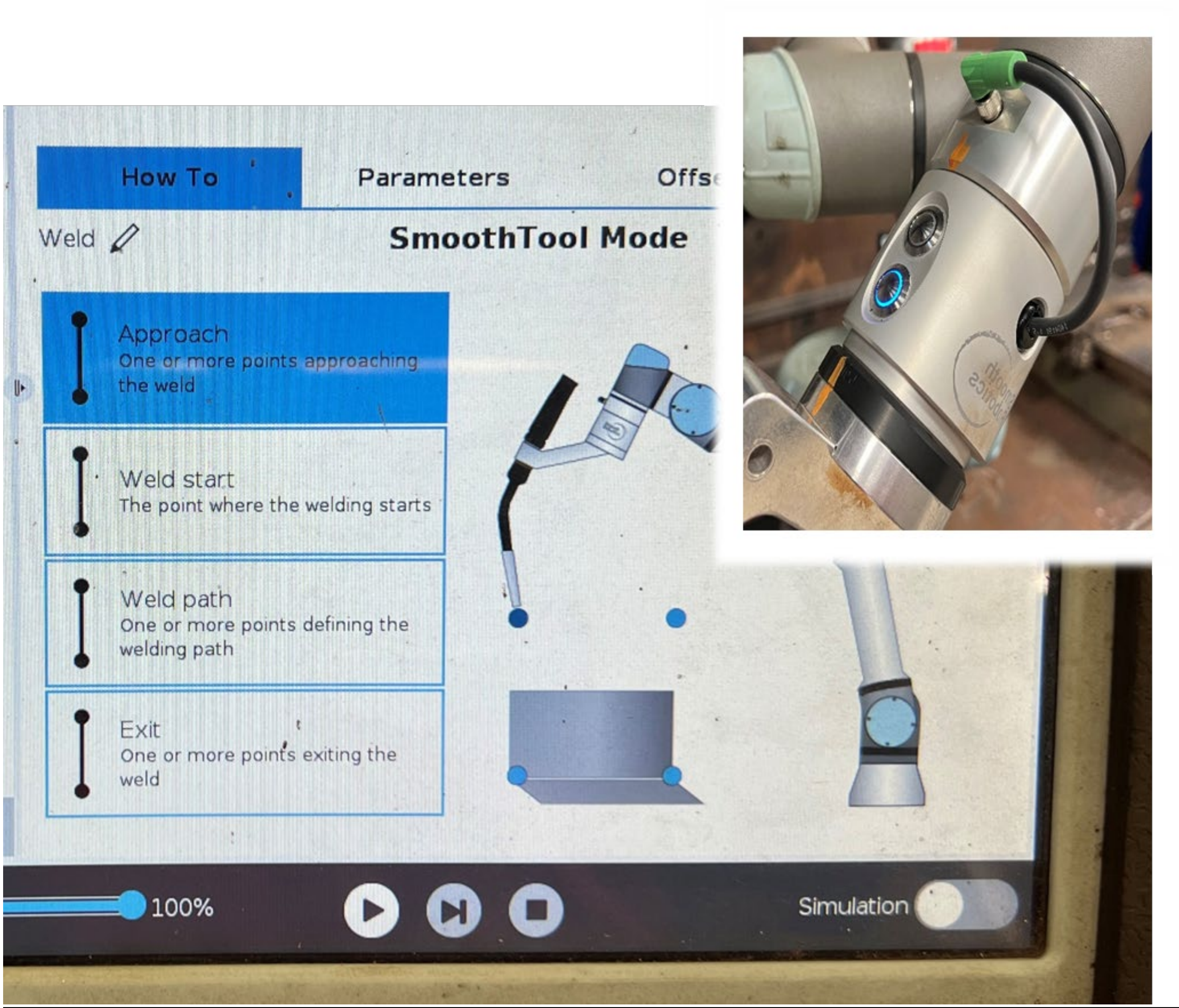


Figure 2. Smooth Robotics User Interface

Using the Smooth Robotics interface, weld programming was able to be done in under 2 minutes. Button short pressing is used to set robot positions and long presses are used to move to the next menu. The user can program approach, weld start, weld end, and retract points.

