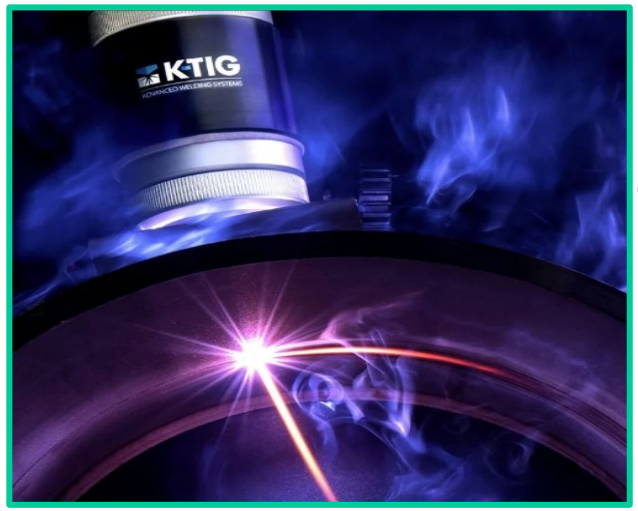
# Welding Technology: R&D to Implementation




## Keyhole Tig Welding (K-TIG)

**Presented By:**
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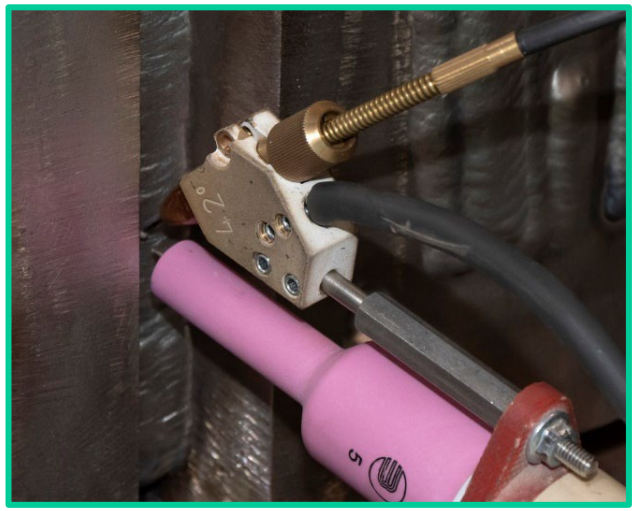

## Semi-Automatic Gas Tungsten Arc Welding (GTAW-SA)

**Presented By:**
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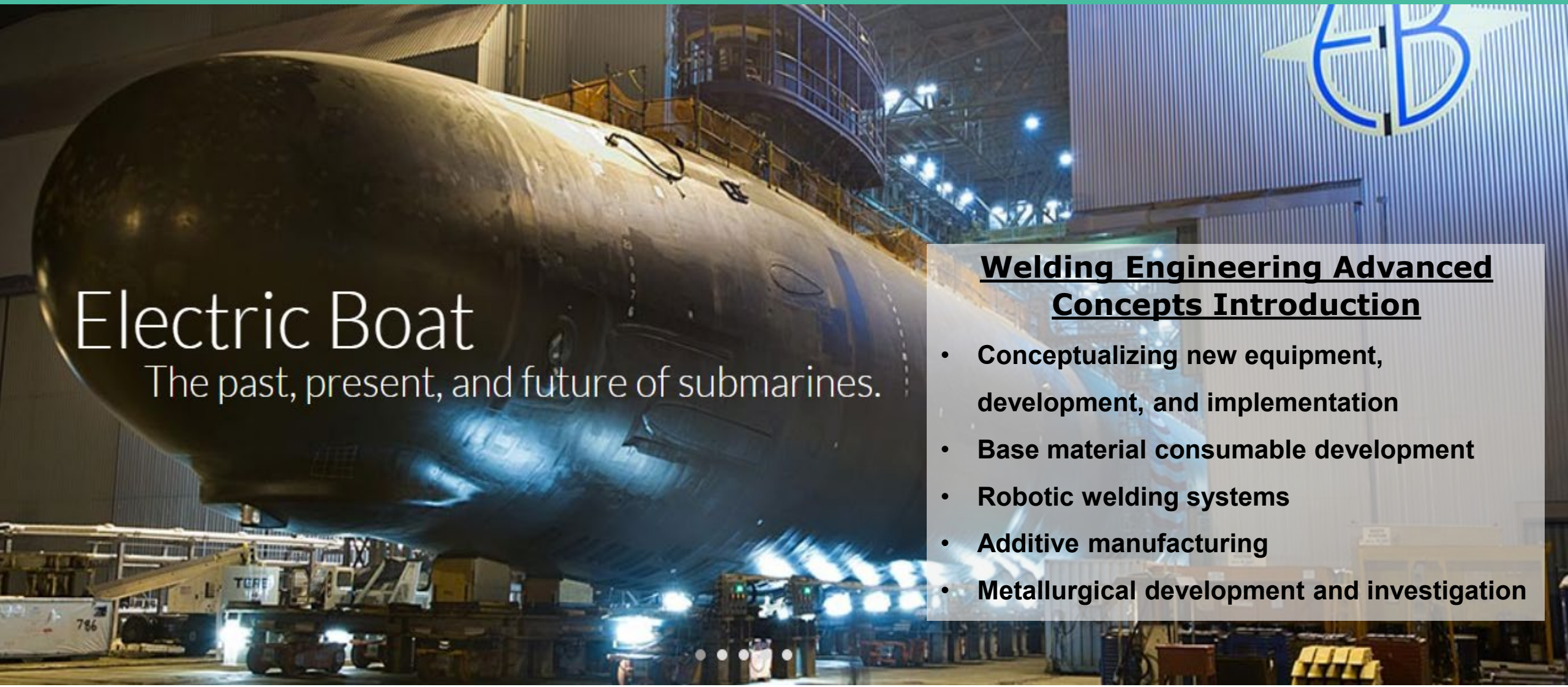
**Prepared under ONR Contract N00014-22-D-7004 as part of the Navy ManTech Program**
**Document Control Number (DCN): 2025-1-22-532; Approval Date: 02/18/2025**

