Tele-Welding – Remote Operation of Shipyard Welding (and other) Equipment

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NSRP Welding Technology Panel Meeting

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Tele-Welding Remote Operation of Shipyard Welding Equipment

Program Funding:	$762,318
Cost Share:	$762,467
Total Project Cost:	$1,524,785
Period:	4/2019 – 4/2021

Project Team

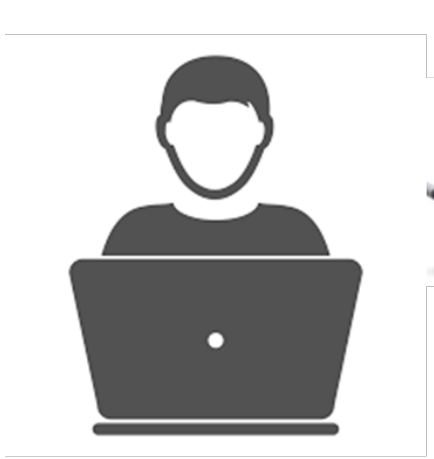
VISIBLE WELDING

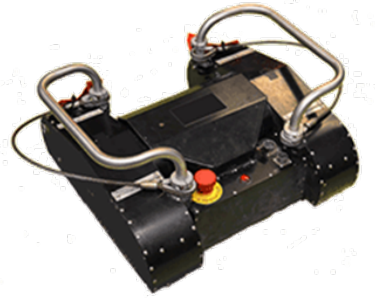
RTT Robotic Technologies of Tennessee LLC

EWI

Newport News Shipbuilding

GENERAL DYNAMICS Electric Boat





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Problem Statement

- The shrinking number of skilled welders, the lack of persons wanting to enter “manual” trades, and the ever-increasing list of hazards and limitations related to welding and other hot work activities make it difficult to find and keep experienced welders.
- In the effort to optimize weight and space, many locations on ships are virtually impossible for humans to reach.
- New methods are needed to allow qualified welders of all physical abilities to enter and to remain in the workforce.

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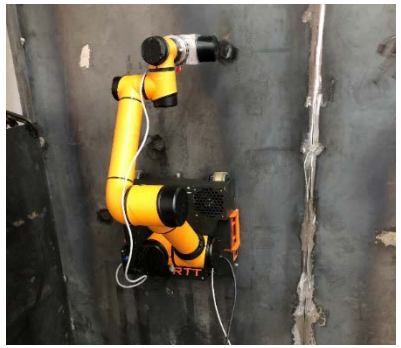
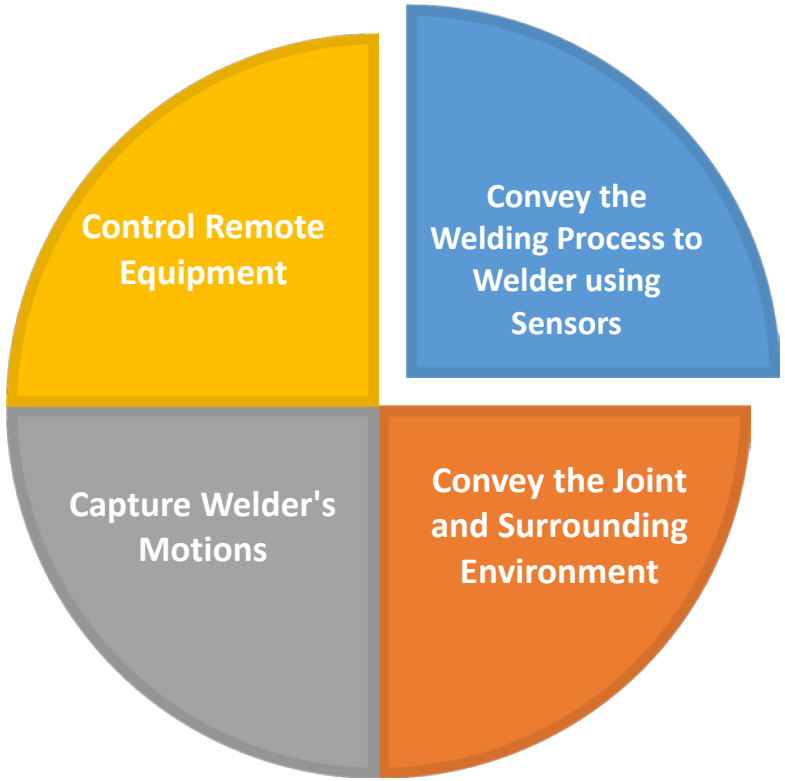
Tele-Welding Technology Overview



