Weld Panel Meeting 2024

“Multi-Function Shipbuilding Robot”

Presented By:

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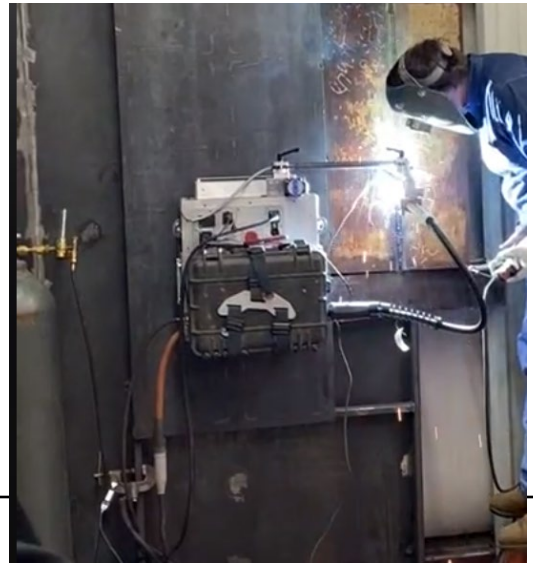


RTT Robotic Technologies of Tennessee LLC

NSRP National Shipbuilding Research Program™ Taking Shipbuilding and Repair to the Next Level

Overview

1. Project Overview/Objectives
2. Prototype Design
3. Base System
4. Control Layout
    1. Local Control HMI
    2. Remote Control HMI
5. Weld Interface
6. Platform
7. Project Schedule
8. Deliverables
9. Questions & Conclusion

Project Overview/Objectives

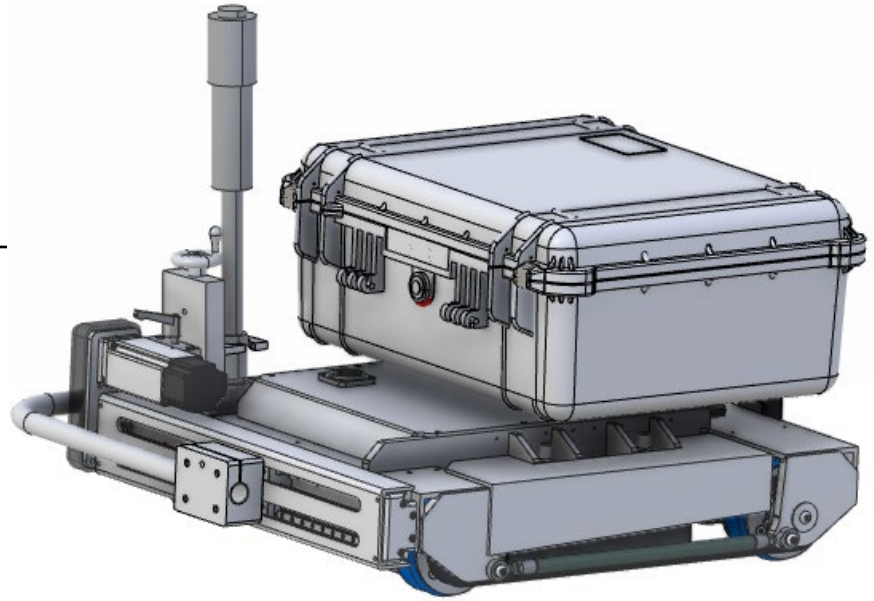
Project Goals

- **Goal 1** – Decrease labor hours and resources required to erect scaffolding and track welding set up.
  - Man-lifts and craft support may still be required for the robotic system and the final inspection processes. However, subsequent elimination of the required scaffolding will provide significant labor savings as well as elimination of the craft services required for setting-up the scaffolding.
- **Goal 2** – Decrease labor hours needed to weld erection joints by 50%.
  - While the weld parameters / weld speed is not expected to change, the “arc on-time” for the weld process will be increased. Thus, the overall hours required to complete the welds will be decreased.
- **Goal 3** – Decrease hours needed to rework and re-inspect welds by 50%.
  - The increased weld quality provided by a mechanized welding process will result in reduction of rework and the resulting re-inspection.

Prototype Design Overview

RTT's Mobile Robot Manufacturing System (MRMS)

- Welding, weld preparation, and inspection tasks
- Vertical and horizontal erection joints
- Trackless mobile robot uses suspended permanent magnets to climb ferrous surfaces
- Skid-steer drive platform allows for turning-in-place maneuvers
- High payload enables the system to carry all necessary equipment and perform manipulation of tooling
- Tooling is mounted to a weaver at the front of the unit



Miller Electric Mfg. LLC

Miller 8VS Suitcase Wire Feeder

Prototype Design – Control Layout

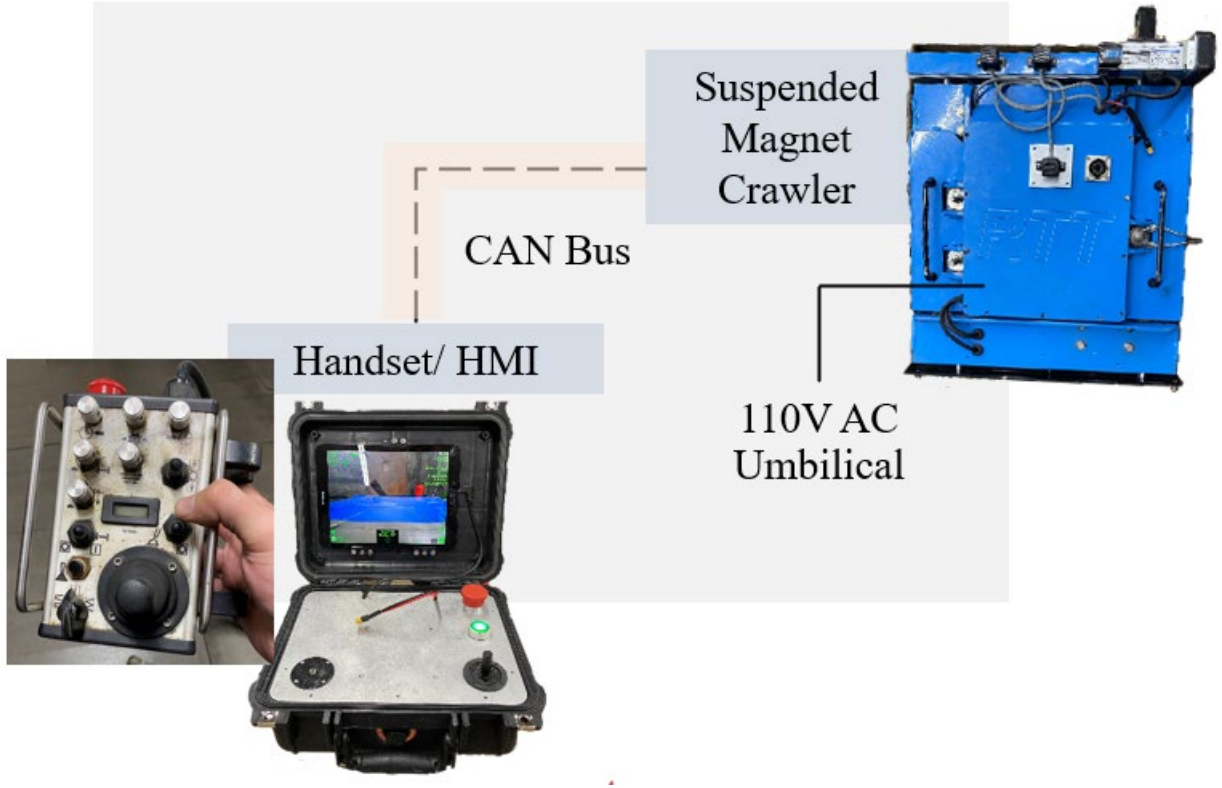
MRMS Control Box and Crawler

- Crawler is powered with 110V AC into an onboard power supply
- Commands sent from a wired pendant handset/ HMI