# General Dynamics Electric Boat




## Welding Engineering Advanced Concepts Introduction

- Conceptualizing new equipment, development, and implementation
- Base material consumable development
- Robotic welding systems
- Additive manufacturing
- Metallurgical development and investigation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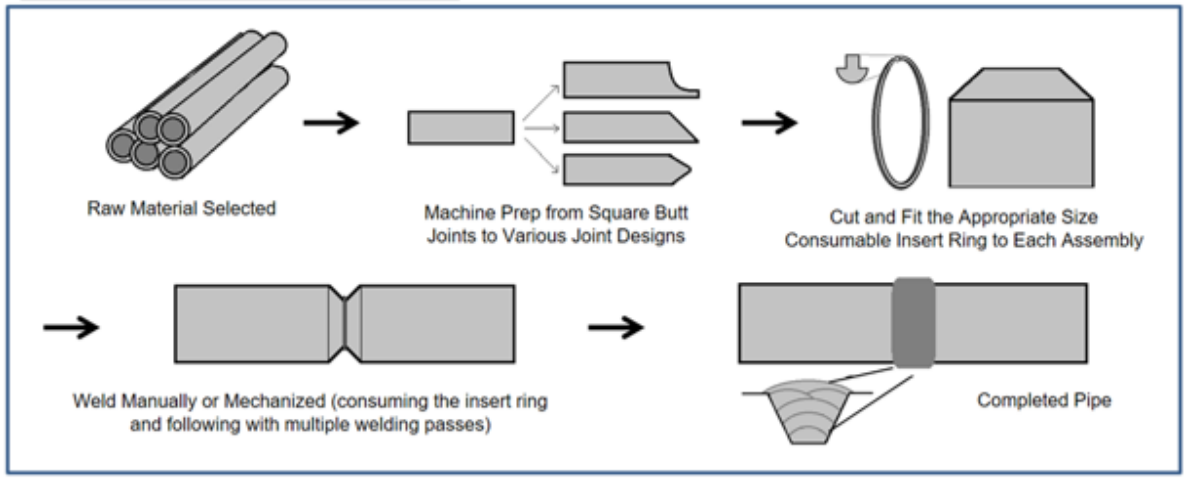
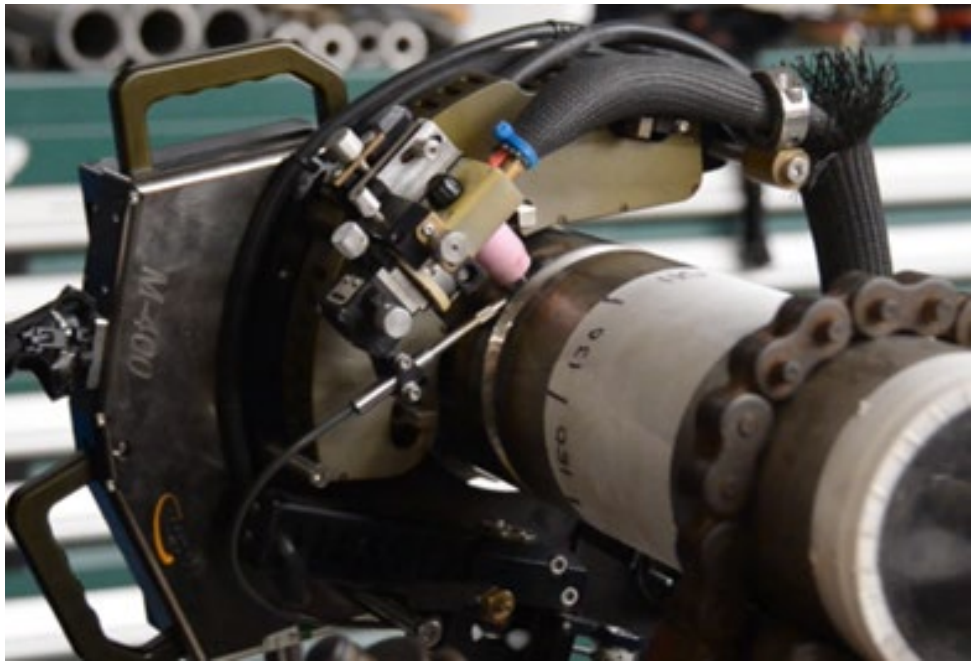
# Current State of Pipe Welding at Electric Boat

**Current State:**

- Excessive labor hours during each step of welding a pipe joint
  - Preparing pipe ends for welding
  - Cutting and fitting consumable rings
  - Interpass operations between multiple weld passes
- Requires highly trained, experienced operators




Current Process at Electric Boat

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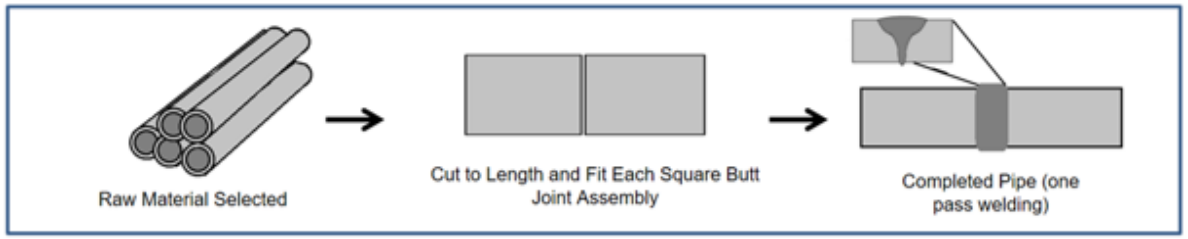
# Keyhole TIG Autogenous Pipe Welding