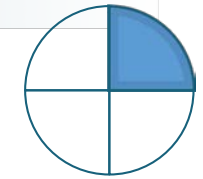
- **Purpose**
  - Develop a system that allows workers to operate the welding process from a remote location yet be in complete control of the equipment
  - Create a method for workers to gain exposure and confidence, and guide future efforts in remote-controlled manufacturing technologies
  - Allow anyone, anywhere to be an active participant in manufacturing enterprise
- **Technology Goals**
  - Develop feedback methods that actively **convey the welding process and surrounding environment** to the worker
  - Develop methods for **capturing worker's responses** or intentions to control a welding operation
  - Develop methods for real-time response of the robotic hardware to **complete the worker's intended** actions to weld

Enabling Tele-Welding



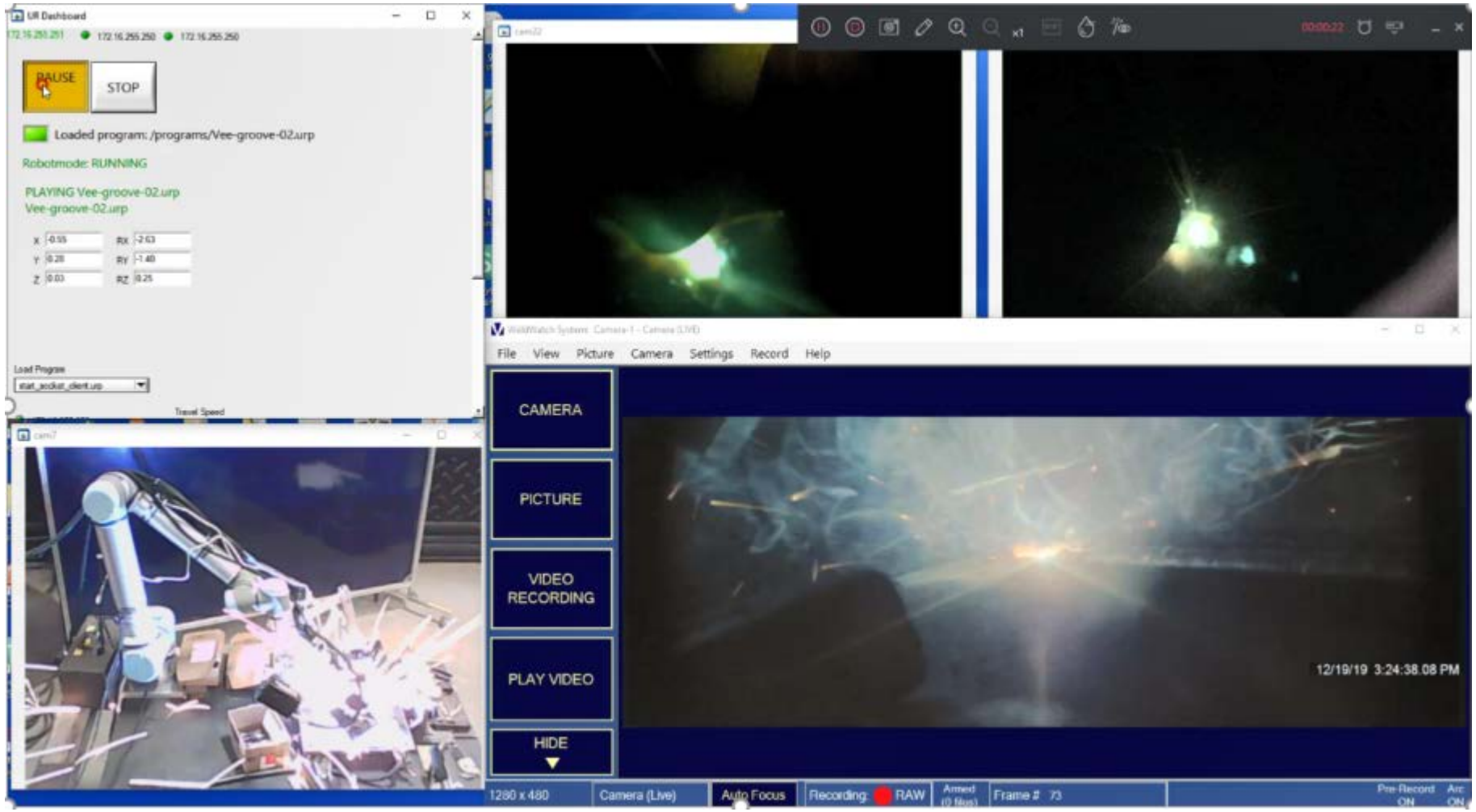
Weld from a remote location, while still in control of the welding process and torch movements.