Hardware on the Smooth Robotics interface includes a relay module with weld on/off control and weld current feedback to stop the program if an arc is not established. EWI added hardware integration for operation and additional functionality. An emergency stop (E-Stop) was added, and a wireless operator station integrated to provide start/stop, up/down, left/right, fast/slow, and E-stop control. Figure 3 provides an overview of the integration of the wireless operator pendant.

Figure 3. Integration of Wireless Operator Control

The list of motion and robot control through the wireless remote pendant and robot I/O include:

- E-stop
- Enable/Start Button (green)
- Up/Down Buttons
- Left/Right Buttons
- Faster/Slower Buttons
- Cycle Start Button
- Additional Function Button

Buttons are incremental and each push of the button will increment the direction or speed of the cobot movement.

Cobot mounting was handled by a magnetic base with which the cobot was secured. This magnetic base has an on/off switch to allow for transport to and from the work area. The magnetic base was a COTS item purchased from Magswitch. An overview of the Magswitch magnetic base mounted to the cobot arm is shown in Figure 4.

Figure 4. Magswitch Setup and Details

Using the Smooth Robotics programming flange, EWI installed the Tregaskiss robotic weld torch provided by Ingalls to create the cobot end effector solution, shown in Figure 5.

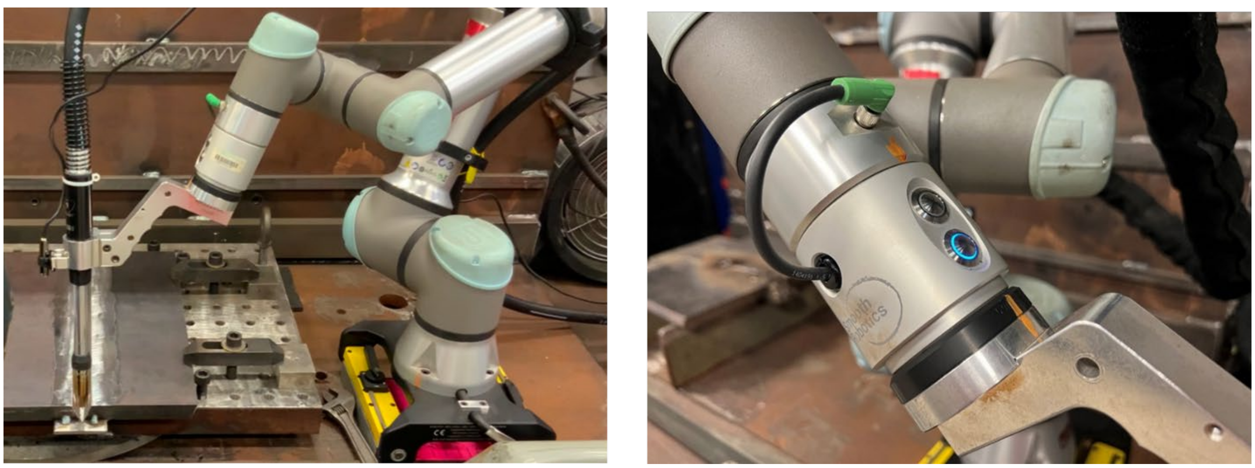


Figure 5. Welding End Effector: Tregaskiss Weld Torch and Smooth Robot Programmable Flange

2.2.2 Cutting Solution

For the cutting task, RTT developed a simplified path planning for starting and stopping cuts. Fusion 360 software was used to path plan. RTT also worked to create a simple shape library that would assist in point-to-point programming, which is also available if Fusion 360 is not used. Fusion 360 allows for importing parts, extruding, defining bevels, and other parameters. A screenshot of Fusion 360 path planning is shown in Figure 6.