Torch Manipulator:

- 4 DOF torch control

2 Independent Control Options
- Handset Pendant
  - Operator within vicinity of MRMS
  - No visual feedback
- Human Machine Interface Workstation
  - Operator is more remote
  - Visual feedback



Control Layout – What will be implemented

As part of this project, RTT will implement two control interfaces, both interfaces are interchangeable and can be use with the prototype hardware

- Local operator interface
- Fully remote interface

The local operator interface is readily used by weld technicians and will facilitate near-term adoption

- This interface will be incorporated for onsite testing

The fully remote interface allows remote operation and will facilitate long-term remote and even some autonomous tasks on the crawler

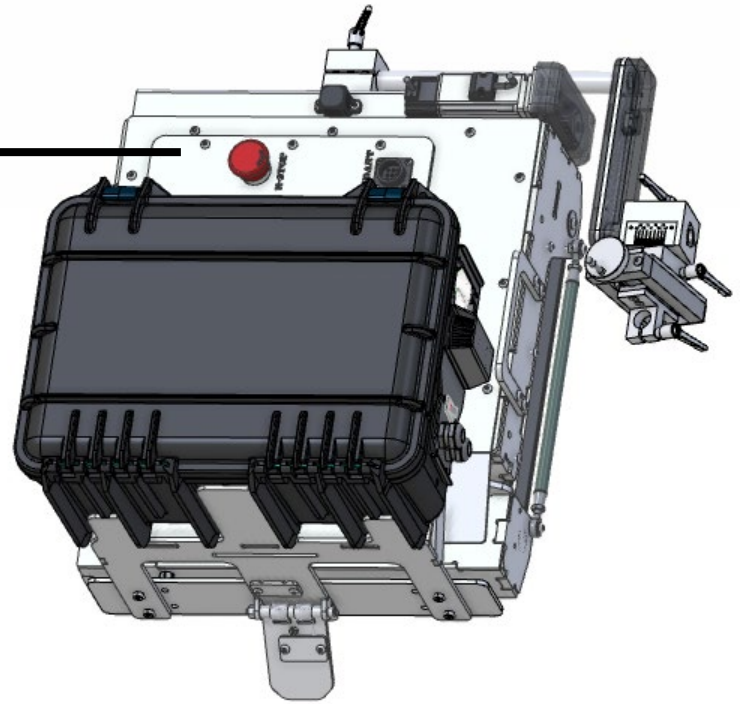
- This interface will be incorporated for demonstration

The following slides demonstrate each interface

Prototype Design – Local Operator Interface

Operator manually adjusts welding parameters from the control panel on the suitcase wire feeder

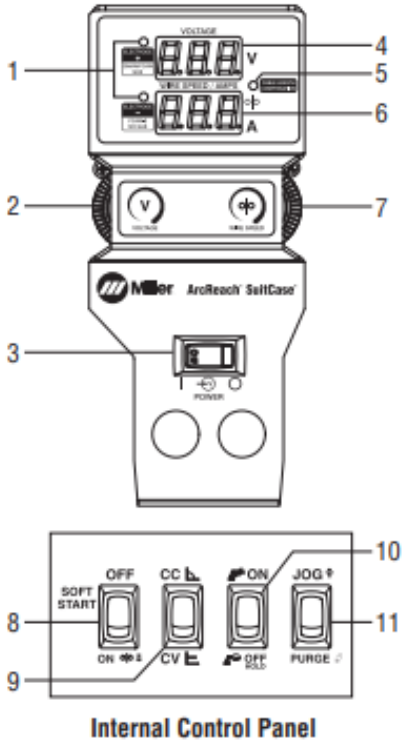
Operator visually inspects system performance and adjusts motion parameters from the handset



Prototype Design – Local Operator Interface

Miller ArcReach SuitCase

- Welding suitcase mounted on crawler
- Settings and display features shown below
  - Display
    - Voltage
    - Wire Speed/Amps
    - Polarity
  - Inputs (Pre & During Welding)
    - Voltage
    - WFS/Amps
  - Inputs (Pre-Weld Only)
    - CC/CV Switch
    - Jog/Purge Switch
    - Soft Start Switch



Internal Control Panel

1. Polarity Indicators
2. Voltage Control
3. Power Control Switch
4. Voltmeter
5. Cable Length Compensation (CLC) Indicator
6. Wire Speed/ Amperage Meter
7. Wire Speed Control
8. Soft Start Switch
9. CC/CV Switch
10. Trigger Hold Switch
11. Jog/Purge Switch

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Prototype Design – Handset Pendant

MRMS Handset Pendant

- Used by operator within 20’ of base unit
- Coiled cable terminating to strain relieved connection on the crawler

Features

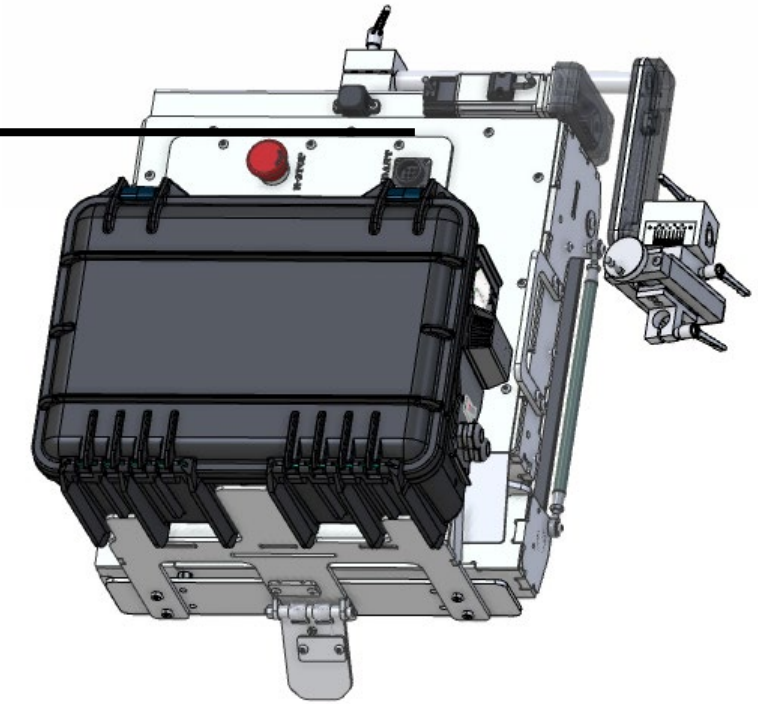
- E-Stop
- Weave Width
- Weave Center
- Weave Speed
- Travel Speed
- Weld Trigger
- Multipurpose
  - Cycles Settings
  - Dwell Times
  - Weave Shape
- Autodrive Switch
- Joystick
- Multicolor IPS Panel Display

Autodrive

- When enabled, autodrive disables joystick inputs and locks the MRMS heading and speed

Prototype Design – Fully Remote Interface

Operator observes welding parameters from HMI workstation remotely



Operator views camera feed and adjusts motion parameters from the instrumentation on the HMI workstation