Convey the Welding Process



- Goal
  - Give the welder sights and sounds of the live welding process to enable enough feedback to make timely welding decisions.
- Methods
  - Cameras and video
  - Audio
- Evaluation Overview
  - Many options for video and sound hardware and software
  - The experienced welder is focused mostly on reading the puddle and hearing the arc
- Future Considerations
  - Delay or latency

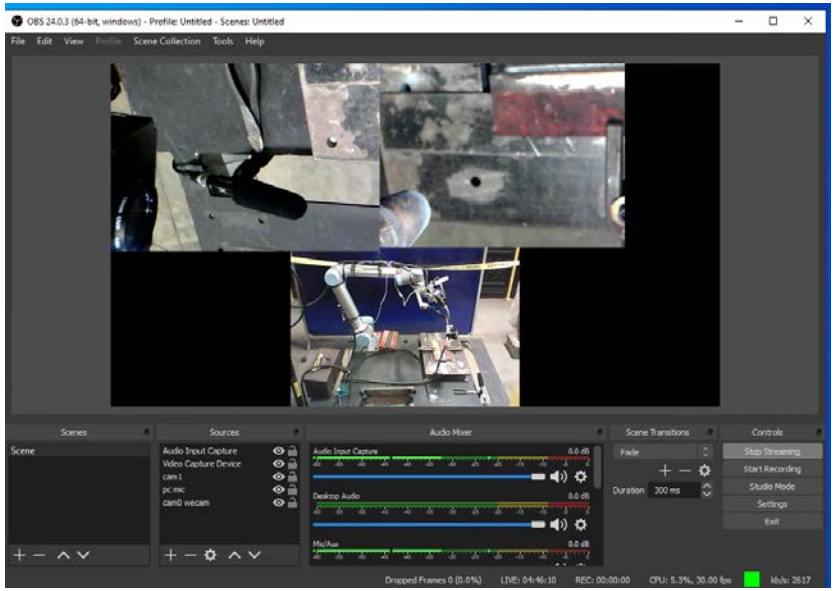
Conveyed the Welding Process

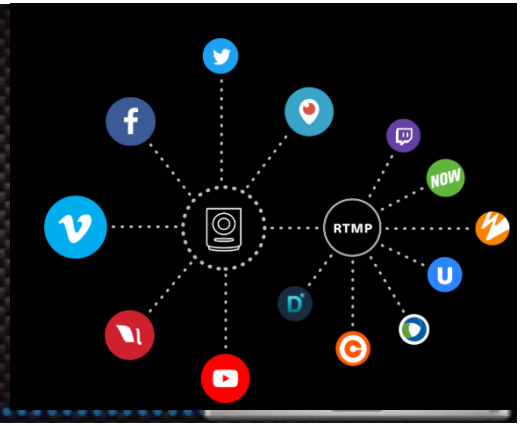


- Inexpensive, digital cameras help with line-up, placement of where to weld.
- Specialty arc welding process camera gives the real-time weld puddle view.
- Microphones add the arc sounds to enable an experienced welder to create acceptable welds remotely.
- Livestreaming camera video and audio provide low latency real-time process.

