

# Virtual Reality Welder Training

*Project No. S1051  
Navy ManTech Program*

*Presenters:  
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Tim Gifford, VRSim  
Nancy Porter, EWI*

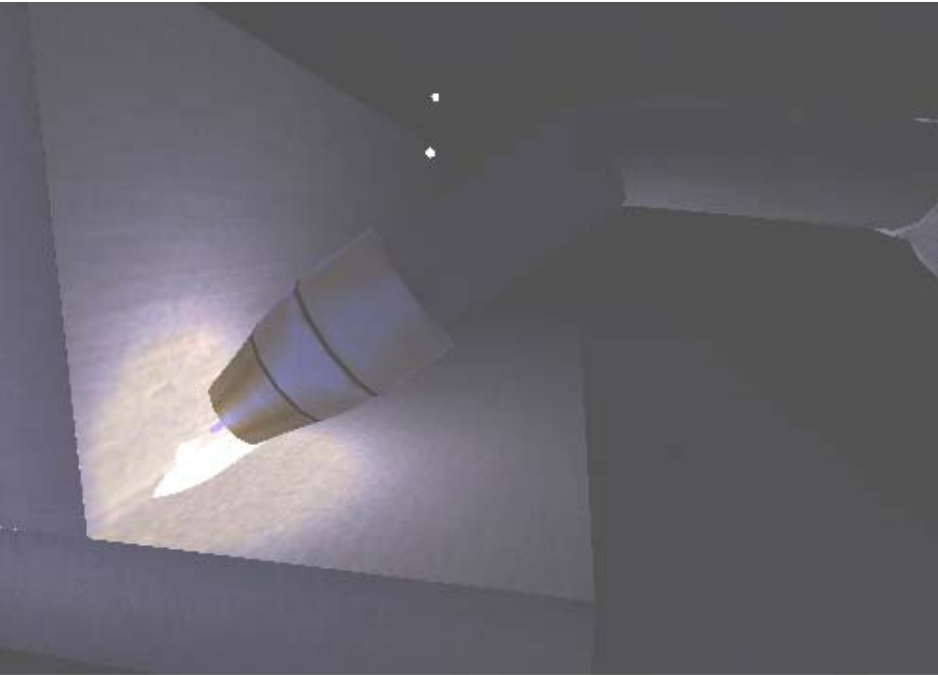
*Project Review for ShipTech 2005  
March 1, 2005  
Biloxi, MS*

**GENERAL DYNAMICS**  
Electric Boat Groton & Quonset Point Facilities

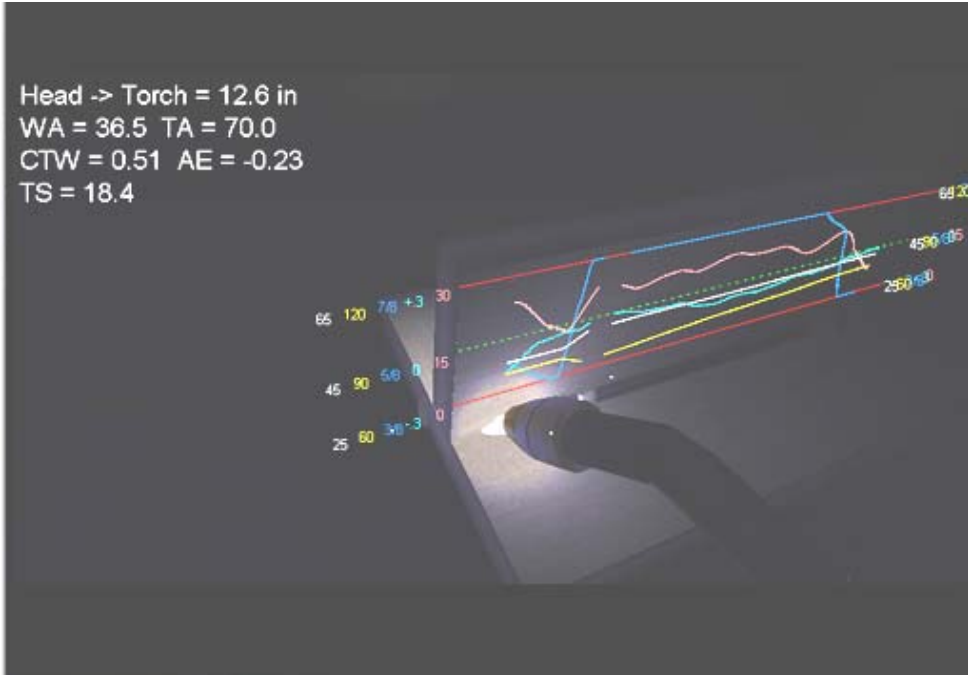
VRSIM



# We had an Idea



Head -> Torch = 12.6 in  
WA = 36.5 TA = 70.0  
CTW = 0.51 AE = -0.23  
TS = 18.4



**GENERAL DYNAMICS**  
Electric Boat Groton & Quonset Point Facilities

# Objective

Demonstrate the Concept of Virtual Reality Technology for Welder Training



# Team Members

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# Welding in Shipbuilding Industry