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Prototype Design – Fully Remote HMI

Fully Remote HMI Workstation

- Used by operator from ground
- Cable terminating to strain relieved connection on the crawler

Features

- E-Stop
- Weave Width
- Weave Center
- Weave Speed
- Travel Speed
- Voltage and WFS
- Weld Trigger
- Multipurpose
  - Cycles Settings
  - Dwell Times
  - Weave Shape
- Autodrive Switch
- Joystick
- Multicolor IPS Panel Display

*Concept image only

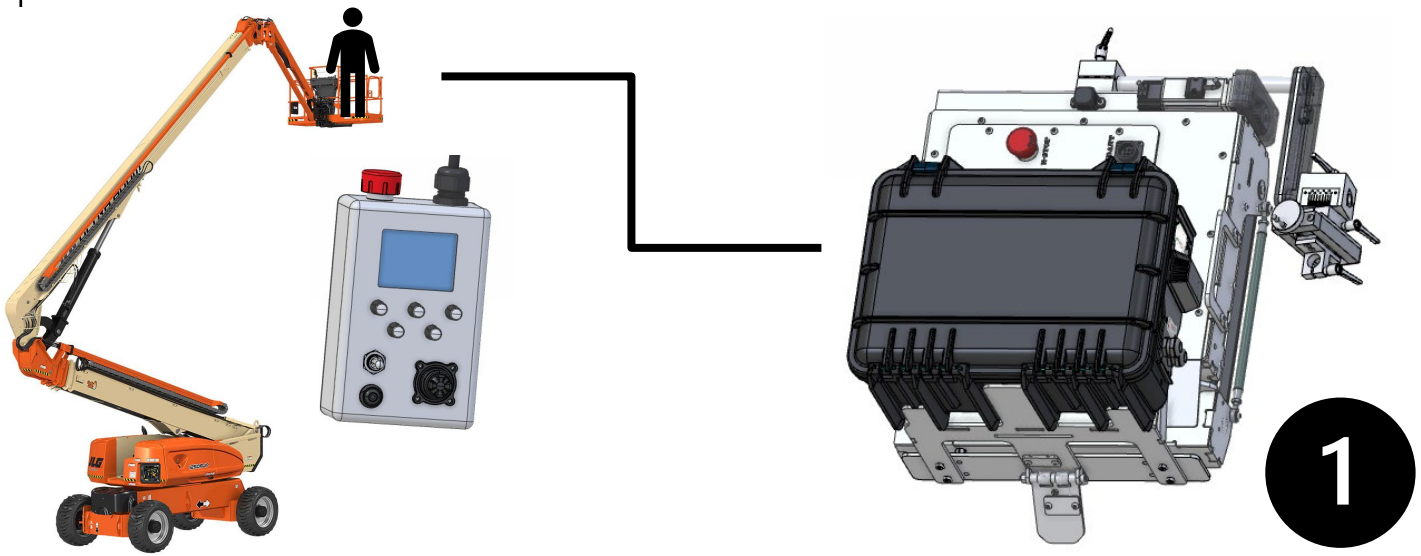
Autodrive

- When enabled, autodrive disables joystick inputs and locks the MRMS heading and speed

Near-Term & Long-Term Implementation

1) Near-term implementation will match what is familiar to weld technicians featuring a local operator interface. The local operator interface will consist of 1) handset pendant for commanding the MRMS position and orientation, torch positioning parameters, and arc state and 2) suitcase wire feeder for adjustment of welding parameters.

2) A fully remote interface will support **long-term remote operation** and explore some autonomous tasks on the MRMS. This will be incorporated for demonstration only.



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Long-Term Remote Operation

- The fully remote implementation for long-term remote operation will investigate options for closed loop and remote control of welding parameters (amps, volts, wire feed speed). Initial in-house-only demonstration will use Miller S-74 MPa wirefeeder with cobot communication interface.
- Information provided to the operator is current weld information
- The HMI screen will output diagnostic information to the operator regarding MRMS status

2

Available System Adjustments

1) Fine-tune programming adjustments are available for torch motion on the local operator interface's handset pendant and welding parameters on the suitcase wire feeder

2) Fine-tune programming adjustments will be demonstrated in-house only at RTT for the fully remote implementation on the HMI.

Handset Pendant Adjustments

- Weave Width
- Weave Center
- Weave Speed
- Travel Speed
- Dwell Times

Suitcase Adjustments

- Voltage and Wire Feed Speed

HMI Adjustments

- Weave Width
- Weave Center
- Weave Speed
- Travel Speed
- Dwell Times
- Voltage *
- Wire Feed Speed *

* Demonstration only at RTT

Closed Loop Welding Demonstration

*Concept image only

- Closed loop or remote control of welding parameters will be demonstrated for long-term remote interface on multi-function shipbuilding prototype
- ***Near-term implementation will require operator in loop using suitcase wirefeeder knobs for parameter adjustment***
- For closed loop welding, plan is to demonstrate using Miller's S-74 MPa wirefeed and cobot communication interface
- ***Demonstrate only at RTT facilities***