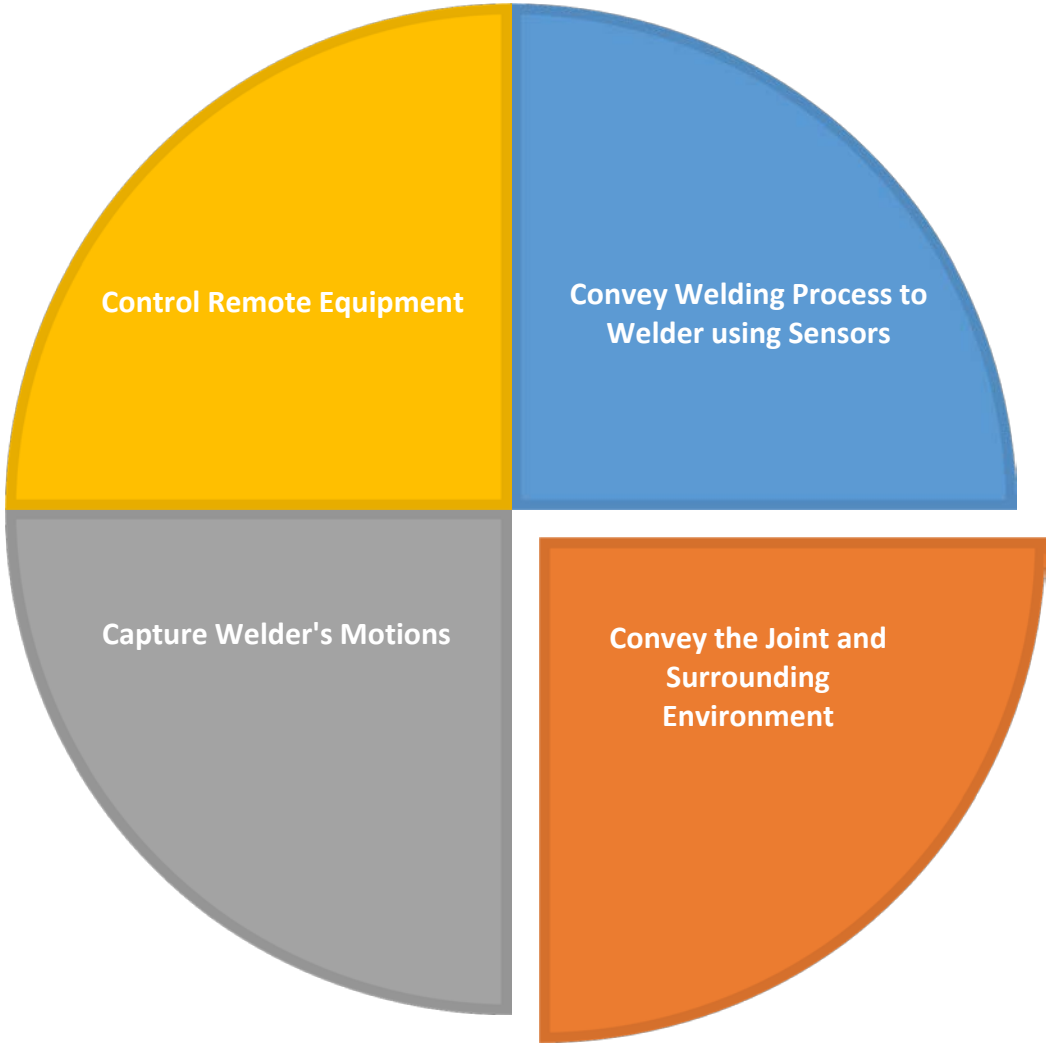
Audio for Weld Process Sound - Evaluation

- Tested several methods to transfer the sounds from the weld booth to the desktop:
  - Windows Remote Desktop
  - PC to PC software (Google)
  - Stand-alone encoder (server)
  - Livestreaming software
- Livestreaming was selected:
  - Both video and audio can be broadcast together
  - Many options for streaming
  - Many options for encoding





Convey the Weld Joint & Surrounding Environment



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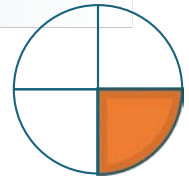
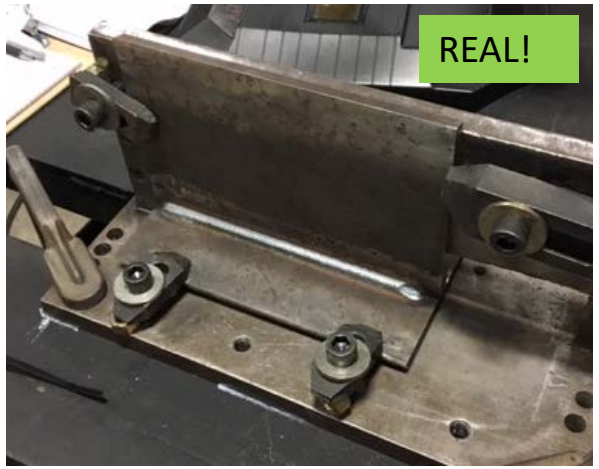
Convey the Weld Joint and Surrounding Environmental Conditions