Using the software interface, a plasma cut is selected as the process, and Miller Electric Spectrum or Hypertherm cutting power sources are definable options. The path planned in Fusion 360 is imported to set the cut path.

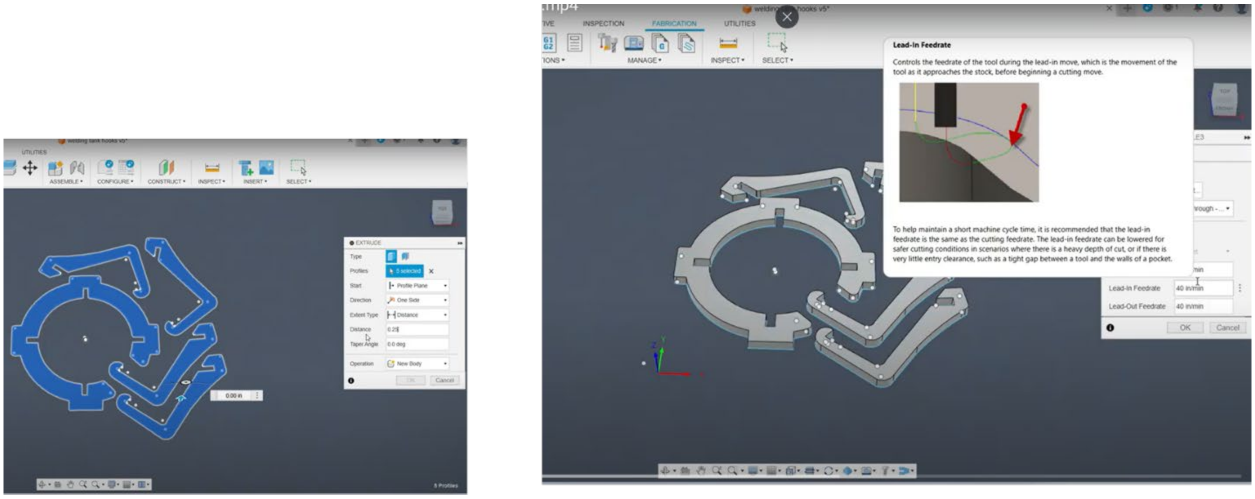


Figure 6. Fusion 360 Cutting Path Planning

RTT developed communication hardware required to interface with processing equipment with their Switch Weld cobot system. The setup uses ethernet or signal leads which go from a power source to a close contactor. RTT was also working on height or volt sense capabilities.