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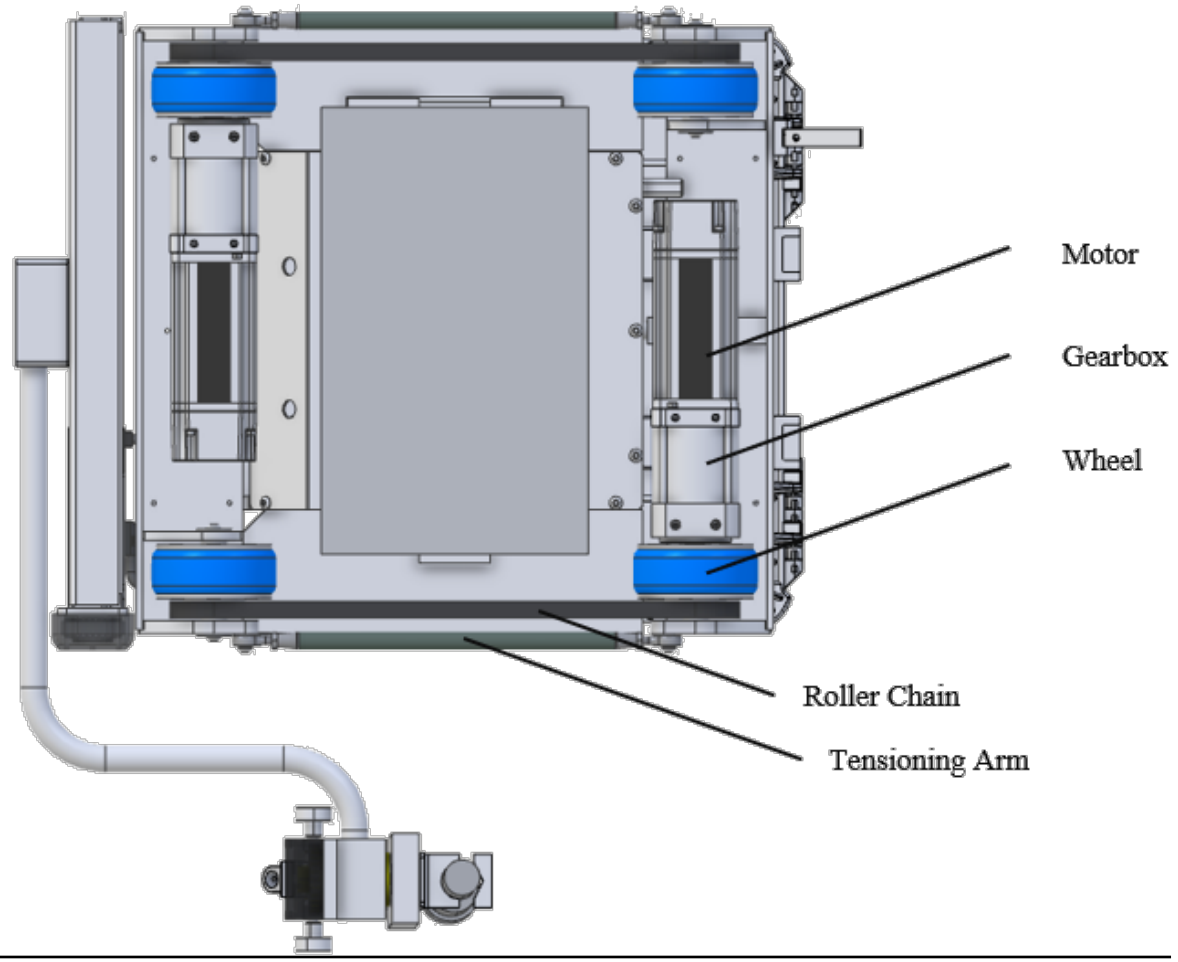
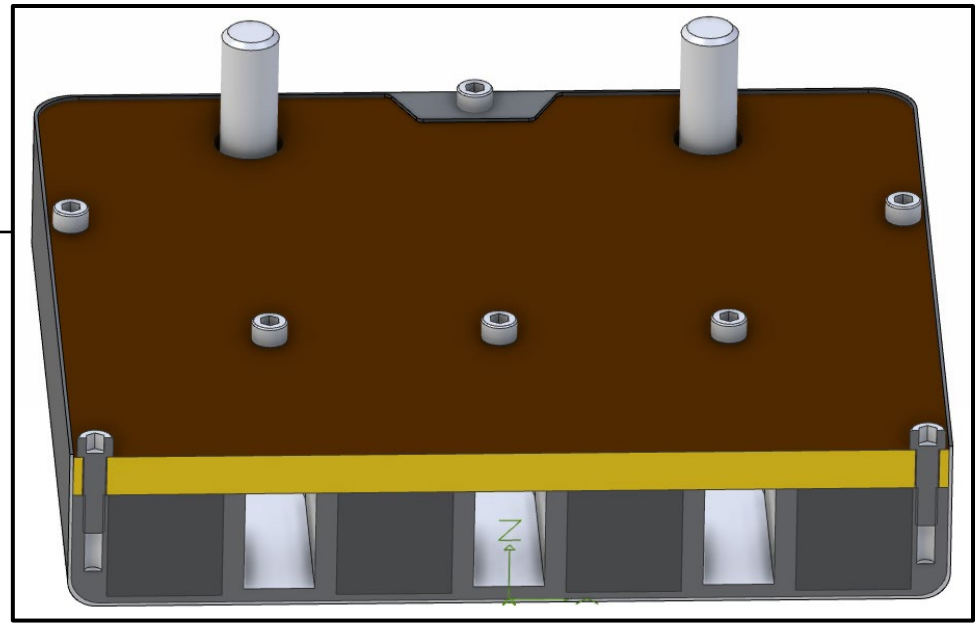
Prototype Design - Drivetrain

MRMS Drivetrain

- Two brushless AC Servo Motors
  - 0.4kW 60V Drive Motors
- 144:1 Gearbox Extended Shaft
- Driven wheels coupled to the same side wheels by roller chain and sprockets
- Skid-steer driven platform capable of performing small-radius turns
- Elastomeric tires on drive wheels designed for temperature, friction and wear



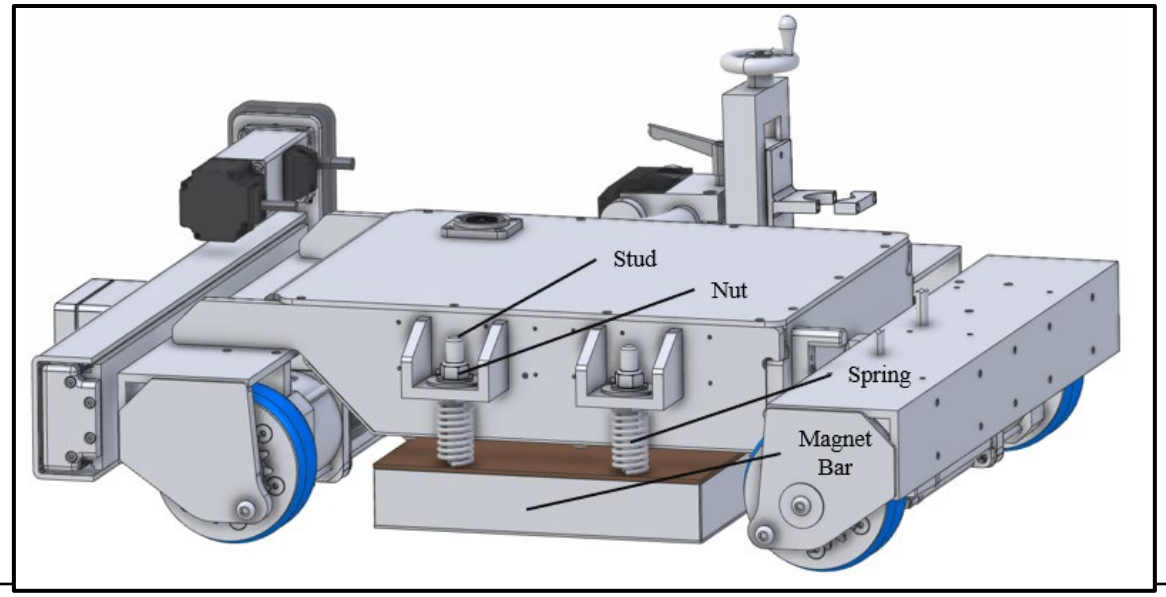
Magnet Suspension



MRMS Magnet Suspension

- Magnet bar secured to the chassis via three threaded studs
- Suspended magnet allows for debris management
- Adjustable normal force between the mobile robot and the driving surface
- Removable magnet makes the system more manageable
- Payload ratings per steel thickness
- Debris shield clips around machined magnet enclosure

In the images, the MRMS base's side panel is hidden along with components from the drivetrain to allow for a better view at the magnet suspension.