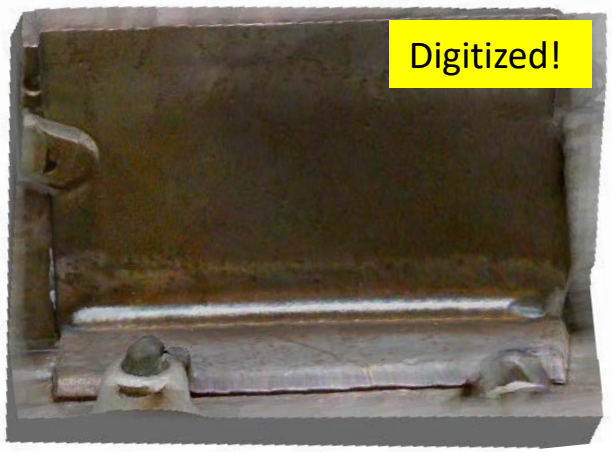


- Goal
  - Digitize the weld joint and surrounding welding environment to enable the welder to feel the environment haptically or see it represented virtually
  - Digitize the environment to coordinate the welder's field of view and frame of reference with the robot's place within it
- Methods
  - IR hand-held scanner
  - Blue light stereovision scanner
  - LIDAR scanning technology
- Evaluation Overview
  - Wide range of commercial and near-commercial options
  - Many possible ways to use the data in future system
- Future Considerations
  - Speed of scanning

Conveyed the Surrounding Environment

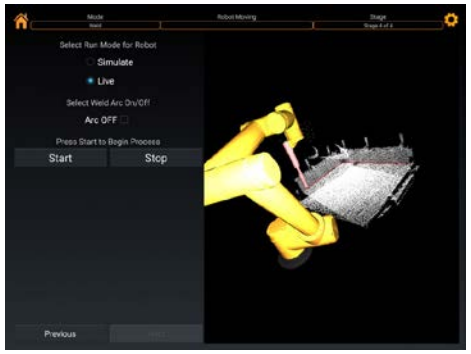
Digitized the Weld Joint and Upcoming Obstacles



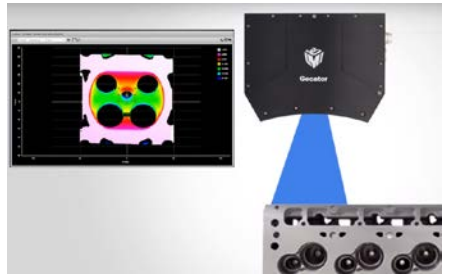


- Scan and Plan before Welding or Digitize in Real Time
  1. Send joint shape to the system to enable haptic response to the scanned area.
  2. Send joint location to the system to align robot and remote manipulator to the same reference plane.
  3. Alert the user of upcoming joint variation or obstacles in the path.

