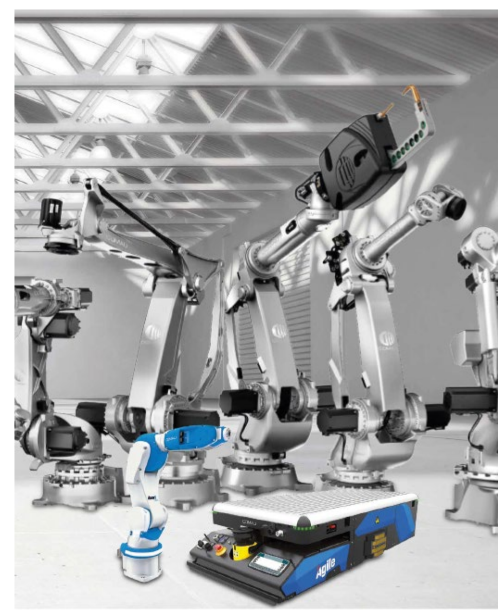
Shipbuilders CoBot Alliance

"Establishment and Operation of a Shipbuilding CoBot Training and Development Center"

(NSRP RA Proposal Control No. 24-02)



Overview of Concept

- Objective – Establish a pipeline for personnel training and qualification, application development, CoBot qualification for Navy work and Research and Development to improve CoBot functionality and versatility in ship construction and repair applications.
- Method –
  - Establish 2 regional Centers, one at NWTC in Marinette, WI run by Northern Wisconsin Technical College and a second at Weld America, Colonnas Shipyard in Norfolk, VA run by GENEDGE, the VA MEP.
  - Equip each center with CoBot application cells,
    - » cutting, grinding, paint removal, fitting and welding.
  - Centers will be equipped with testing equipment to fully qualify all processes,
    - » emphasis on equipment that can perform the fatigue cycle tests that are currently required by NAVSEA Tech Pub 248.1 for robotic welding.

Initial Locations

Shipbuilding CoBot Alliance

Need/drivers

- CoBots are changing the face of manufacturing worldwide
- CoBots have inherent characteristics that make them well suited for shipbuilding (ease of training, collaborative working, portability, ease of use)
- High rates of adoption in other manufacturing industries
- All shipyards are wrestling with how to learn, train, implement CoBots, right now

Shipbuilding CoBot alliance

- Early consortium and framework to provide central location for:
  - Training, demonstration, design for implementation, support, growing community of learners, new workforce development
- Model to develop curriculum, space, collaborations
- Develops tools (curriculum, resources, techniques) that will be freely shared to expand or create more training centers near areas of high need

Physical centers

- Training cells with multiple CoBots from major vendors for shipbuilding community including Miller Copilot, Lincoln Cooper, Comau MR4 and EASB Edge
- Trainers and support personnel both full time and as needed
- Cells available for practice, training, demonstration, evaluation for shipyards and suppliers
- Each center to have 1-2 implementation demonstrations; demonstration of practice and in-field demonstration
- Centers will gather data for evaluation of CoBot-produced welds for qualification

Notes and Key Outcomes

- Timing is critical for this work
  - Centralized training, development and evaluation center is of need to all yards
  - This need is now
  - It will inform yards as they plan to spend critical dollars in new technology
- This proposal started with small yards to achieve earliest in-field implementation and in order to avoid a bias
- The developments (Curriculum, training, training for trainers, even physical CoBot training cells) will be shared and can be transferred to other sites during the life of the project
- Two centers will start – Wisconsin and Virginia, we expect these to grow to during the project to support key needs of the shipyards to develop CoBot knowledge and database