**Keyhole TIG (KTIG) Technology:**

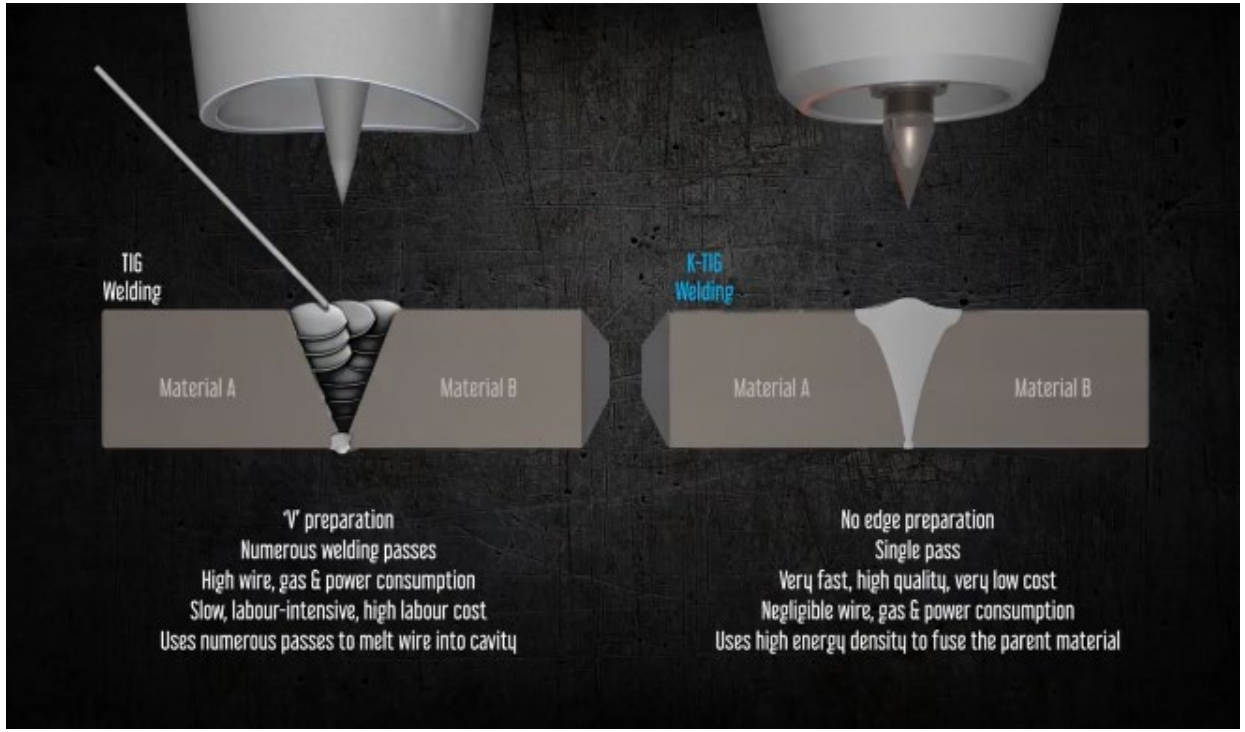
- Reduces Operational Hours:
  - Machining
  - Fitting
  - Welding
- Single pass welds
- No filler material required
- Produces a keyhole effect to create a seam weld

**Why KTIG?**

- Used commercially for seamed pipe
- Used in nuclear plants




**Process if Autogenous Technology is Introduced**




- **KTIG:** Weld pipe diameters as small as 4 in. and thicknesses up to 0.315 in. in a single pass.
  - Testing will go beyond this thickness to potentially expand limitations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# Technical Approach

**ONR Period of Performance:**

**3rd Quarter FY 2023 through 4th Quarter FY 2024**

## Phase I

**Task 1** – Project Initiation – 100%

**Task 2** – Feasibility Assessment - 100%

**Task 3** – Validate Material Candidate Identification – 100%

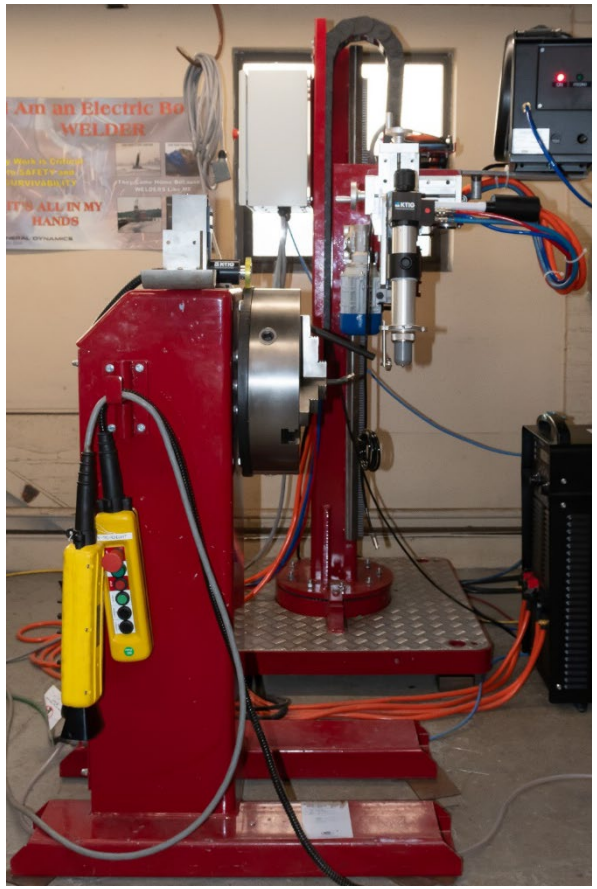
**Task 4** – Define NAVSEA Qualification Requirements -100%

**Task 5** – Create Test Plan to Evaluate Weld Quality – 100%

**Task 6** – Develop Welding Parameters for Pipe – 80%

**Task 7** – Execute the Weld Quality Test Plan – 25%

**Task 8** – Phase I Reporting




**Equipment delivered and installed at GDEB**

## Phase II

**Task 9** – Establishing Test Types

**Task 10** – Create a Test Plan for Evaluation

**Task 11** – Execute the Special Testing Evaluation Plan

**Task 12** – Final Reporting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# Task 2 – Feasibility Assessment (Completed)