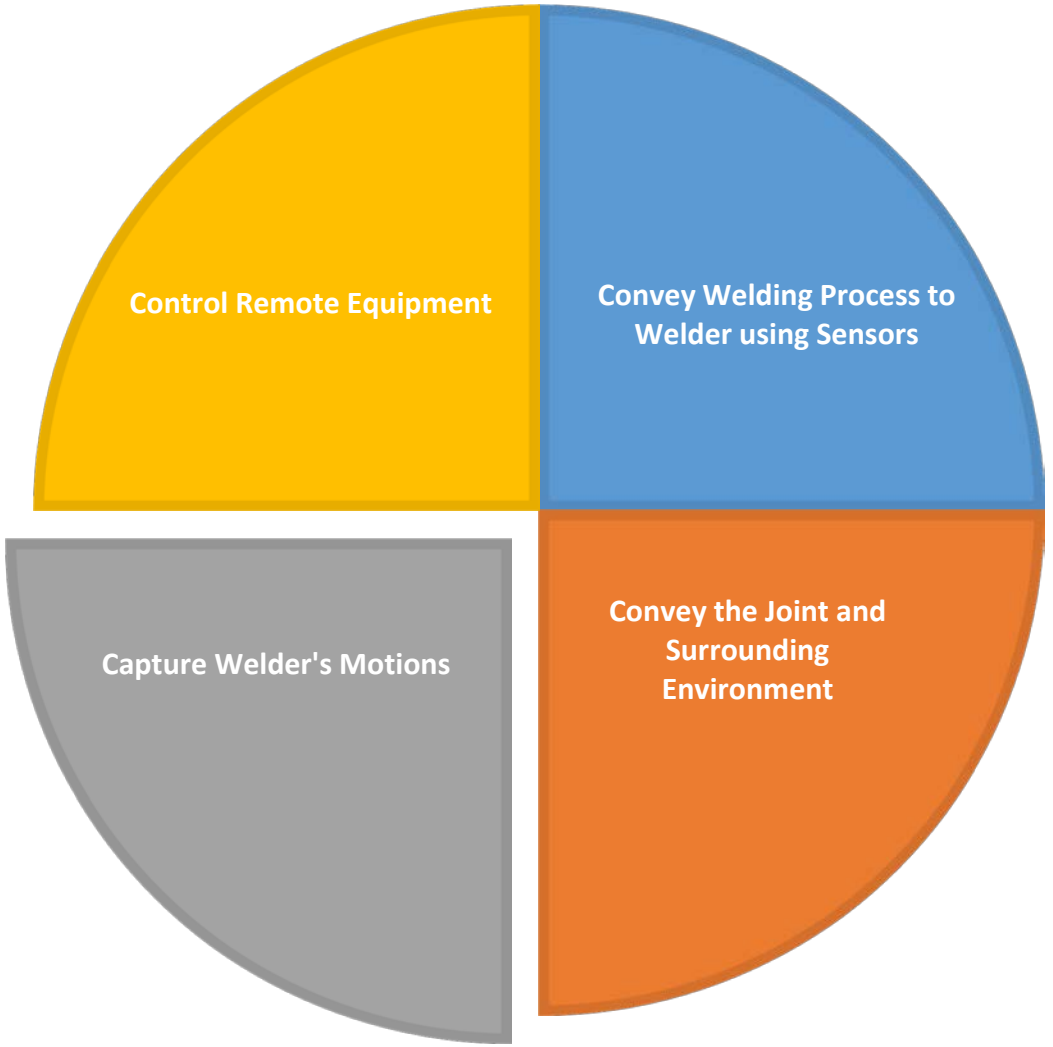
Scan Before Welding



Scan in Real-time



Capture the Welder's Motions



Capture Welder's Motions

- Goal
  - Capture the welder's motions while making a weld and send these motions to a remote robot
- Methods
  - Desktop robot (master-follower approach)
  - Optical target tracking system
  - 3D Stylus mouse
  - Data gloves
- Evaluation Overview
  - All technologies captured motions
  - Some technologies are more complex
  - Direct control using the stylus was most enticing to welders
- Future Considerations
  - Natural vs unnatural motion
  - Comfort of sensing device
  - Established welder versus a new hire

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Captured the Worker's Response & Movements