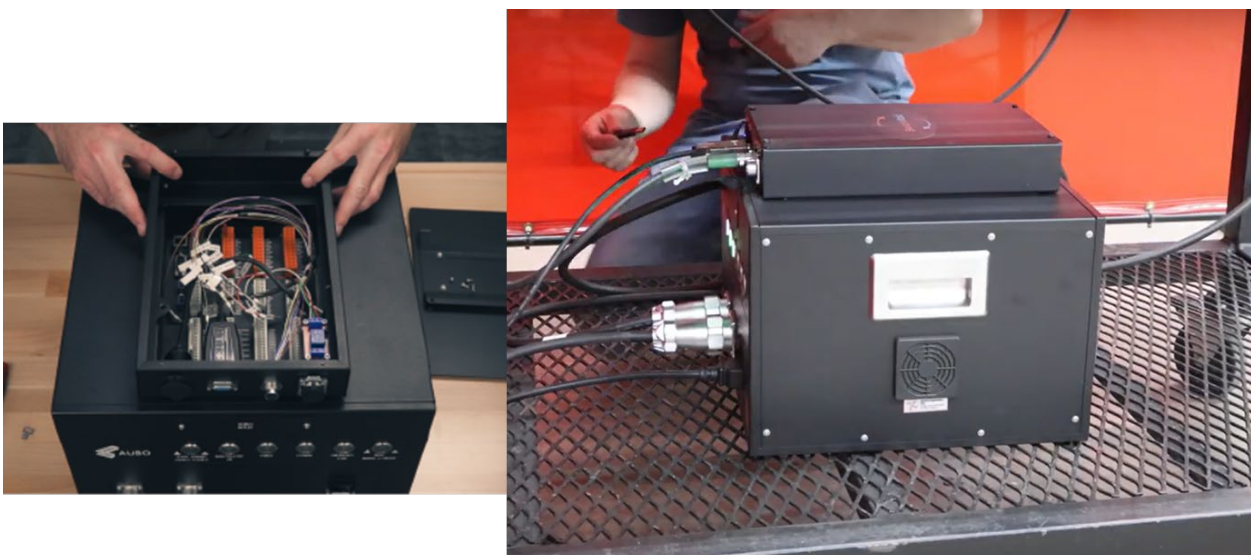


Figure 7. RTT Cutting Solution Communication Hardware

For mounting, RTT had a previously developed mounting base plate for their Aubo cobot to demonstrate the path planning to cut demonstrations. For demonstrations on larger scale mockups, a Magswitch magnetic base similar to the one used by EWI was selected.

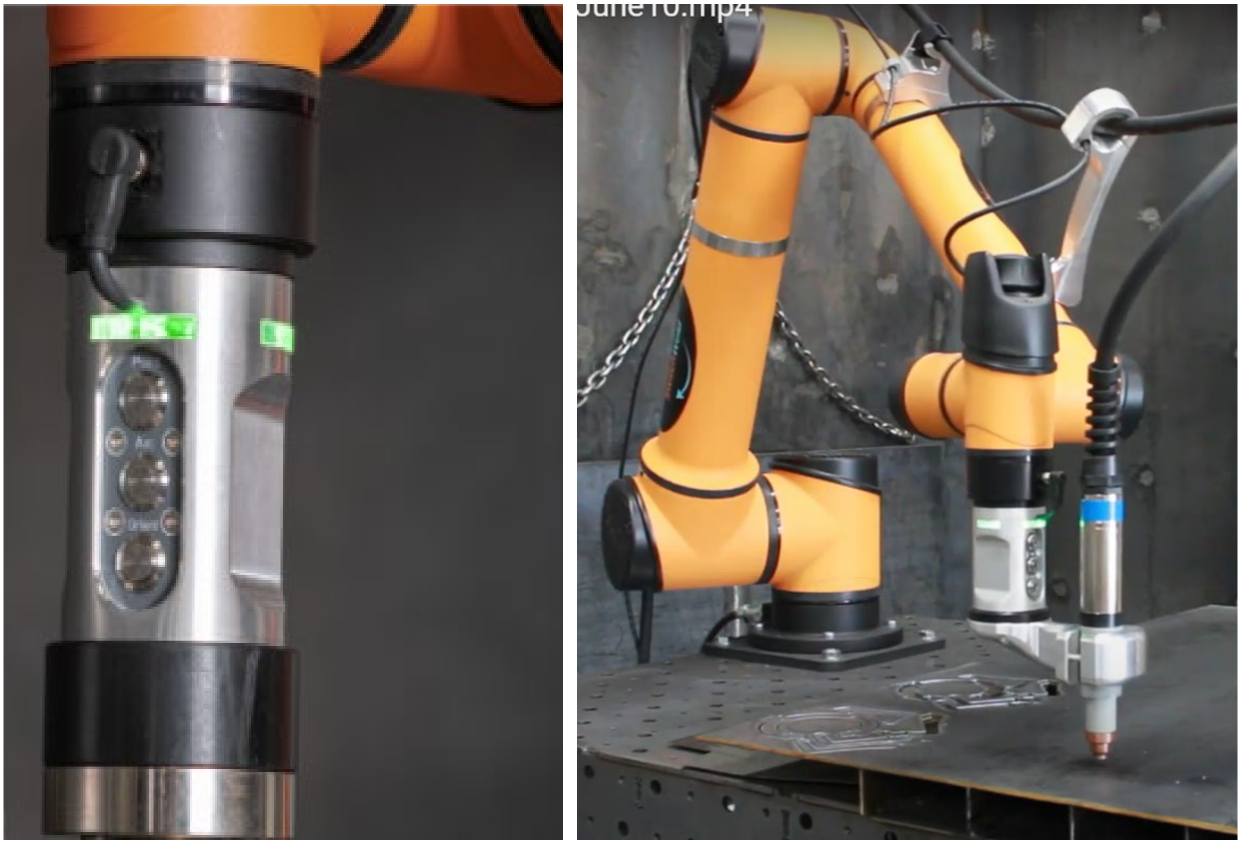
RTT Aubo Cobot with Magswitch   RTT Aubo Cobot with Mounting Plate