- Feasibility welding completed on flat plate
- Flat plate chosen to reduce initial costs & get a grasp of the KTIG process
- Material selection based on current shipyard usage

GENERAL DYNAMICS
Electric Boat

*Appendix A: Test Assembly Quantities and Identification*

| Assembly Material | Thickness (in.) | #Samples |
|---|---|---|
| A | 0.125 | 8 |
| | 0.375 | 8 |
| B | 0.125 | 4 |
| | 0.375 | 4 |
| C | 0.125 | 4 |
| | 0.25 | 4 |

| Assembly Material | Thickness (in.) | #Samples |
|---|---|---|
| D | 0.125 | 4 |
| | 0.375 | 4 |
| E | 0.125 | 4 |
| | 0.375 | 4 |
| F | 0.125 | 4 |
| | 0.375 | 4 |


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# Task 2 – Feasibility Assessment Results

Table 1 – Results of Tensile Testing to Reference (b)

| Sample Material Type | Date Tested | Yield @ 0.2% Offset (psi) | Ultimate Tensile Strength (psi) | Elongation at Fracture (%) | Reduction (%)[1] |
|---|---|---|---|---|---|
| F | 07/09/24 | 59,518 | 102,456 | 41 | 51 |
| B | 07/09/24 | 50,759 | 88,619 | 50 | 34 |
| B | 07/09/24 | 51,202 | 90,372 | 46 | 32 |
| B | 07/09/24 | 86,491 | 116,841 | 50 | 37 |
| B | 07/10/24 | 47,442 | 85,946 | 50 | 35 |
| B | 07/10/24 | 47,433 | 85,585 | 33[2] | N/A[3] |
| C | 07/09/24 | 53,782 | 65,523 | 26 | 24 |
| A | 07/09/24 | 23,663 | 45,242 | 39 | 45 |
| A | 07/09/24 | 23,388 | 43,702 | 34 | 32 |
| A | 07/10/24 | 25,456 | 47,714 | 46 | 32 |
| D | 07/09/24 | 31,224 | 61,430 | 23 | 44 |
| D | 07/09/24 | 34,181 | 65,910 | 37 | 49 |

- During initial feasibility, undercut was a concern
  - Further parameter development was completed to eliminate undercut
- For Task 6, undercut will be evaluated and adjudicated as applicable

Satisfactory Seam Weld for Material D


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# KTIG Conclusion

- **Upcoming Activity**
  - **GDEB to finish parameter development on required materials**
  - **GDEB to continue executing weld quality test plan**
- **Upcoming Deliverables**
  - **Weld Quality Report**

| Material Type | Min. Pipe Size (in.) | Max Pipe Size (in.) | Min Wall Thickness (in.) | Max Wall Thickness (in.) |
|---|---|---|---|---|
| Stainless Steel | 5.00 | 14.00 | 0.12 | 0.432 |
| C | 4.00 | 12.00 | 0.25 | 0.562 |
| A | 4.00 | 5.00 | 0.237 | 0.258 |
| F | 4.00 | 13.00 | 0.176 | 0.76 |

| Proposed Destructive and Non-Destructive Testing for All K-Tig Level I Qualifications (Base Material Agnostic) | Required Testing or Number of Tests |
|---|---|
| Tensile | 2 |
| Guided Bends | 3 |
| Macro Etch | 4 |
| Volumetric (Radiographic/Ultrasonic) | X |
| Liquid Penetrant | X |
| Magnetic Particle | X |


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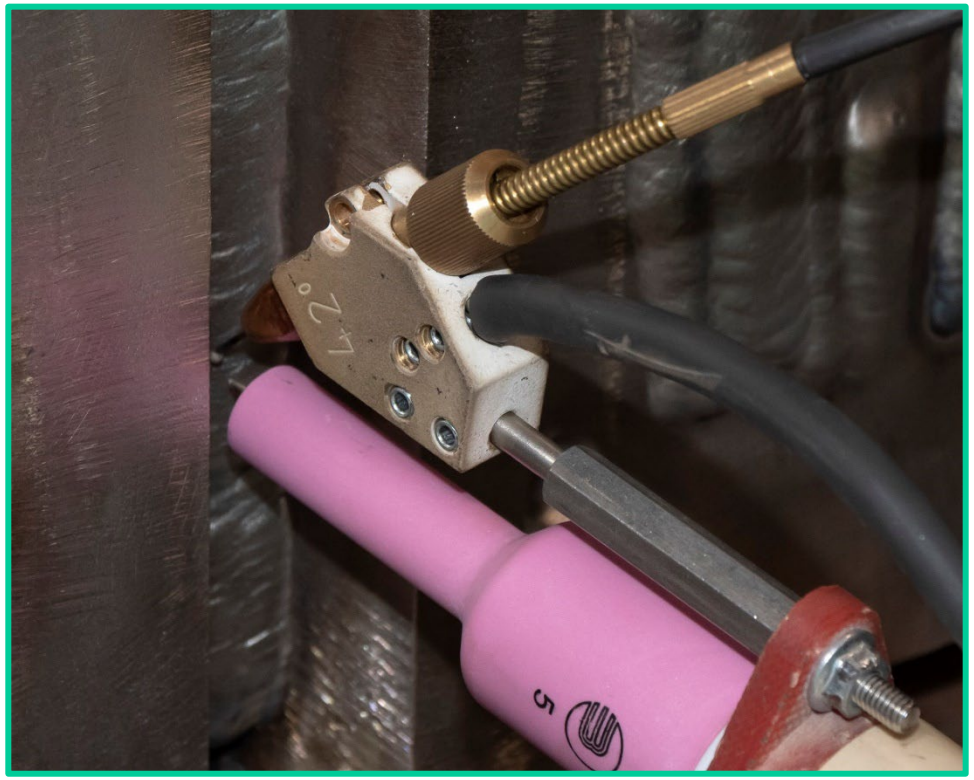
# Semi-Automatic Gas Tungsten Arc Welding



**Presented By: Shawn Bittmann**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# Why Semi-Automatic Gas Tungsten Arc Welding?