What a CoBot cell and early implementation might look like: Miller Copilot™

Curriculum to be developed

Proposed CoBot Training Modules and deployment schedule (details in Appendix)			
Title (Year 1)	Primary objectives	Title (Year 2)	Primary objectives
Collaborative robot operations	Fundamentals of programming and working with CoBots	Integrating vision systems with CoBots in manufacturing:	Integrating weld sensors with CoBots
Collaborative Robotics Welding I	Fundamentals of programming weld operations with CoBots	Collaborative Robotics in advanced manufacturing roles	Applications of CoBots to other manufacturing tasks (plasma arc, grinding, cold spray, etc.) case studies.
Collaborative Robotics Welding II	Intermediate skills at CoBot weld programming: complex shapes, simple sensors	CoBot safety: implementation to meet technical standards on safety	Review of ISO 10218-1,2 and ISO/TS 15066 standards for CoBot safety
Collaborative Robot Mechanical, Electrical, Maintenance	perform CoBot maintenance	Collaborative Robotics Portable Welding	Using CoBots in mobile or portable applications

Perform fabrication on small runs of small to medium size components

Direct implementation of commercial systems

Located in welding shop

Available for on-sight training/practice when not in production use

Curriculum

Curriculum

Overview of courses

Table II Proposed CoBot Training Modules and deployment schedule (details in Appendix)

Title (Year 1)	Primary objectives	Title (Year 2)	Primary objectives
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Collaborative Robot Mechanical, Electrical, Maintenance	perform CoBot maintenance	Collaborative Robotics Portable Welding	Using CoBots in mobile or portable applications