Figure 8. RTT Cutting Solution Mounting Options

RTT used their SwitchWeld Navigator programmable flange and mounted a plasma cutting torch to create the cutting end effector. The SwitchWeld Navigator has the following features:

- Free Drive
- Point
- Orient
- On/off
- Status LED

An overview of the RTT cutting solution, including the developed end effector, is shown in Figure 9.



SwitchWeld Navigator Programmable Flange

RTT Cutting Solution including Plasma Cutting Torch End Effector

Figure 9. RTT Cutting Solution

2.3 Task 3 – Test Plug and Play Cobotics Solutions

The purpose of this task was to test the welding and cutting solutions developed during Task 2, create operator training materials, and identify operator qualification requirements per TP248.

2.3.1 Welding Solution Tested

Using the developed welding cobot solution and welding parameters provided by Ingalls, EWI tested the setup first by fillet welding several 3/8-in. thick TP248 Group S-1 plates in the horizontal (2F) weld position. Welds were made with.052-in. diameter E71T-1 filler wire and 100% CO_2 shielding gas. The Ingalls welding parameters used were 250 inches per minute of wire feed speed, 25.0 volts, and 12 inches per minute travel speed. Figure 10 shows in process welding of the fillet plates using the developed solution.

Figure 10. Horizontal Fillet Testing of Developed Weld Solution

For the groove weld qualification demonstration plate, a MIL-STD-22D B1V.1 joint design was selected. Plates were TP248 Group S-1, 1-in. x 18-in. x 6-in. with 1/4-in. x 20-in. x 3-in. TP248 Group S-1 backing. All welding of the groove plate was done in the flat (1G) weld position.

Welds were made with.052-in. diameter E71T-1 filler wire and 100% CO_2 shielding gas. The Ingalls welding parameters used were 250 inches per minute of wire feed speed, 25.0 volts, and 12 inches per minute travel speed. Figure 11 shows in process welding of the groove plate using the developed solution.

Figure 11. Flat Groove Testing of Developed Weld Solution

To confirm sound weld was deposited, the welded plate was nondestructively inspected per NAVSEA Technical Publication 271 (TP271) requirements for visual (VT) and magnetic particle (MT) and evaluated against MIL-STD-2035A Class I acceptance criteria. All acceptance criteria were met.

This process was categorized as Mechanized Robotic within TP248 (revision 1). Because of this, operator qualification was identified as Level II, which would not require repeated mechanical testing if qualification was done using Level I qualified welding procedures.

EWI created an operator manual for training and use of the developed welding solution. This manual can be viewed by contacting NSRP.

2.3.2 Cutting Solution Tested

RTT tested the developed cutting solution by path planning a round cut shape in Fusion 360, transferring the cut path onto the Aubo cobot, and cutting with the plasma torch end effector on a cylinder. Cut quality was confirmed to be satisfactory.