Evaluated Methods to Acquire Motion and Provide Haptic Feedback

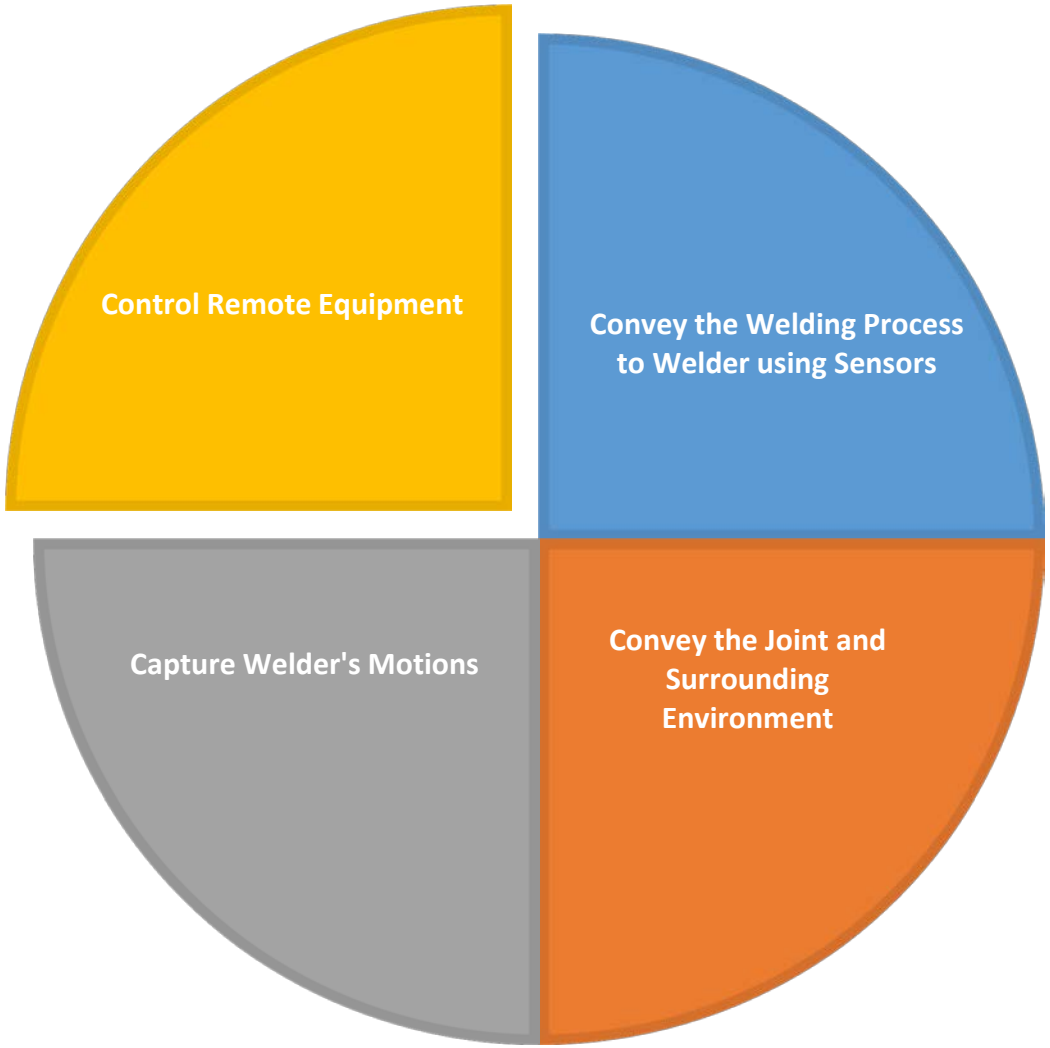
Drag-to-teach cobot with 6 DOF

6DoF optical tracking with multiple cameras and capture software in a single plug-and-play package

Gloves sense direction and orientation

Stylus mouse senses 6 DOF

Control the Remote Equipment



Control Remote Equipment

- Goal
  - Control the robot and convey the welder's desired motions to enable manual welding control at the remote environment
- Methods
  - Joystick mouse
  - Haptic stylus mouse
  - Master-follower with two robots
- Evaluation Overview
  - All methods transferred the motion from user to robot.
  - Direct control using the mini-robot was least complex and did not require a PC.
  - Stylus mouse seemed easiest to move ergonomically.
- Future Considerations
  - Latency in response versus command
  - Fatigue in dragging mini-robot

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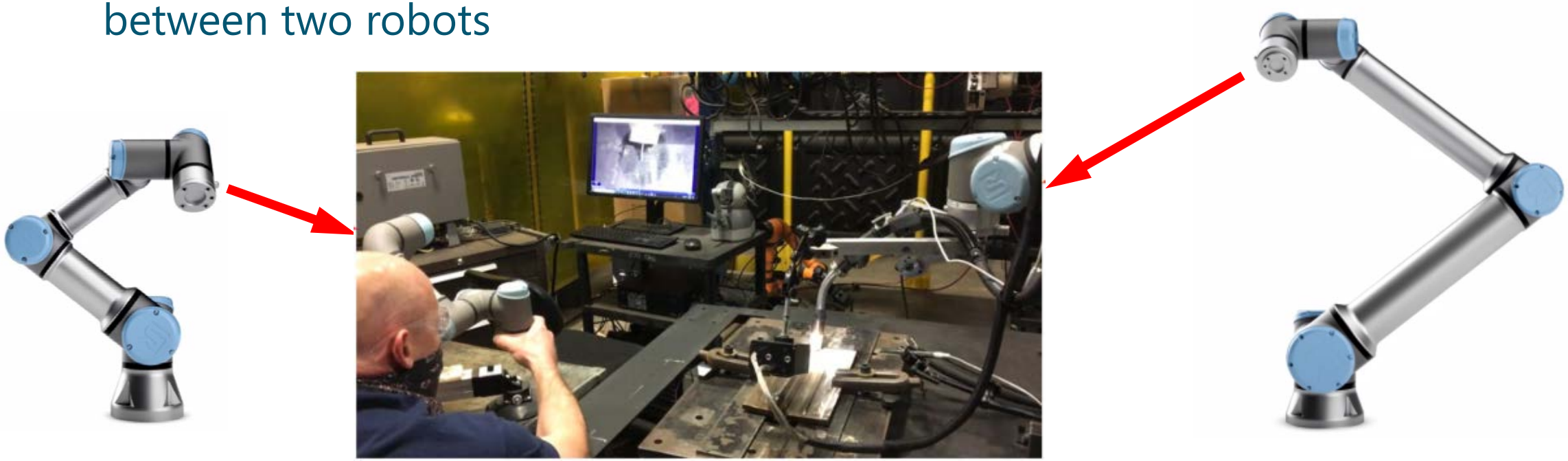
Evaluation of Master-Follower Control Method