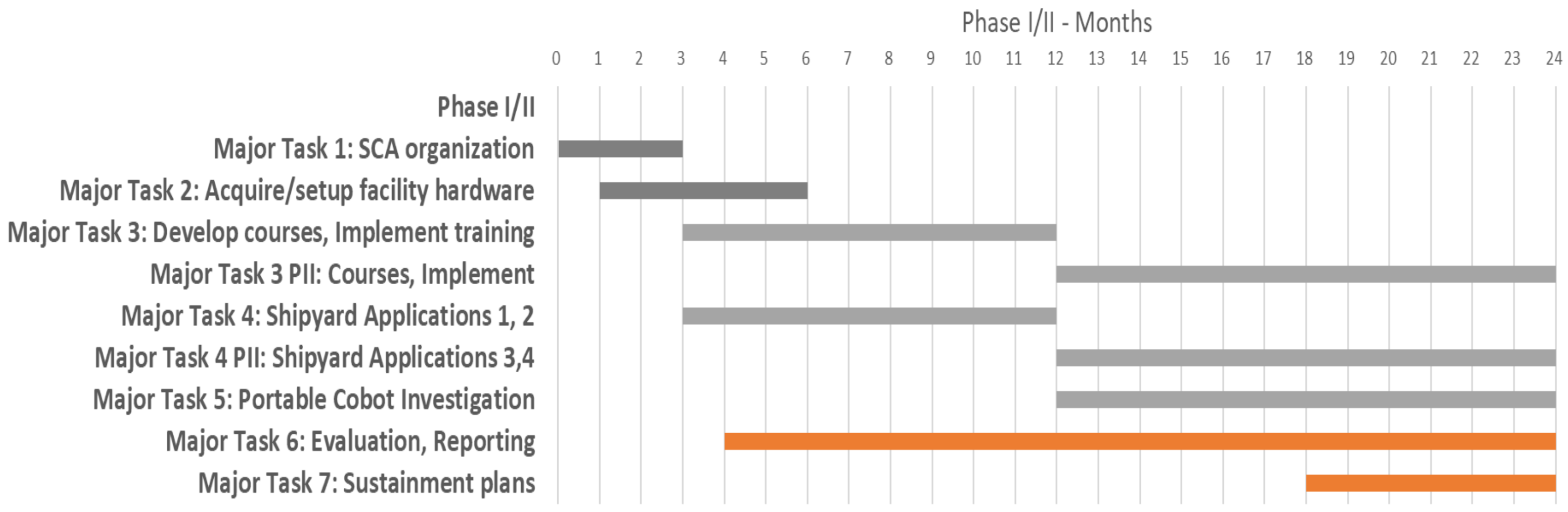
Sample Course Content

Collaborative Robot Operations	Collaborative Robotic Welding 1	Collaborative Robotic Welding 2	Labs
0. Safety			0. Safety controls and setup
1. System Overview	10. Welding		1. Proper setup and configuration
2. Power, connection, setup	11. Advanced Program Functions		2. Basic system control
3. Basic Motion Control	12. Practical Considerations		3. Advanced Motion Control
4. Teach Pendants	13. Managing program files		4. Weld Operations – Groove and Fillets
5. Errors	14. Calibration		5. Weld Operations – Circular
6. Robot Motion planning	15. Preventative Maintenance		6. Weld Operations – Weave control
7. Creating a Program	16. Common Problems and solutions		7. Weld Operations – Advanced weld control
8. Testing/ Running a Program	17. Planning robotic welds		8. Optimizing Weld Operations
9. Editing a Program			9. Debugging

Participants

- Committed vendors
  - Lincoln Electric
  - Miller Copilot
  - ESAB
  - Comau
  - SwitchWeld
  - Atmospheric Plasma Solutions
- Committed shipyards
  - FMM Marinette
  - Newport News Shipbuilding
  - Colonnas Shipyard
  - Master Boatbuilders
  - Pacific Shipyards
- Management Team
  - CahillConsulting, LLC
  - Hepinstall Consulting Group, LLC
- Center Management
  - NWTC
  - GENEDGE
- Technology Team
  - Robotic Technologies of Tenessee
  - Edison Welding Institute
  - VA Digital Maritime Center

Timeline


Phase I/II - Months
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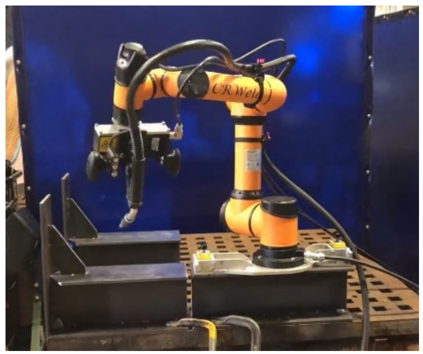
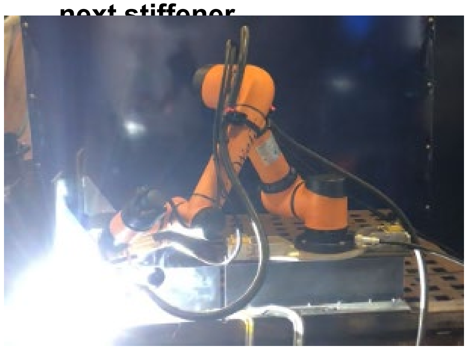
Phase I/II
Major Task 1: SCA organization
Major Task 2: Acquire/setup facility hardware
Major Task 3: Develop courses, Implement training
Major Task 3 PII: Courses, Implement
Major Task 4: Shipyard Applications 1, 2
Major Task 4 PII: Shipyard Applications 3,4
Major Task 5: Portable Cobot Investigation
Major Task 6: Evaluation, Reporting
Major Task 7: Sustainment plans

High Mobility CoBots in Ship Manufacturing

Portable CoBot

1) **Operator places HMMR on stiffener and switches mag-locks**
2) **Robot scans and welds stiffener and gusset on either side**
3) **Operator releases mag-locks, slides HMMR to the next stiffener**





CoBot Integrating with Positioner

CoBot: A definition

CoBot – <u>Co</u>llaborative ro<u>Bot</u>

Robot intended for direct human interaction with shared space or proximity (IFR)

- **Traditional robotics – separate robots from human contact during operation (safety)**
- **Cobots – achieve safety through weight, materials, geometry, sensing, controls**

Recent development (1997 patent) stemming from GM robotics center and University research