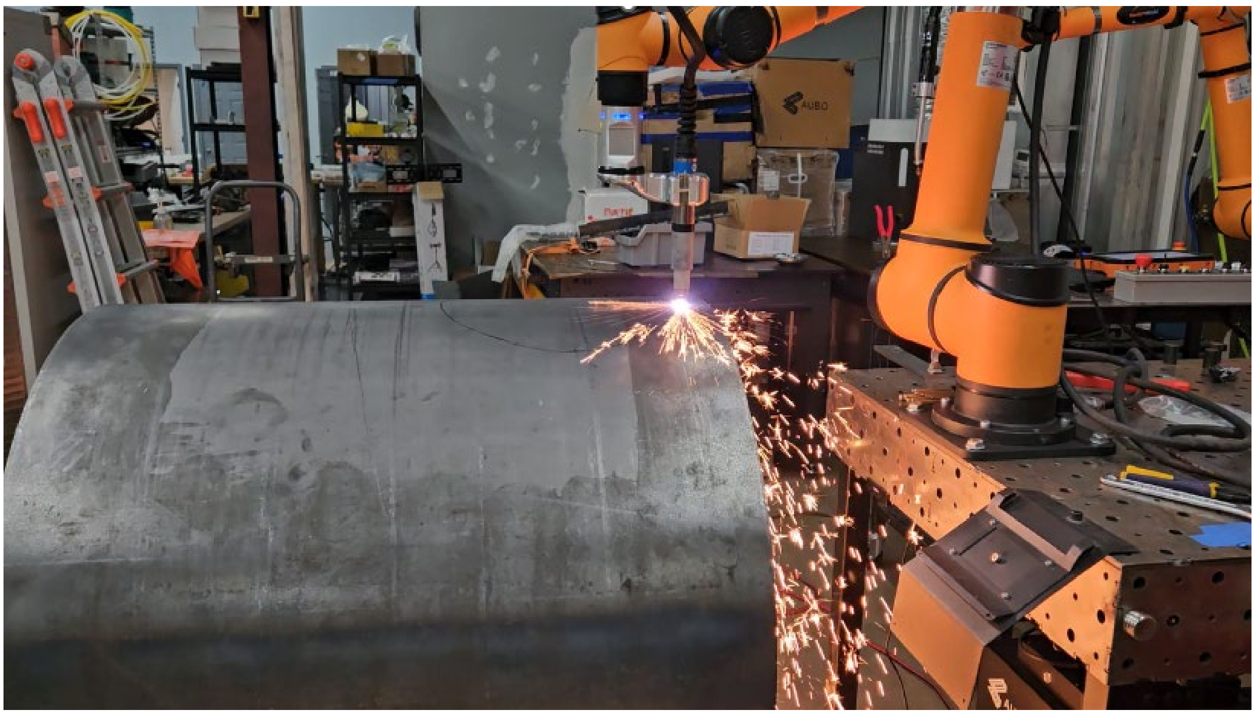


Figure 12. Cutting Solution Test on Large Diameter Pipe

2.4 Task 4 – Shipyard Demonstration and Technology Transfer

This task aimed to demonstrate the developed welding and cutting solutions to the project team. Ingalls hosted EWI and other project team members for an onsite demonstration of the welding solution, and RTT provided a virtual demonstration of the cutting solution.

2.4.1 Welding Demonstration at Ingalls

Ryan Gneiting of EWI traveled to Ingalls on January 27, 2025, to prepare the cobot welding solution within Ingalls' welding laboratory. Working with shipyard staff, Ryan prepared a weld cell and plates for subsequent demonstration.

On January 29, 2025, EWI demonstrated the developed cobot welding solution on plates provided by Ingalls. Corner wrap welds were programed with three points around corners.

Multipass welds were also performed in 1/2-in. thick V-Groove plates with four single passes using the weave feature. Circular welds were done on a tie down repair weld. Figure 12 shows examples of the programmed corner wrap welds made during the welding demonstration.