Prototype Design – Tool Interface

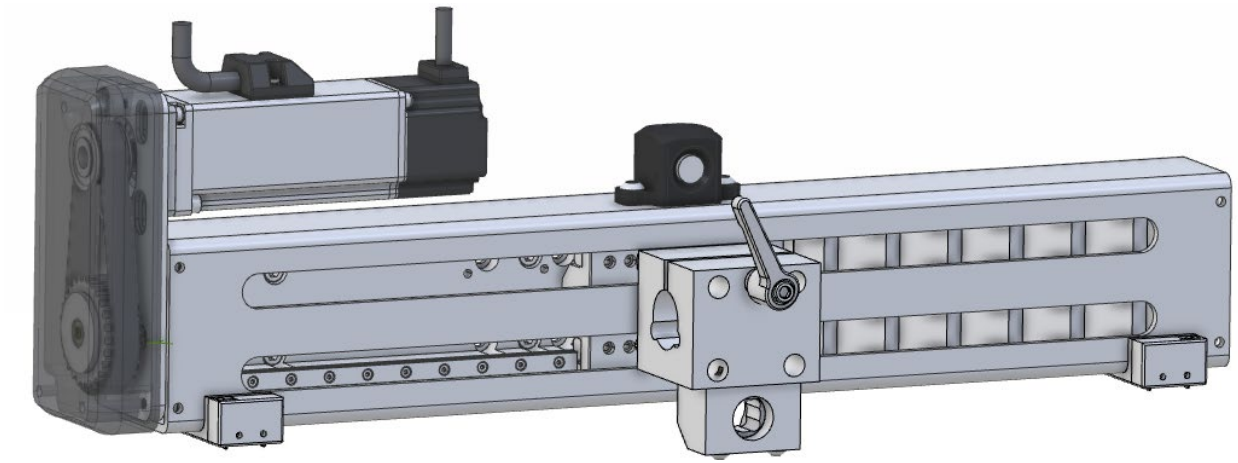
MRMS Torch manipulator:

- 4 DOF, contains Weaver plus toolbar and torch holder

Weaver

- Interfaces the MRMS and any tooling equipped
- Tooling options: welding torch, cutting torch, or NDT probe
- Linear rail driven by another brushless AC servo motor
- Motor is coupled to the rail's ball screw via a custom pulley assembly

- Limit switches added to either side of the weaver to prevent unintentional tool misuse
- Waycover bellows added over linear rail for environmental consideration



Prototype Design – Welding Tooling

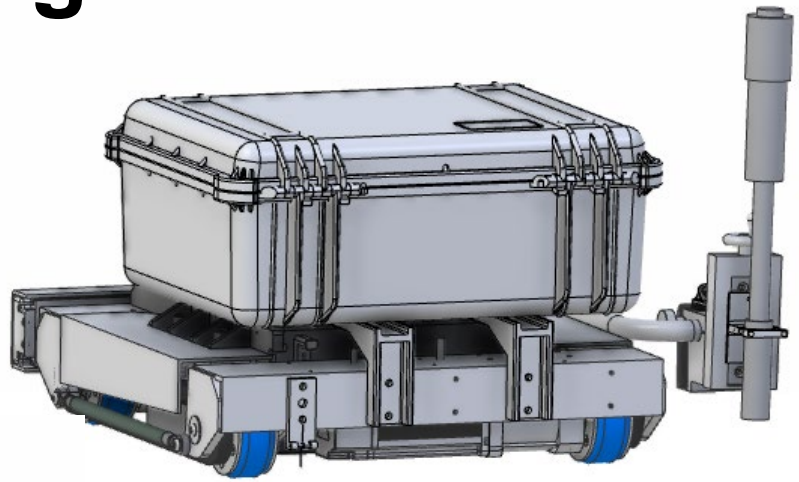
Torch Manipulator

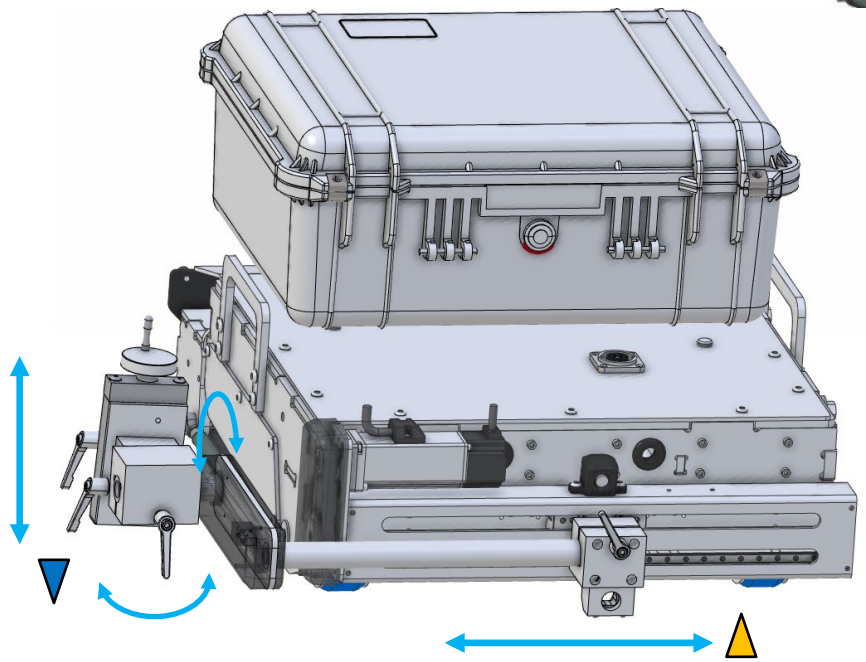
Torch and Suitcase Mount

- Bracket will not inhibit functions of suitcase
- Allows for connection of a Miller 8VS ArcReach wire feeder to the MRMS base.