Four Levels of Collaboration between worker and cobot (IFR)		
Coexistence	Work side by side (no protective barrier)	
Sequential Collaboration	Share the workspace	
Cooperation	Work on the same part, at the same time	
Responsive Collaboration	Cobot responds to worker	

Cobot companies - timeline

- Cobotics (late 1990's) - Automotive assembly
- Kuka cobot – 2004 (LBR series)
- Universal Robotics (2008)
- Rethink Robotics – (2011) Baxter
- Yasakawa (Motoman, 2013)
- AUBO robotics (2014, Smokie Robotics)
- FANUC (2015) CR series
- ABB (2015) YuMi
- Welding Examples
  - Fabtech 2018 – 2 welding cobots
  - Fabtech 2023 - 20+?

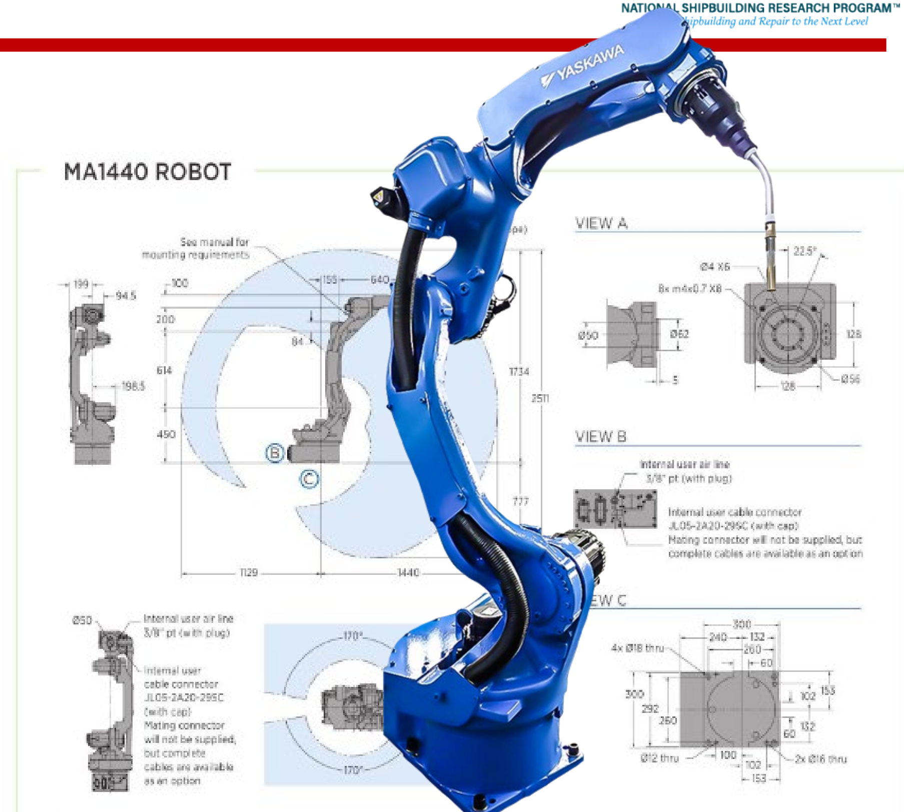
Comparing robot specifications: Collaborative Vs. Traditional

UR10 Technical specifications

Item no. 110110

6-axis robot arm with a working radius of 1300 mm / 51.2 in

Weight:	28.9 kg / 63.7 lbs
Payload:	10 kg / 22 lbs
Reach:	1300 mm / 51.2 in
Joint ranges:	+/- 360°
Speed:	Base and Shoulder: 120°/s. Elbow, Wrist 1, Wrist 2, Wrist 3: 180°/s. Tool: Typical 1 m/s. / 39.4 in/s.
Repeatability:	+/- 0.1 mm / +/- 0.0039 in (4 mils)
Footprint:	Ø190 mm / 7.5 in
Degrees of freedom:	6 rotating joints
Control box size (WxHxD):	475 mm x 423 mm x 268 mm / 18.7 x 16.7 x 10.6 in



All dimensions are metric (mm) and for reference only.
Request detailed drawings for all design/engineering requirements.