| Gas Tungsten Arc Welding (GTAW) Manual |
|---|
| Low deposition rate |
| Less hazardous alloy fumes |
| Manual feed wire |
| Increased weld cleanliness |
| Requires higher level of skill |
| Increased accessibility |

| Gas Metal Arc Welding (GMAW) Semi Auto |
|---|
| Higher deposition rate |
| Hazardous alloy fumes |
| Automatically feeds wire |
| Requires cleaning |
| Suitable for all skill levels of welders |
| Decreased accessibility |

| Gas Tungsten Arc Welding (GTAW) Semi Auto |
|---|
| **Mid-deposition rate** |
| **Less hazardous alloy fumes** |
| **Automatically feeds wire** |
| **Increased weld cleanliness** |
| **Suitable for all skill levels of welders** |
| Decreased accessibility |



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# GTAW-SA MANTECH to Implementation

**Start of MANTECH**
Participant organizations: ONR,CNM, GDEB, EWI

**Purchase Considerations**
- AZZ hot pulse weld
- CK Worldwide
- EWM TigSpeed
- Tip TIG

**Final MANTECH Report**
- Section of EWM TigSpeed
- EWI conducted initial welding
- GDEB performed shipyard viability

**GDEB Shipyard Implementation**
- Procedures developed for applications in the shipyard
- Qualification of welders
- First use in production

2019 — 2021 — 2023 — 2024 — 2025

CENTER FOR NAVAL METALWORKING

GENERAL DYNAMICS Electric Boat

We Manufacture Innovation

**Selection was based on:**
- **Commercial off the shelf (COTS) availability**
- **Support for Mantech activities/schedule**
- **Equipment ergonomics**
- **Equipment capabilities**

- **EWM was selected due to meeting a variety of capabilities, including filler wire reciprocation**
- **Extensive parameter development and testing completed by EWI**
- **GDEB verified deposition rate and performance for GDEB applications in the shipyard**

- **GDEB is currently implementing GTAW-SA in various heavy deposition applications**

EWM TigSpeed


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# Benefits of Wire Reciprocation

- Feeding wire is reciprocated into the weld puddle causing a break in the surface tension
- Surface tension fluctuation while welding aids in flow and control of the puddle
- Reduction of oxides and impurities in the weld as weld puddle is disrupted by wire

Slow motion video of reciprocation at 6-Hz while welding with Material F


EWM TigSpeed


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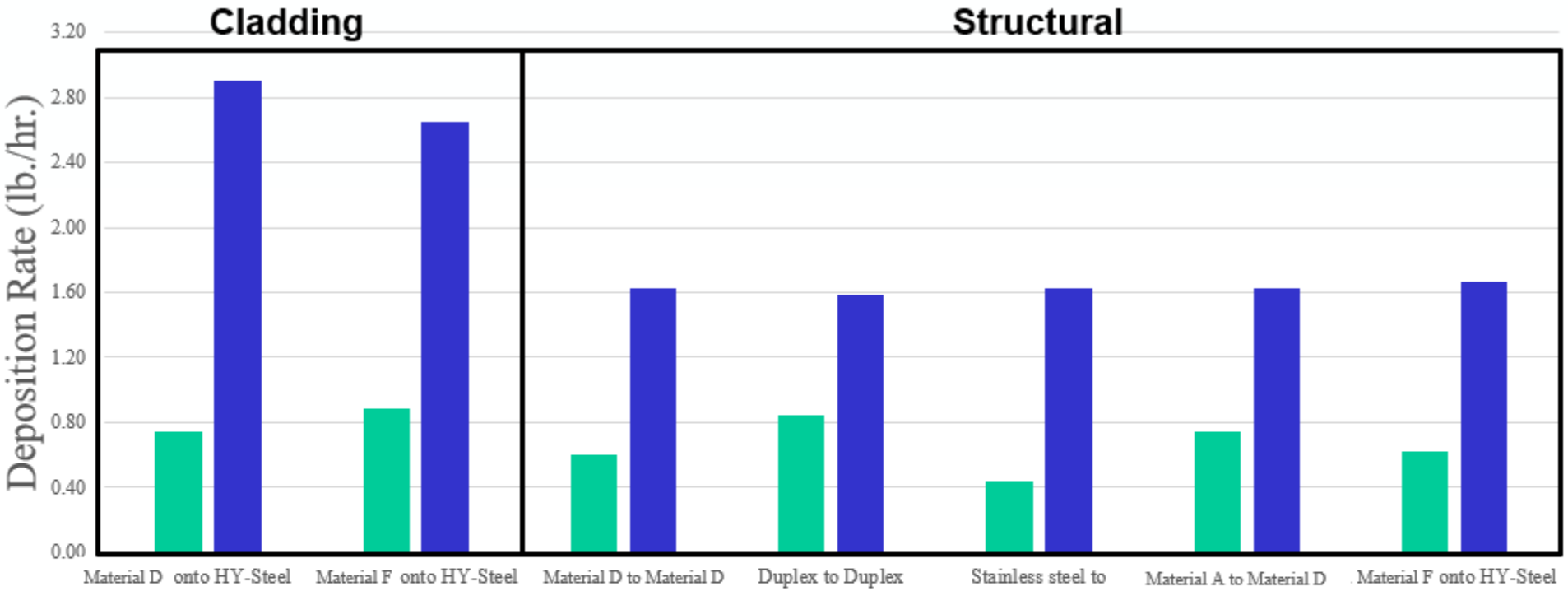
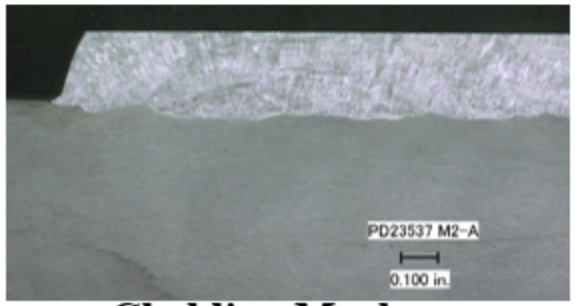
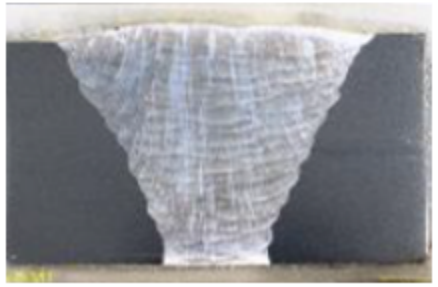
# Shipyard Benefits with GTAW-SA