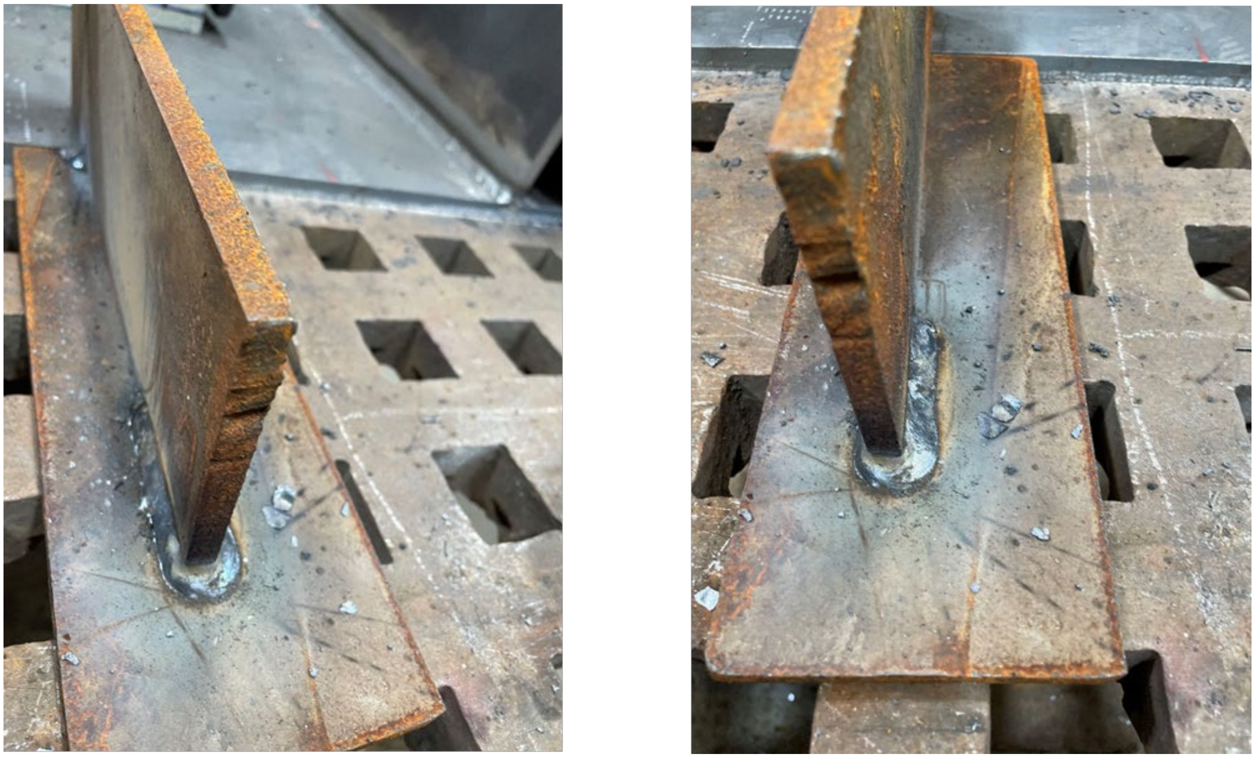


Figure 13. Corner Wrap Welds during Weld Demonstration at Ingalls

Feedback from Ingalls staff was positive; operators appreciated the ease of use of the wireless operator pendant and overall programming simplicity.

2.4.2 Cutting Demonstration at RTT

Using Microsoft Teams as a virtual presentation resource, RTT provided a demonstration of the developed cutting solution on March 4, 2025.

The demonstration began with a general welcome and introductions and a brief overview of the cutting solution. RTT then gave a review of path planning within Fusion 360, transfer to the Aubo cutting solution, then demonstrated cutting planned paths on steel plate. This cut was made with a bolted flange plate and the cobot mounted to a fixture table.

Figure 14. RTT Cutting Demonstration: Path Plan to Cut

The next part of the demonstration involved using the Aubo mounted to a large pipe with the Magswitch magnetic base. A circular cut was programmed into the cutting solution, and the cut was made live for virtual participants to witness. This demonstrated the ability of the plasma end effector as well as the kinematics of the cobot arm to articulate about the pipe curvature to produce the programmed circular cut shape.