SPECIFICATIONS

Axes	Maximum motion range [°]	Maximum speed [°/sec.]	Allowable moment [N•m]	Allowable moment of inertia [kg•m²]
S	±170	230	-	-
L	+155/-90	200	-	-
U	+240/-175	230	-	-
R	±150	430	10.5	0.28
B	+90/-135	430	10.5	0.28
T	±210	630	3.2	0.06

Controlled axes	6
Maximum payload [kg]	6
Repeatability [mm]	±0.08
Horizontal reach [mm]	1,440
Vertical reach [mm]	2,511
Temperature [°C]	0 to +45
Humidity [%]	20 - 80
Weight [kg]	130
Power rating [kVA]	1.5
Internal I/O cable (feeder control)	18 conductors
Internal gas line	(1) 3/8" connection

Similar payload and reach, 29 vs. 130kg arm mass

Cobot Theory, Standards and guidelines

- ISO 10218-1/2:2011 Safety Requirements for Industrial Robots
- ISO/TS 15066:2016 Robots and robotics devices – Collaborative robots
- Subject to Quasi-static and transient effects
- Bounds on mass, speed control, and torque sensing

→

Operational impacts on cobot design

- **Weight/mass**
- **Speed**
- **Accuracy**
- **Stiffness**
- **Exterior shell**

Cobot features

- **Real-time force sensing**
- **Speed-limiting**
- **Defined working boundaries**

Portable coBot applications:

HMMR (Cobot on mobile platform)

Man-Portable cobot systems

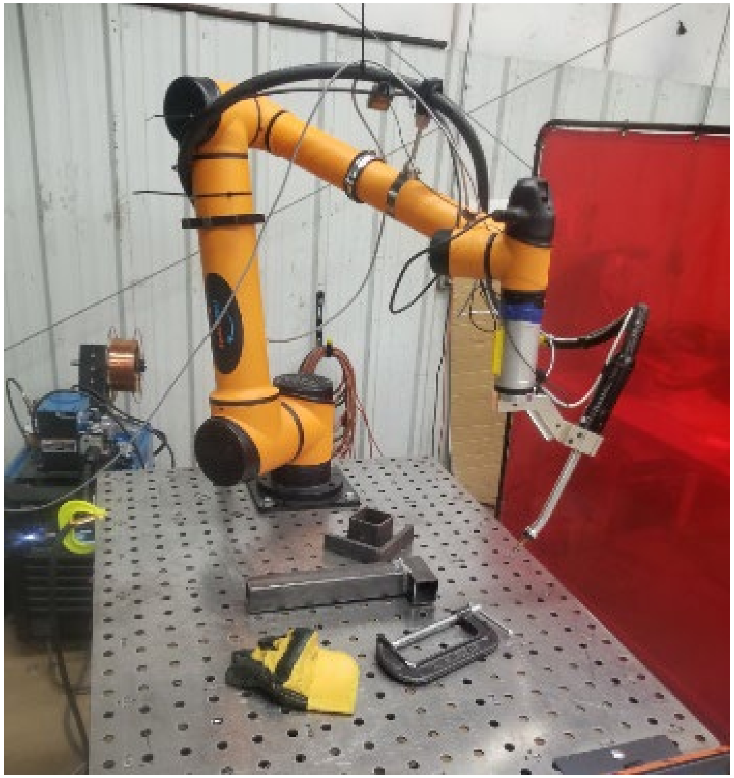
Integration with track/positioners

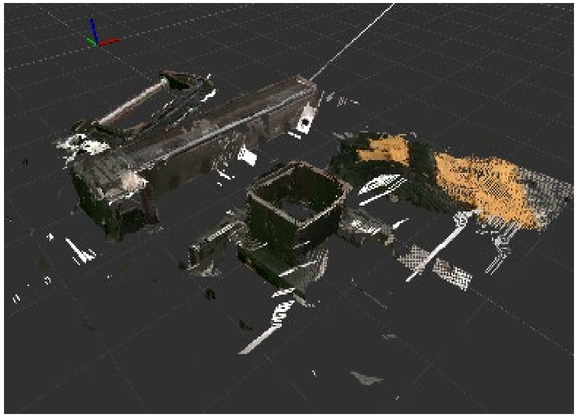
Cobot workspace sensing to Aid protability