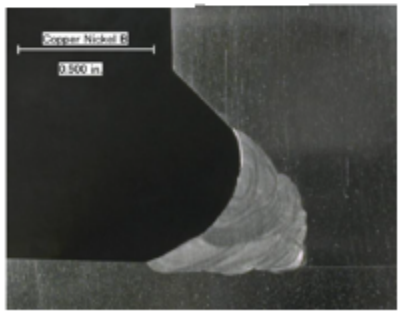



Cladding Mockup

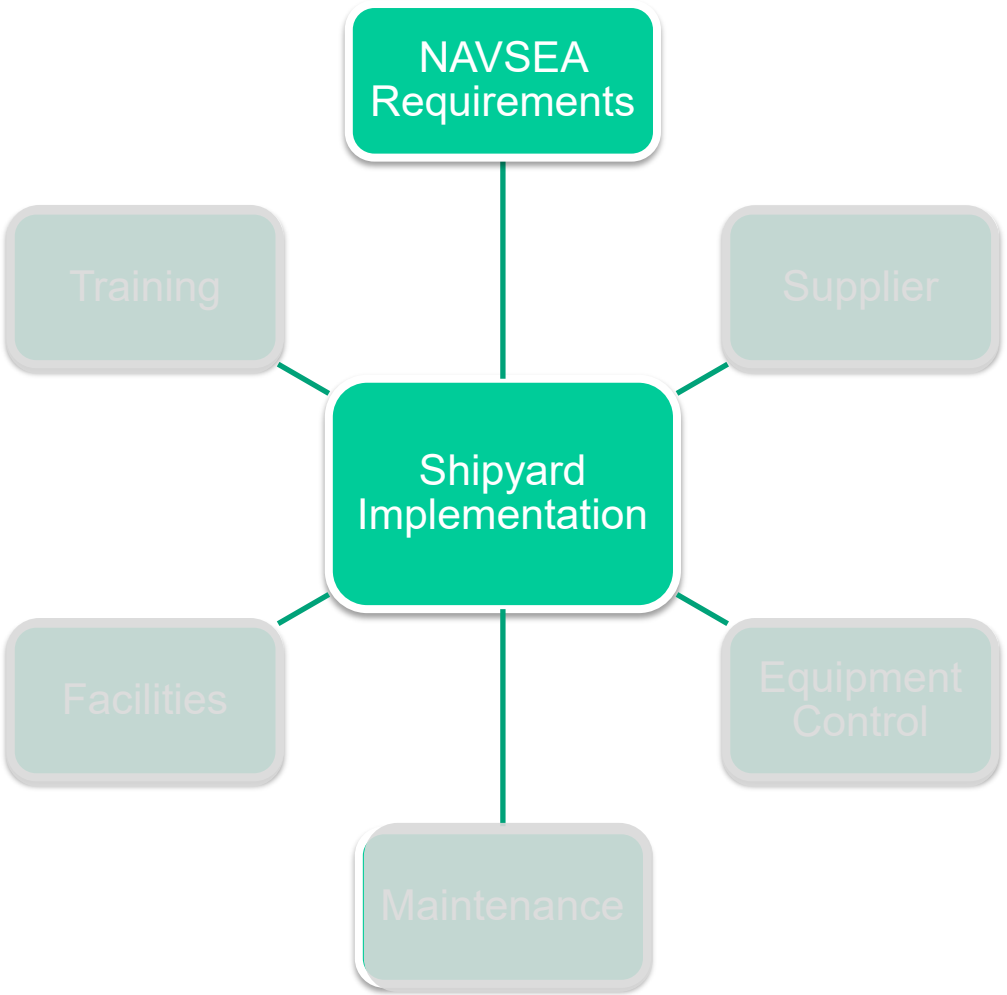


Butt-joint Mockup



Boss weld Mockup

# Shipyard Implementation




## NAVSEA Requirements

- Technical Publication 248 is silent to GTAW-SA process and is considered a “special weld”
  - Special welds require NAVSEA approval for all procedure qualification records
- GDEB and NAVSEA developed requirements for performance and procedure qualification
  - Process-specific Essential Elements
    - Tungsten to wire angle