▼ Contact-to-work distance, work angle, and travel angle are set manually

▲ Weave center, width, speed, dwell times changed dynamically from user input

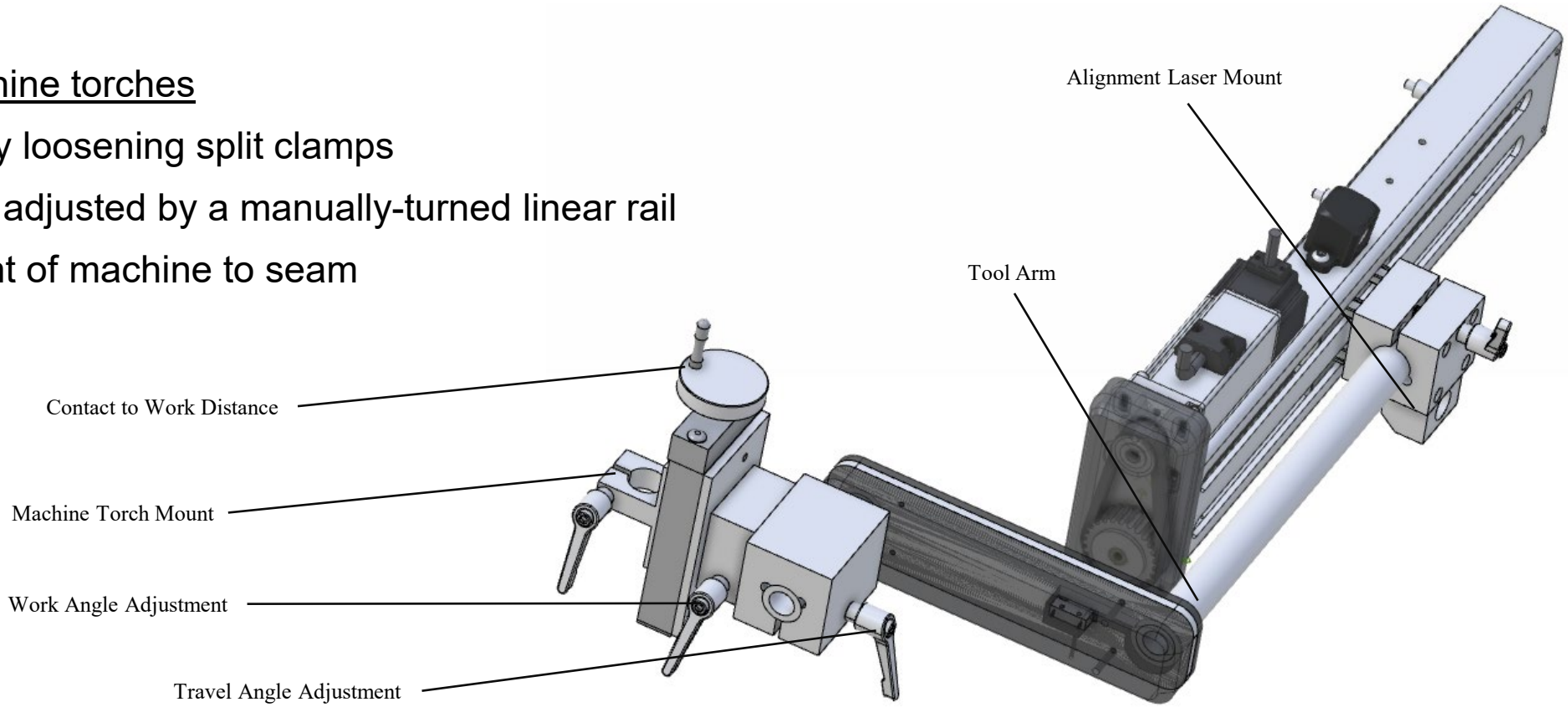




Torch Mount and Laser Alignment

Torch Mount and Laser Alignment

- Adjustment of the contact-to-work distance, work angle, and travel angle
- Designed for machine torches
- Angles adjusted by loosening split clamps
- Torch-tip distance adjusted by a manually-turned linear rail
- Laser for alignment of machine to seam



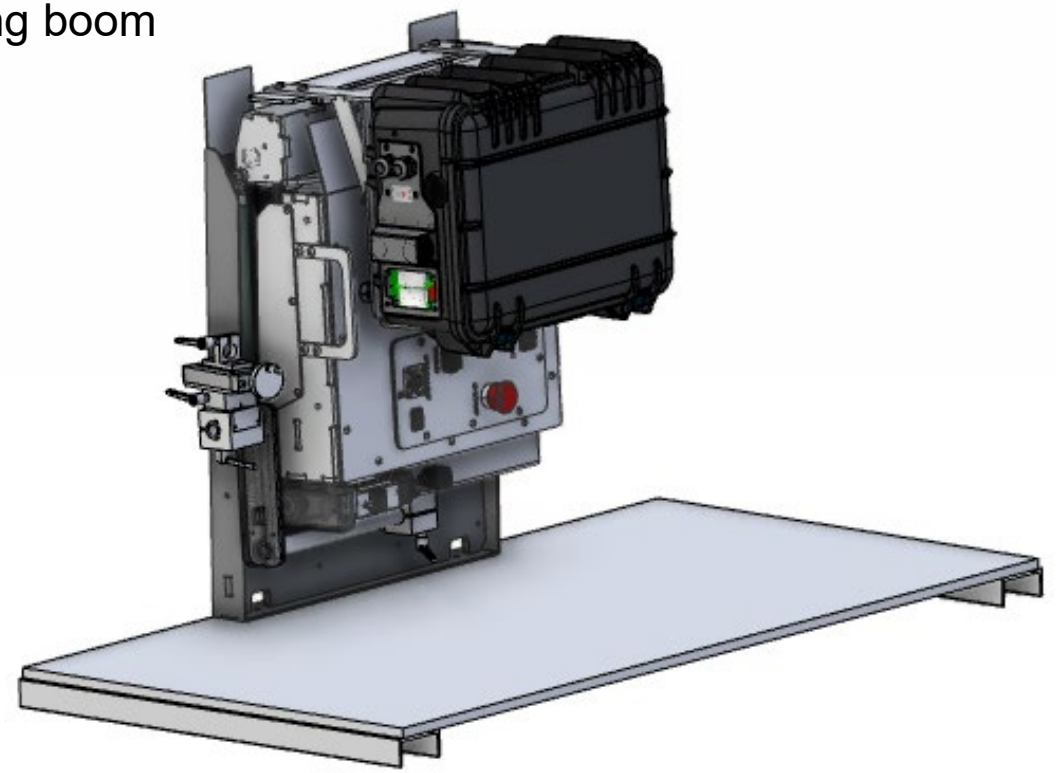
Camera System(s)

- Cameras will be necessary for fully remote interface in long-term implementation
  - Remote Welding
  - Surface Preparation
  - Inspection
- Camera feed will output to display on the HMI workstation for the remote operators viewing
- System architecture will support the addition of these cameras in future efforts
- Audio and video feedback has already been demonstrated on a prototype MRMS (shown at Ingalls site visit)

Prototype Design – Deployment Skid

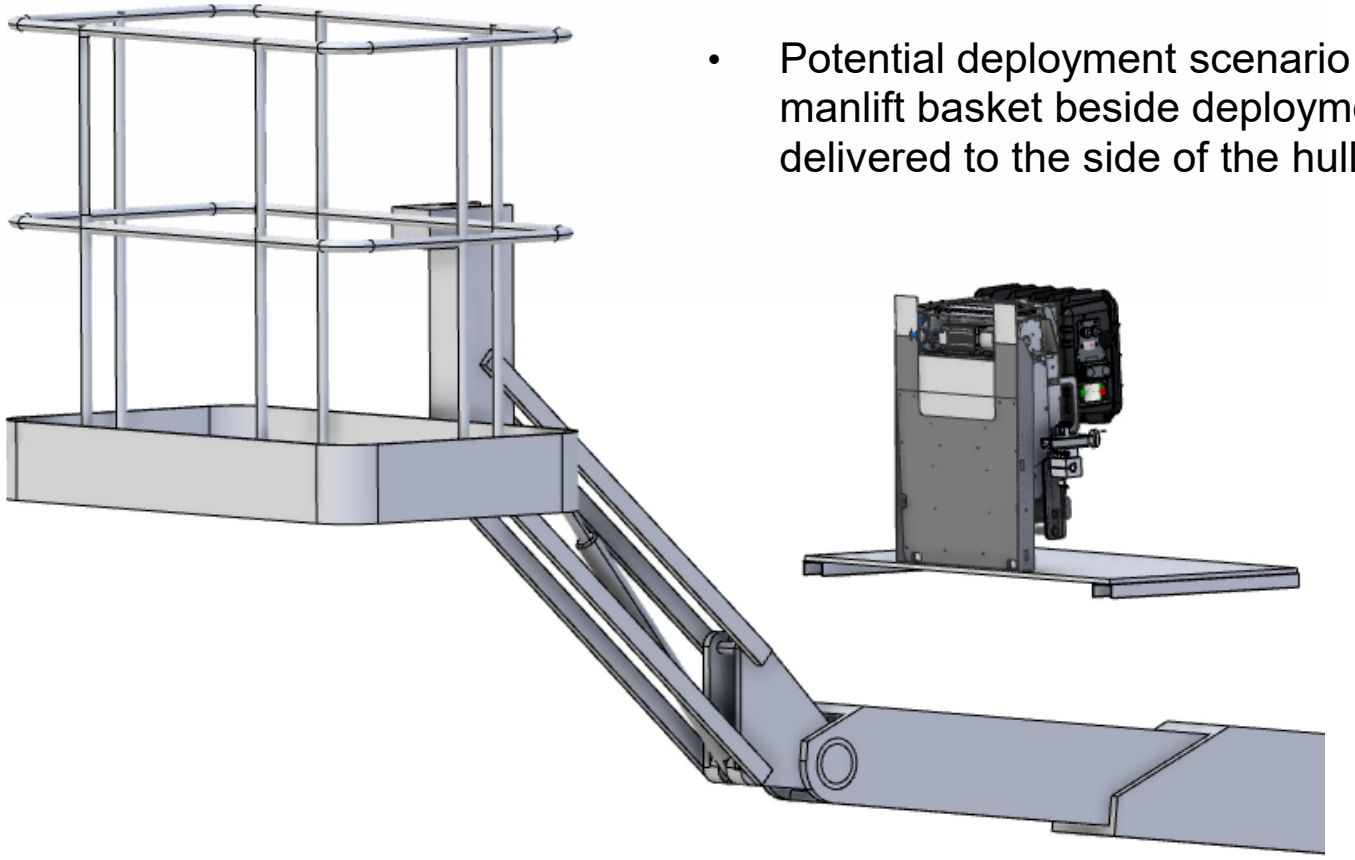
MRMS Deployment Skid

- Base is coupled to tray via the system's suspended magnet
- Deployment skid delivered to ship hull by telehandler extending boom
- Operators meet crawler at ship's hull in manlift
- System is driven by handset onto hull from skid