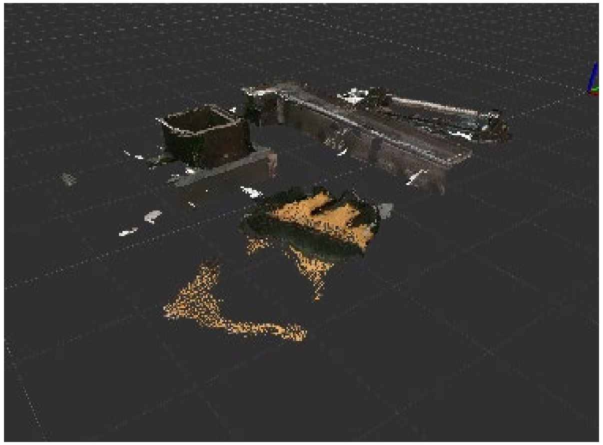
Portable Welding Cobot with end-effector-mounted depth camera

Scan Workspace, ID trained workpiece

Localize



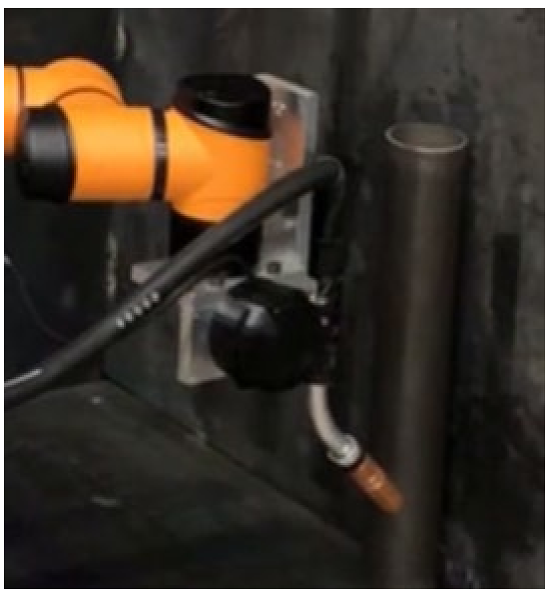


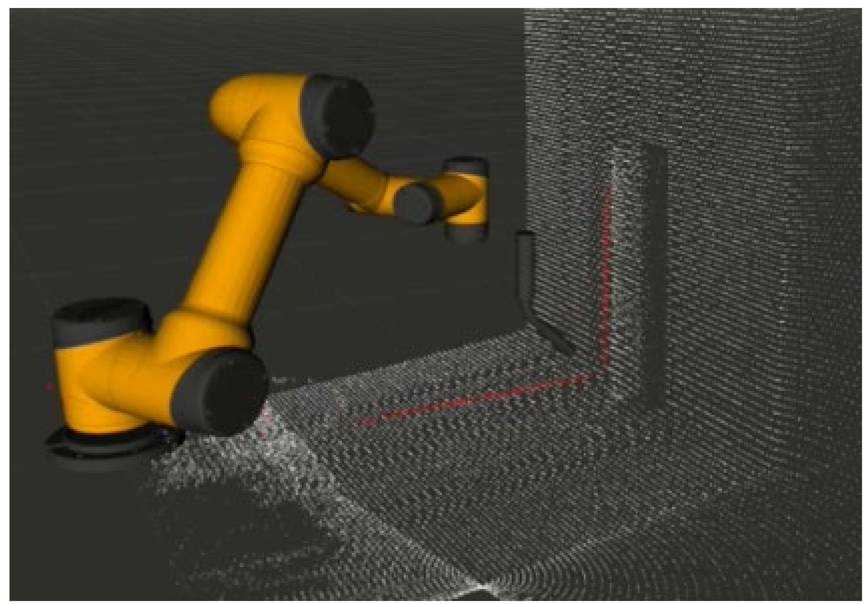


Scanning Tool – Lidar

Scanning Lidar

- Generate point cloud
- Use to find key features
- Detect objects

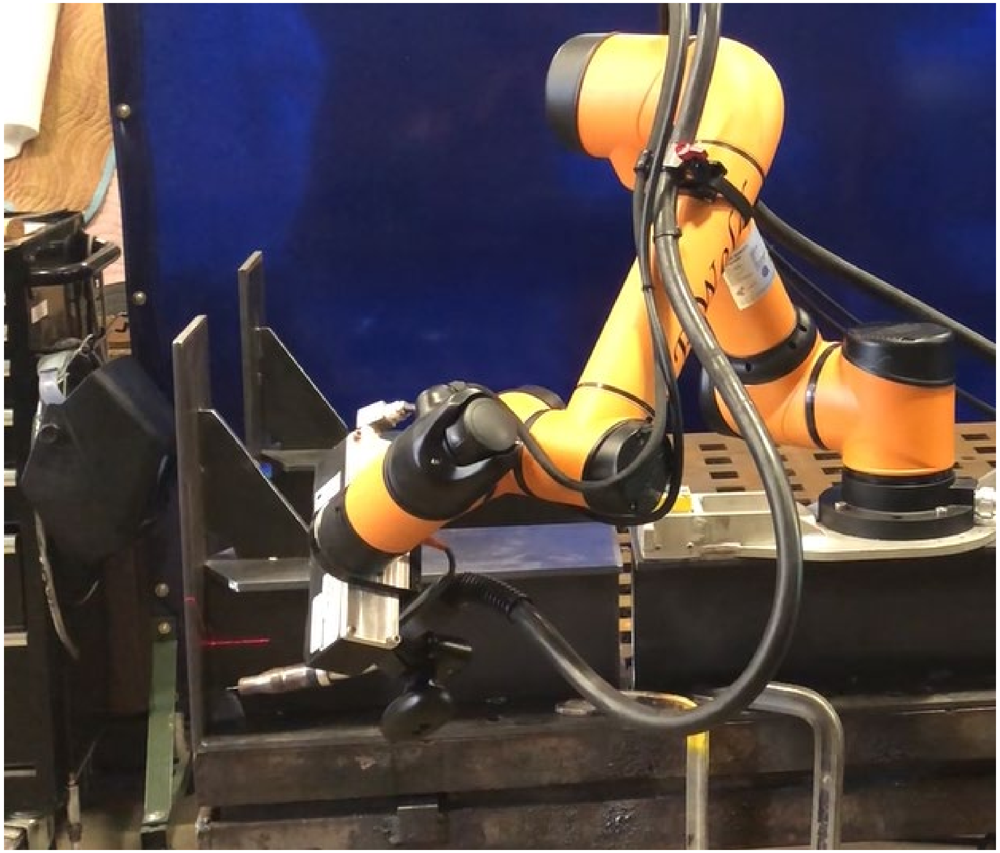




Laser Line Scanning

Laser-line or Structured Light

- **High resolution scan of the work seam**
- **High resolution**
- **Small viewable space**
- **Predefine workpiece**



Sample Problems for Portability

1) **Increase the range of opportunities for mechanized welding through a lightweight, portable (or mobile) robot**
2) **First, apply to general fillet weld types**
    1) **2F (Horizontal)**
    2) **3F (Vertical)**
    3) **4F (Overhead)**
3) **Second, apply to specific jobs (welds joining stiffeners to deckplate, bulkhead intersections)**