    - Tungsten to wire distance
    - Wire Reciprocation Frequency
  - Approval of procedure qualification records by Authorized Representative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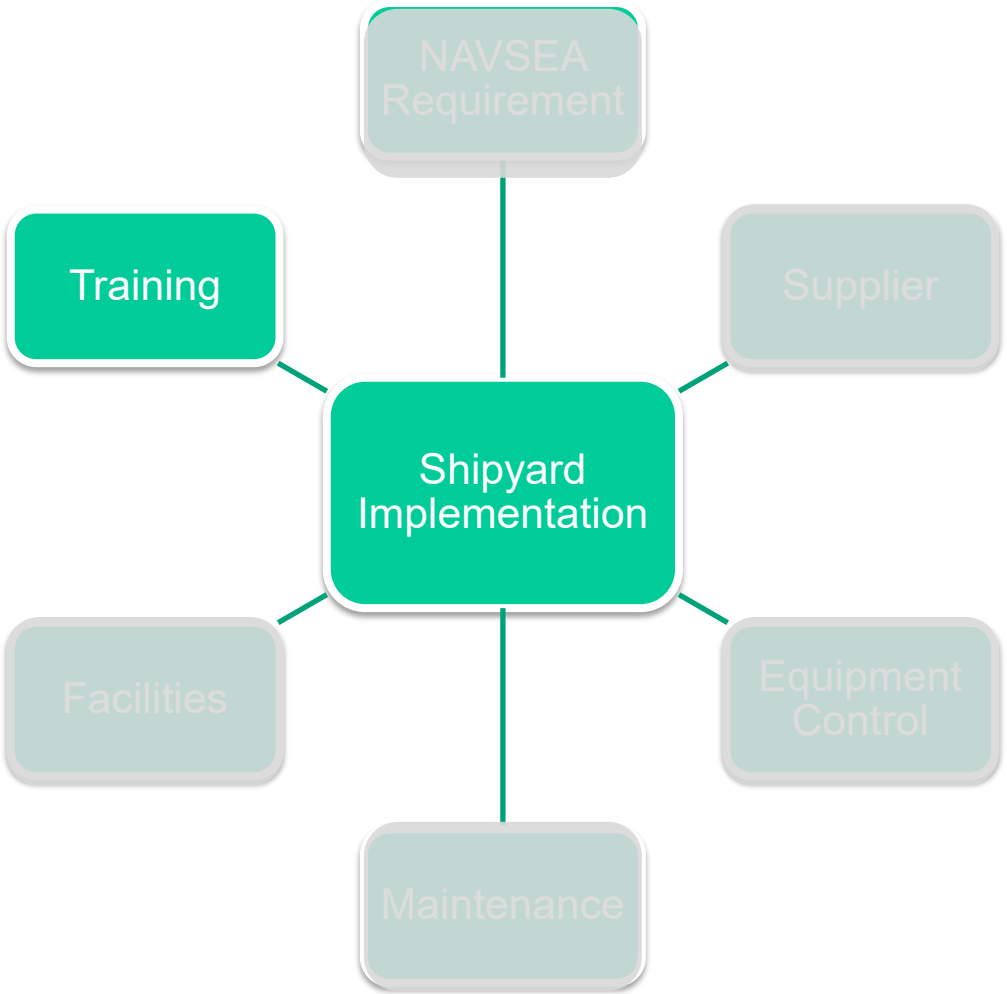
# Shipyard Implementation




## Training

- Weld school instructors
- Introducing new process to existing record systems
- Qualification records for welders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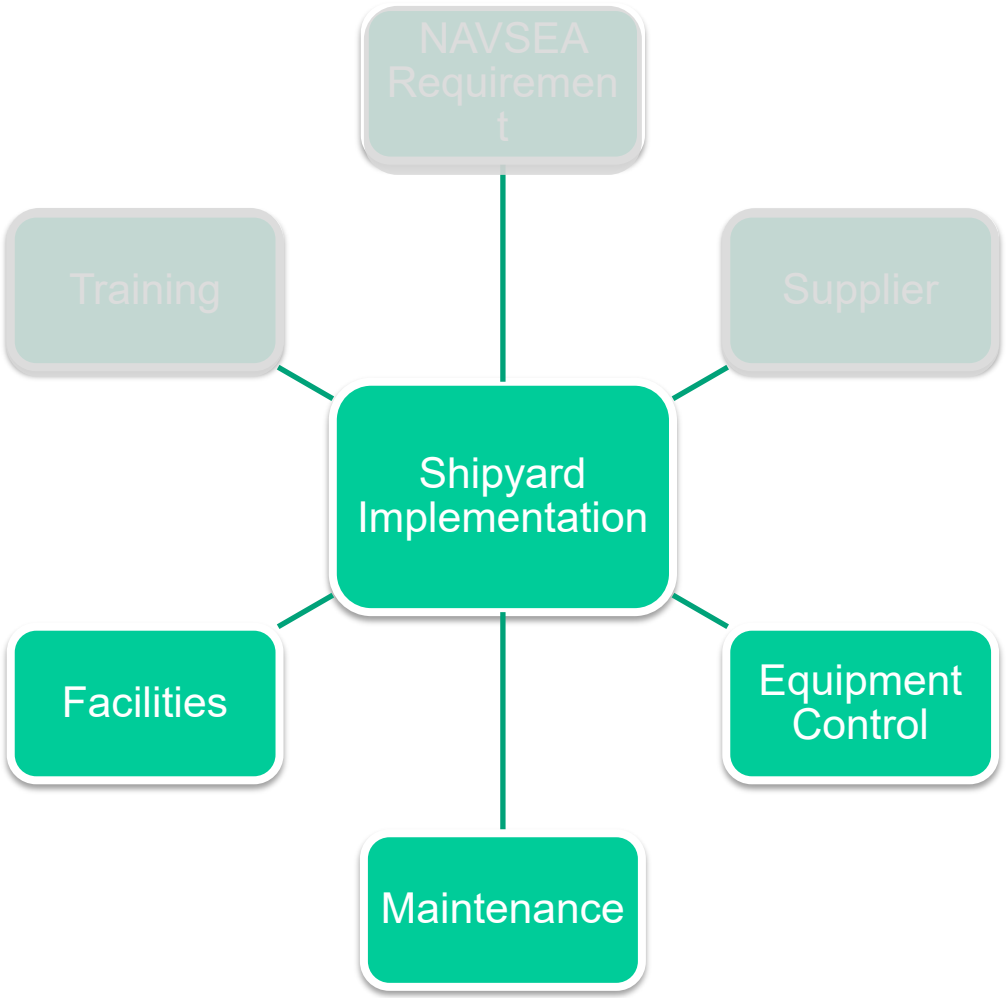
# Shipyard Implementation