UR3- Mini desktop robot

- Evaluated the master-follower approach to convert motion from the small desktop robot to welding robot on the shop floor
- Control method of a direct connection between two robots



Evaluation of Haptic Stylus Mouse Control Method

Current Status

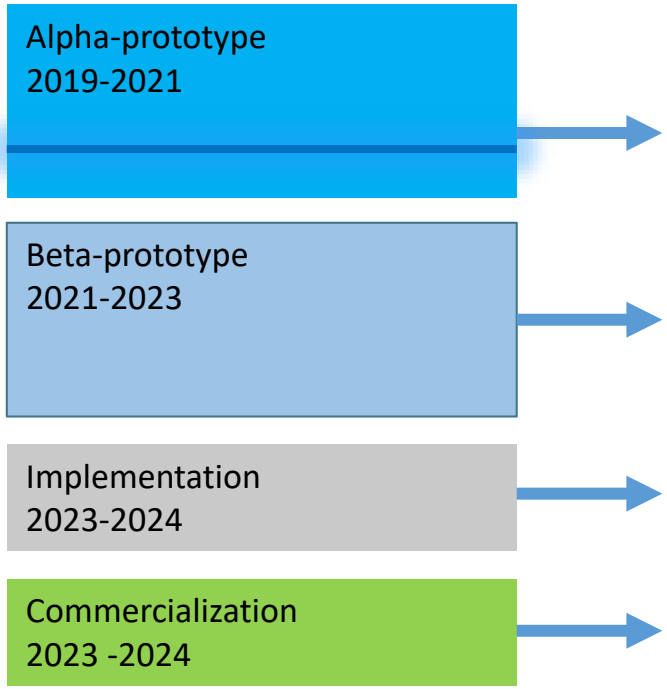
- Two platform solutions have been selected for integration with tele-welding for leave-behind demonstrations of the equipment to the shipyards – a mechanized crawler and a robotic arm.
- The tele-welding technology is being adapted to be used on different platform types.
- New technologies are being evaluated for adding to the system and some technologies are being removed.

Phase 2 Tasks – Create and Demonstrate Portable Prototype

10. Finalize Functionality Specification
11. Create Prototype System Design Architecture
12. Create Mock Shipyard Welding Application (and environment)
13. Demonstrate at EWI
14. Demonstrate System at Shipyards and Begin Evaluation Period
15. Reporting

Phase 2 = June 2020 thru March 2021

Tele-Welding Roadmap - *Shipyard* Applications



In early 2021, a Tele-welding Alpha prototype system will be demonstrated at EWI and in shipyards, allowing shipyard welders the chance to experience Tele-welding.

In early 2023, a Tele-welding Beta prototype able to withstand shipyard use will be delivered to the shipyard and ready for implementation.

Commercial partner supports Tele-welding platform during implementation

Commercial offering of Tele-welding system

Tele-Welding Benefits and Impact

- **Benefits**
  - Shifts welding into a high tech, clean environment
  - Lures next-generation workforce candidates toward welding and manufacturing as a career choice
  - Expands geographical labor pool “beyond the fence”
  - Allow personnel of diverse physical capability levels to be fully productive
- **Business Case Impact**
  - Increased worker productivity
  - Decreased cost of seeking, hiring, and training large numbers of local personnel to meet production
  - Increased first-time quality rate as the most skilled welders can be deployed anywhere, virtually
  - Reduced injury or illness by removing worker from hazardous location

Questions?

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