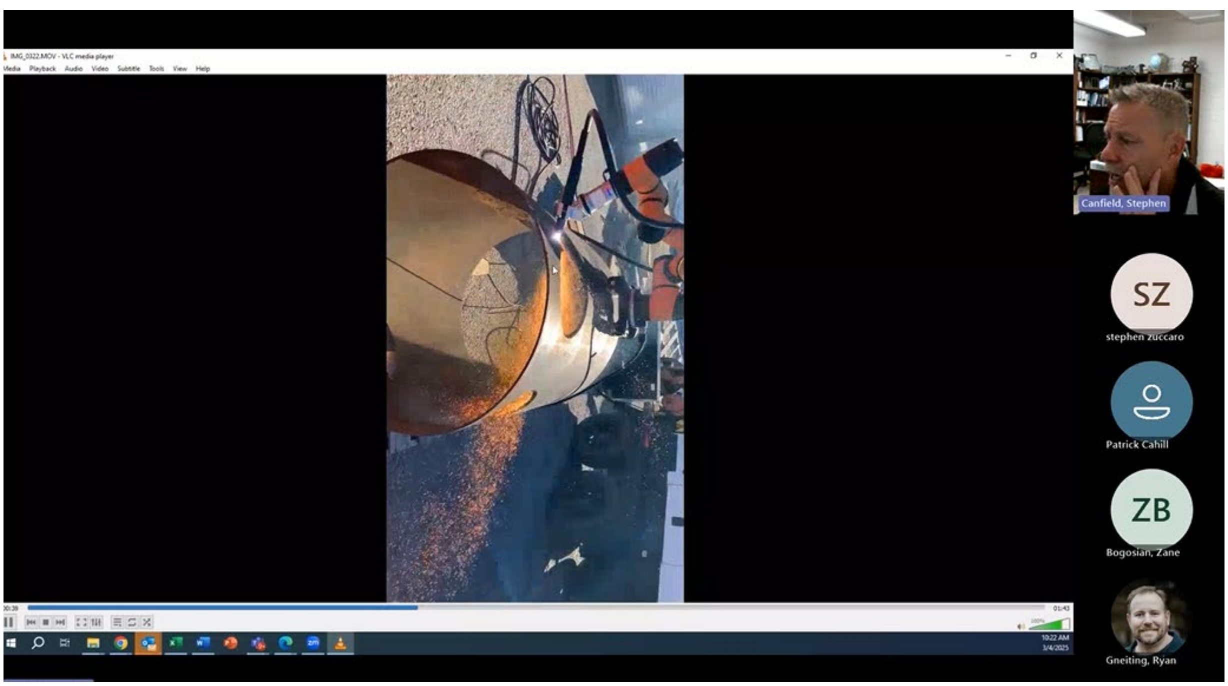


Figure 15. RTT Cutting Demonstration: Circular Cut on Large Pipe

3.0 Technology Transfer and Implementation

All project objectives were completed within the period of performance.

The technology transfer event occurred during the NSRP All Panel conference on 2/26/25 in Charleston, SC, where results from this project were presented.

4.0 Conclusion and Recommendations

This project aimed to develop a simple but effective plug and play solution that would allow a shipyard to use a cobot as a motion system that could be connected to previously installed welding and cutting power supplies at the shipyard.

EWI was able to successfully develop and demonstrate a plug and play cobot welding solution in the horizontal fillet (2F) and flat groove (1G) welding positions using legacy shipyard welding parameters. This was done through a qualification demonstration test assembly and onsite demonstration at Ingalls Shipyard. A welding solution operator and training manual was created and shared with NSRP.

RTT was able to successfully develop and demonstrate a plug and play cobot cutting solution in a variety of positions using standard off the shelf plasma cutting equipment. This was done through a virtual demonstration at RTT.

It is recommended that the results of this project be evaluated by interested parties for deployment of plug and play cobot solutions on shipyard applications using legacy welding equipment and procedures.