## Shipyard

- Equipment control center was trained for maintenance of equipment
- Introduction of new equipment into existing resource tracking systems
- Consumable parts list and stocking of new parts for production in our tool cribs
- Multiple sites that utilize different power disconnects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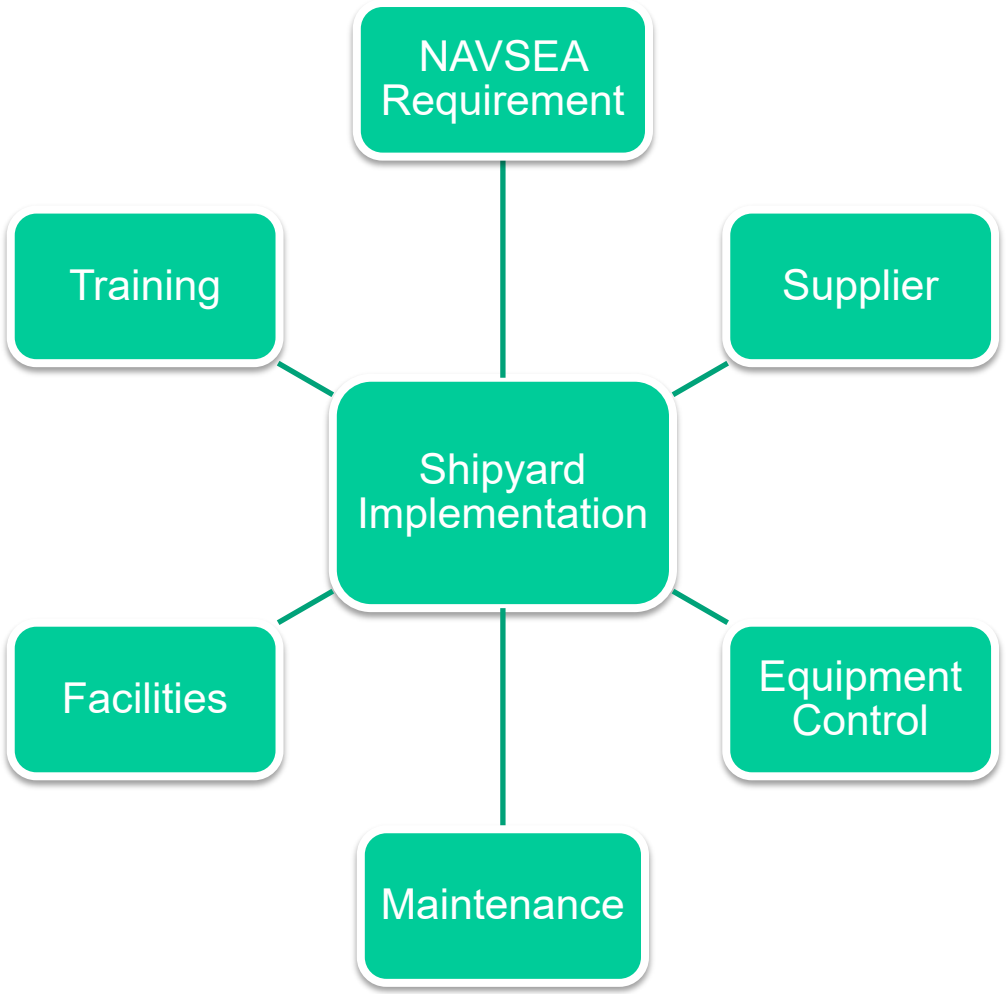
# Shipyard Implementation




**Supplier is essential partner for implementation**

- **In person training for weld instructors and equipment personnel**
- **Equipment support**
- **Availability**

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ewm® WE ARE WELDING


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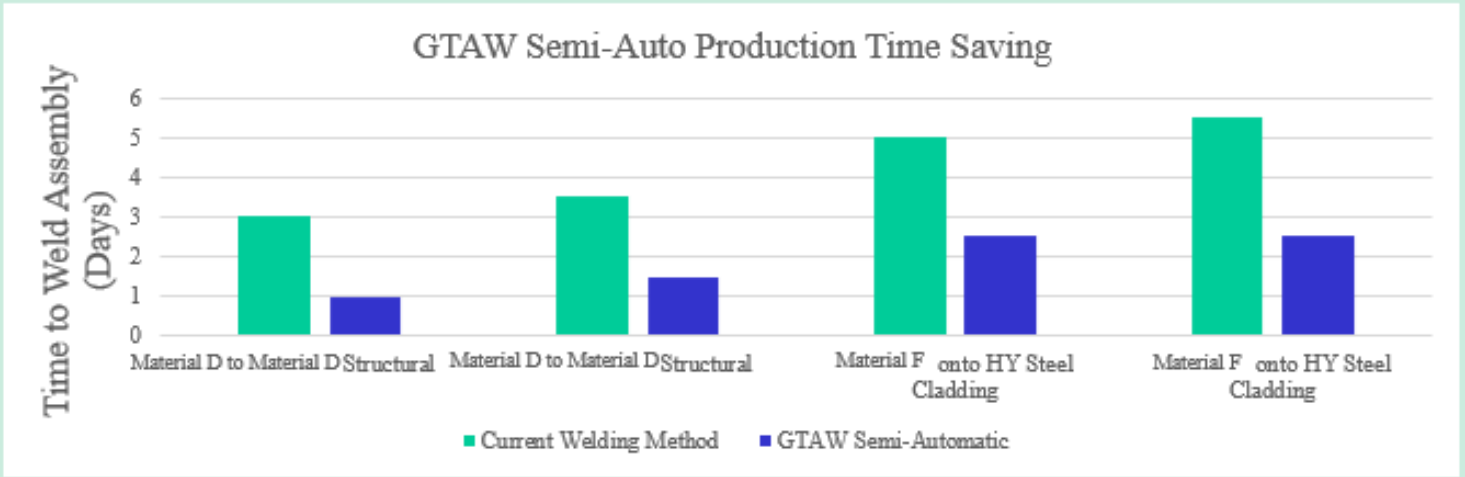
# Summary

## GTAW-SA Benefits




- Availability of parts and equipment (consumable and non-consumable)
  - Method of stocking in both shipyards
- Internal training of instructors, welders, and maintenance personnel
- Internal tracking system
- Partnered Supplier
  - Training for equipment control center personnel and weld instructors
  - Service equipment, supply parts, and customer support

## EB Welding Procedures

| Application | Base Material | Filler Material |
|---|---|---|
| Cladding | HY-Steel | Material F |
| | HY-Steel | Material D |
| Structural | Material D | Material D |
| | HY-Steel | Material F |
| | Duplex to HY-Steel | Material F |
| | Duplex | Duplex |

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# Questions?

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