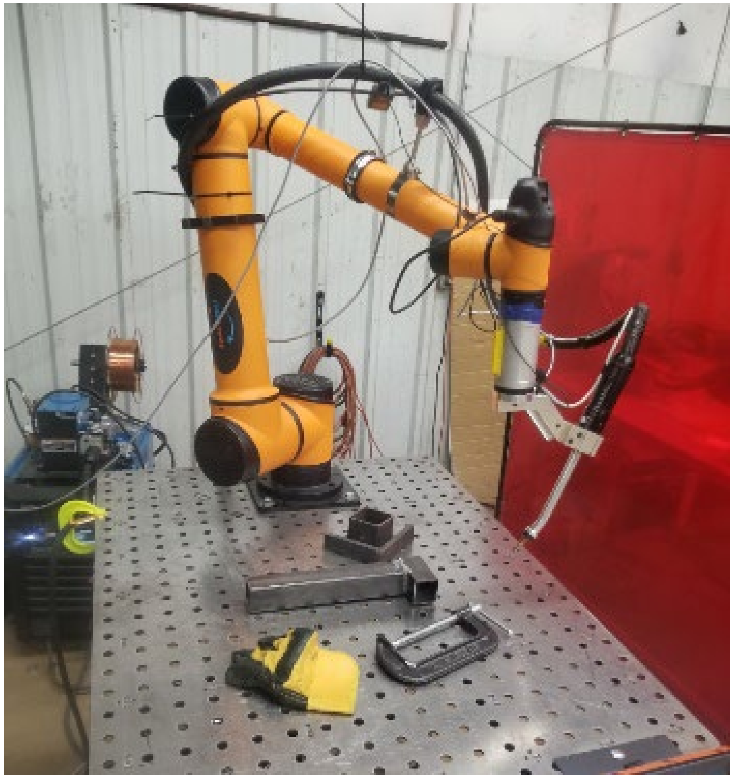
Motivating problem:

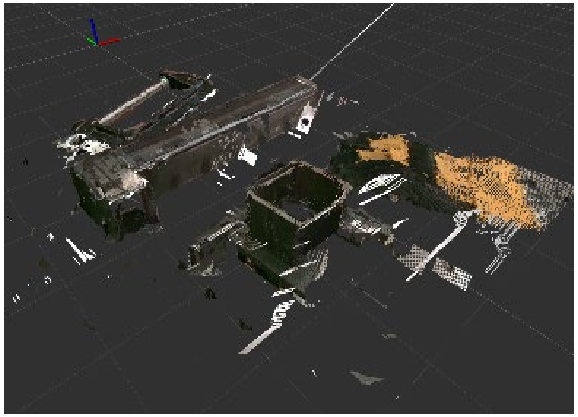
Demonstration of Scanning Automated Path-planning

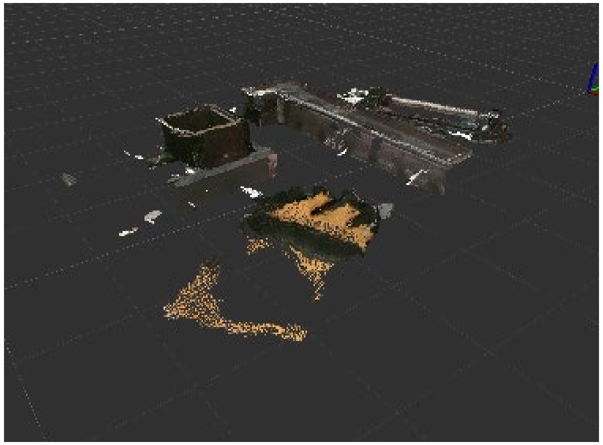
Portable Welding Cobot with end-effector-mounted depth camera

Scan Workspace, ID trained workpiece

Localize







CahillConsulting, L.L.C.

RTT

Ex Scientia Tridens, '83

Demonstration of HMMR Hardware

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Questions