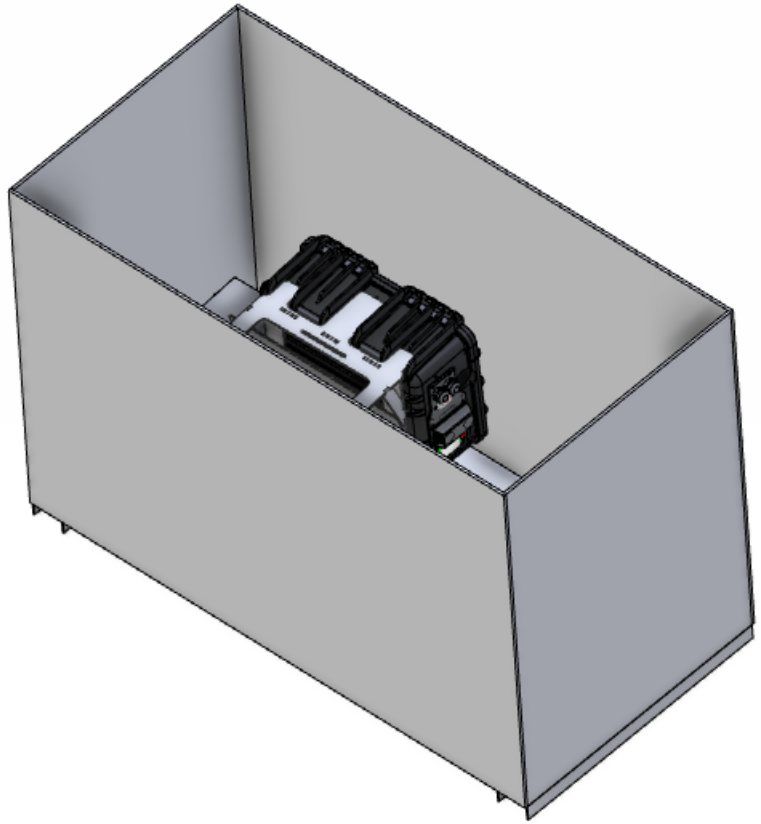


https://www.cat.com/en_US/products/new/equipment/telehandlers/telehandlers/109500.html

Prototype Design – Deployment Skid

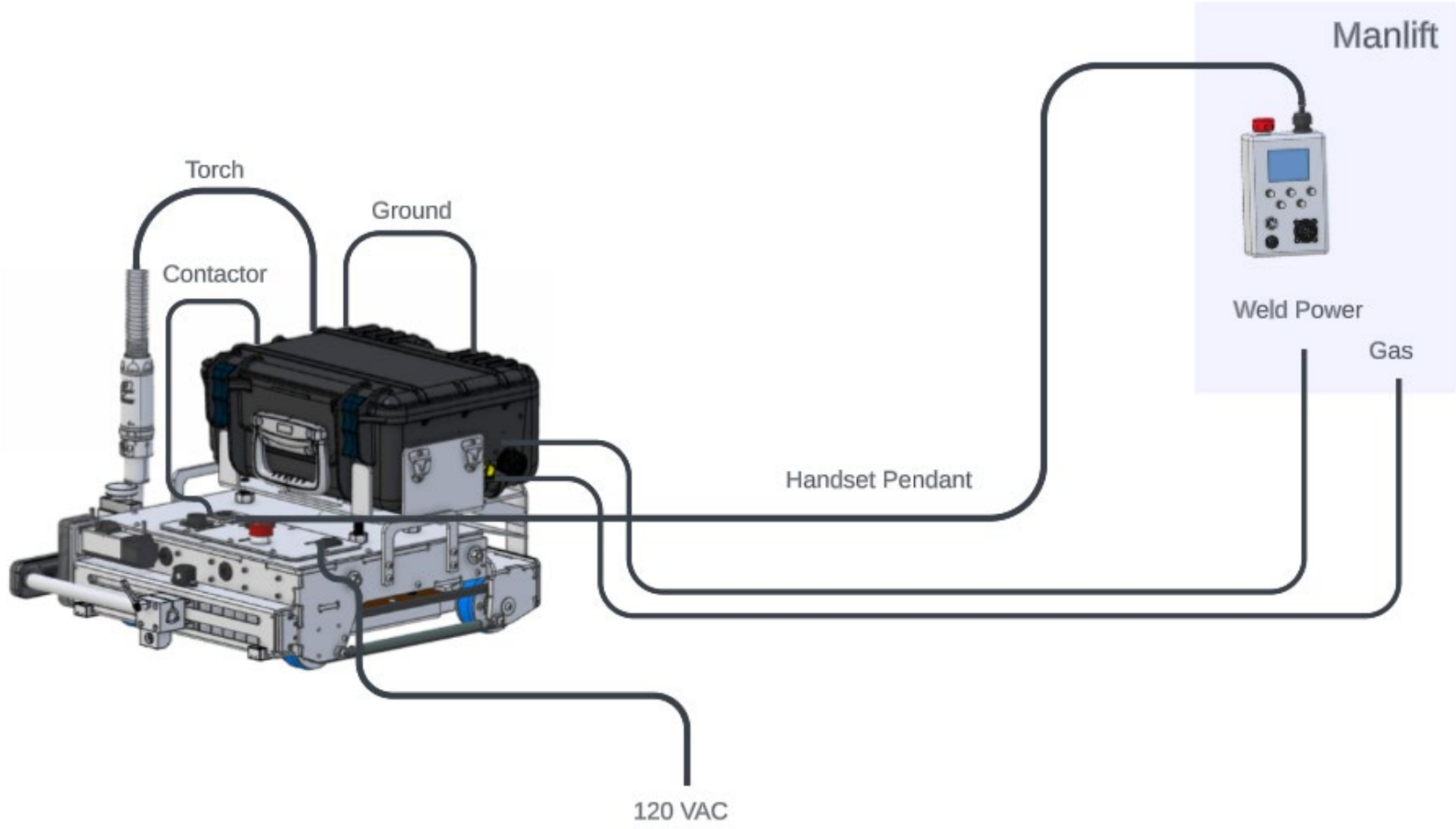


- Potential deployment scenario with manlift basket beside deployment skid delivered to the side of the hull



- Weatherproof storage skid for MRMS system

Prototype Design – Cable Management



Prototype Design – Wear Items

Maintenance

- Wear Items
  - Life of tires to be calculated
  - Replacing tires creates risks in damaging drive motors
  - Performed by RTT
  - No other known wear items on the MRMS system

Tire life to at minimum exceed the life of all welding consumables

Requirement completed and documented
Requirement completion in progress
Requirement tentatively completed needing verification
Slated for future efforts

Welding Equipment

The proposed welding system will be based on a Miller Dimension 650 welder with Miller 8VS ArcReach wire feeder suitcase

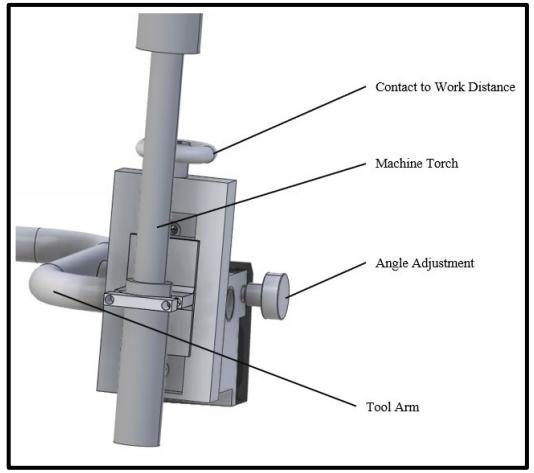
The Miller 8VS ArcReach wire feeder suitcase will be mounted to the MRMS base

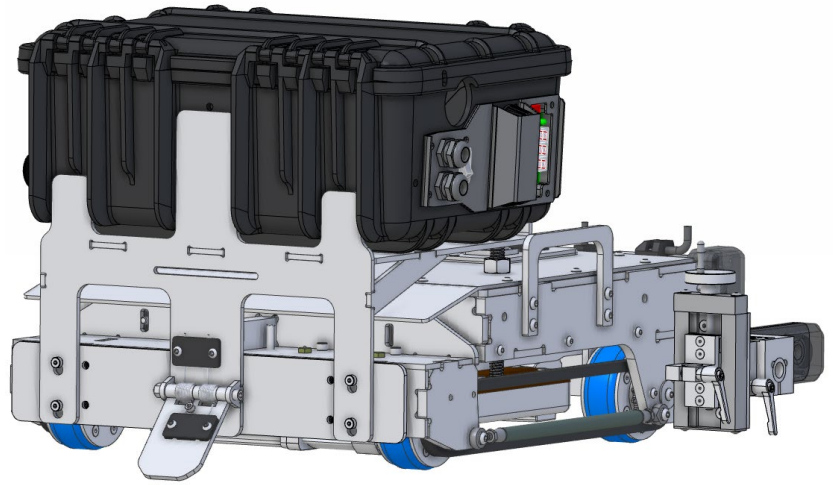
The MRMS base will provide a grounding connection for the Miller 8VS wire feeder

The weld system will have monitoring/data capture including but not limited to welding parameters (amps, volts, WFS, travel speed weave width and dwell)

The welding system will allow the operator to make fine-tune programming adjustments during welding to ensure weld quality

- Torch mount demonstrated during Ingalls' site visit





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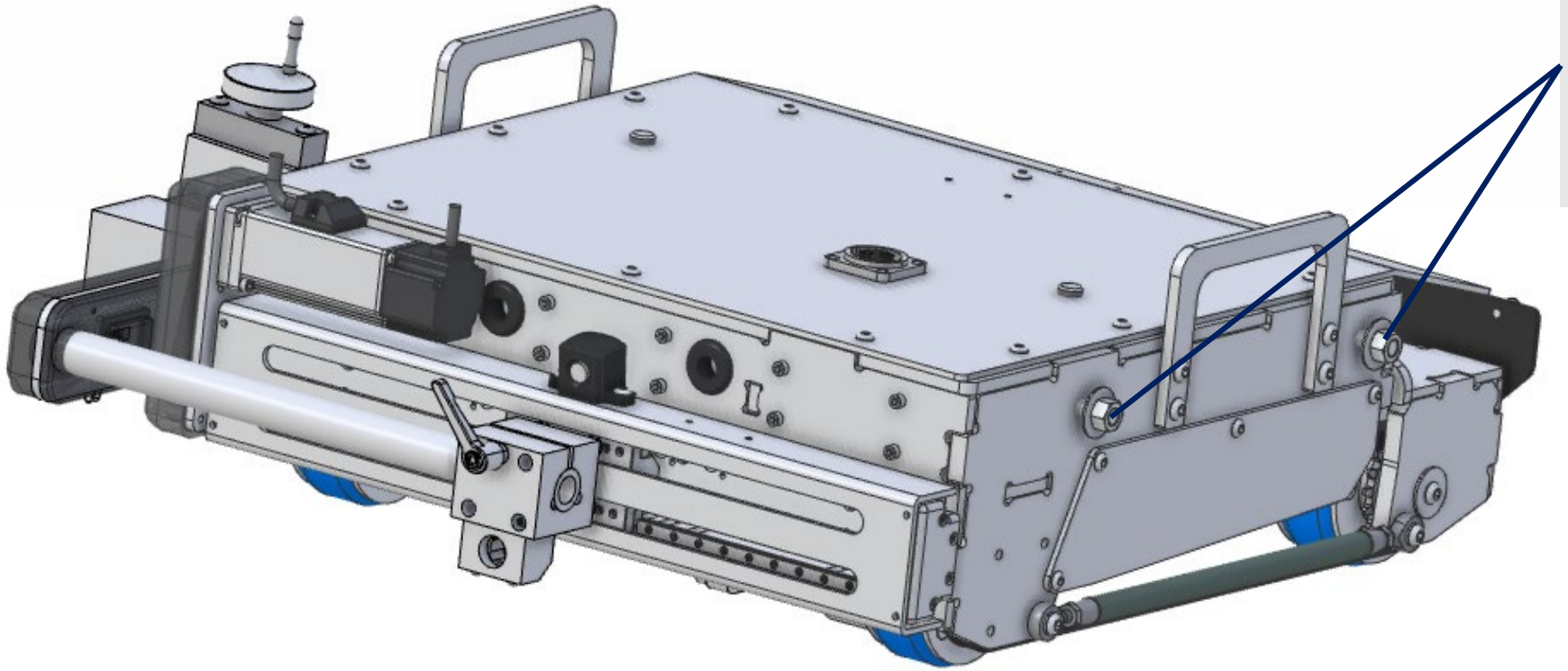
MRMS Requirement – Welding Procedure

- The welding system will be capable of welding materials specified by the shipyard
- The welding system will be capable of welding plate thickness ranging from 3/16 to 1-1/2 using typical weld procedures associated with these plates
- The welding system will use FCAW process conforming to requirements
- The welding system will be capable of welding joints specified by the shipyard
- The welding system will be capable of using filler materials specified by the shipyard
- The welding system shall be able to accommodate a pre-weld maximum joint offset of 1/8 inch

- The welding system will be capable of welding full penetration following existing procedures
- The welding system will incorporate path planning and weld sequencing operations to produce welds acceptable to specified standards

MRMS Requirements – Safety



Safety tether and cable strain relief attachment points. Same on opposite side of crawler

Images of Prototype System and Testing at RTT

Welding Trials

- The system is aligned with the weld seam using the projected laser line
- The torch is adjusted for work angle, travel angle, and contact-to-work distance
- The torch is manipulated via the toolbar connected to the belt-driven linear rail carriage

Images of Prototype system and testing at RTT

Factor of Safety Test
375 lbs

Welding Trials

Handset Pendant