- **Most major connections on ships are welded, such as pressure hull butts and frames, bulkheads, tanks, foundations, decks, piping systems and machinery items**
  - Hours of welding in average submarine hull - 1 Million to 1.3 Million hours (25% manual)
- **Types of Welding used**
  - Gas Metal Arc Welding (GMAW, MIG, Spray, Pulse & Short Arc) ← **Initial Focus**
  - Shielded Metal Arc Welding (SMAW) - Stick Electrode
  - Submerged Arc Welding (SAW)
  - Gas Tungsten Arc Welding (GTAW, TIG)
- **Annually EB accounts for 35,000 hours of welder training. With a cost of more than \$600K**
  - Industry wide estimated cost -- \$5 Million per year
  - Estimated all industries expenditures for welding training -- \$18 Million per year
  - Shipbuilding / Navy use of Virtual Welding Trainer indicates a potential savings of \$2.5 Million per year.

# **Increase Training Effectiveness**

## **Decrease Labor and Material Cost**

### **Leverage New Technologies to Enhance Traditional Learning**

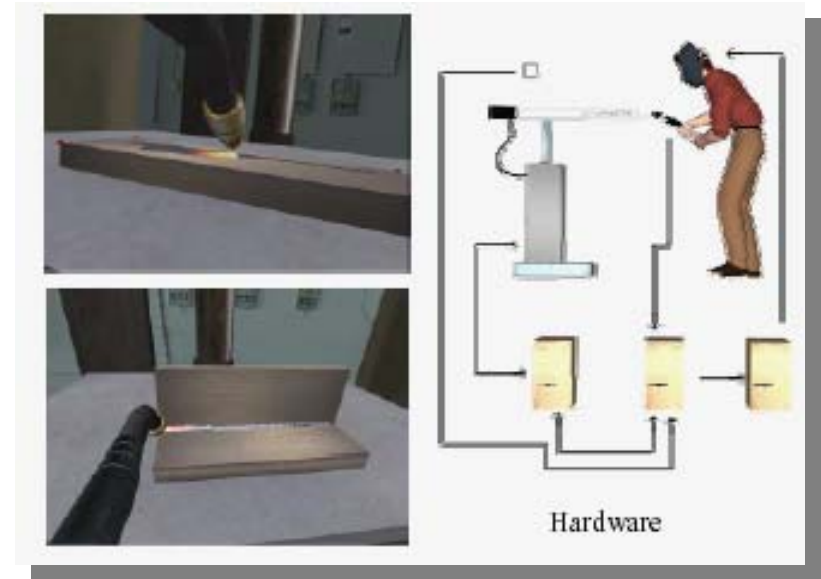
- **A virtual welding trainer would be used to build the skills of new welders and enhance the skills of existing welders in order to increase the quality of welded structures in shipbuilding.**
- **Our vision for a virtual welding trainer is that it replicates the physical characteristics / environment of welding, such as:**
  - **Striking an arc, drag, arc feedback**
  - **Executing the proper motion, pacing - speed of travel**
  - **Impact of arc physics on horizontal welds**
  - **The sounds associated with changes in tip-to-work distance**
  - **The look of fusion / sparking**



# Increase Training Effectiveness Decrease Labor and Material Cost

## Using Simulations Integrated With Virtual Toolkits Provides a Robust Way To Learn

- 100% feedback for learner/welder
- Guided simulations (ghosting)
- No environmental impact
- Clean and Safe
- Only the final qualification plate for each welding process would be physically welded. Even this concept may be challenged.



# Benefits

- A 2% increase in GMAW productivity alone will result in a \$325k savings per submarine hull.
- More highly skilled welders produce higher quality welds which contain fewer workmanship defects, thus reducing weld repair costs.
- Applications: VIRGINIA class submarine production, Seawolf, Ohio and Los Angeles class repairs; surface ships
- Rough Order of Magnitude ROI  $\cong$  4:1

**GENERAL DYNAMICS**  
Electric Boat Groton & Quonset Point Facilities

VRSIM



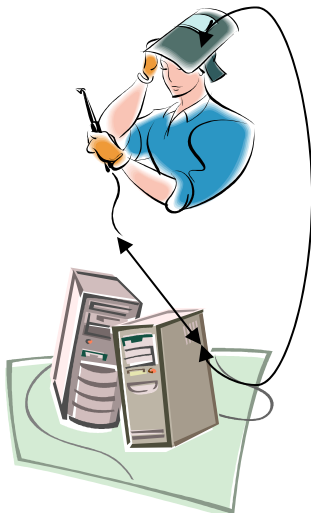
# Virtual Welding Trainer

## Forms a Foundation for Follow-on Efforts

Initial Program  
Scope

### Virtual Welding Trainer For GMAW

50% savings achieved by providing 100% feedback to trainees & reducing and targeting instructor contact time



- Longer Term Vision
- Benefits gained from leveraging plans, methods and lessons learned to virtual simulations of other manufacturing processes

Database

Distributed  
Enterprise  
Wide

**Feedback Elements**  
Visual, haptic, auditory prompts and guides assist user through modules and identify errors and corrective measures. Different applications applied to follow-on efforts

Other Welding Types  
SMAW - GTAW - TIG

Other Capitalization

Equipment Operations

Decision Making

Technical Maintenance

System Maintenance

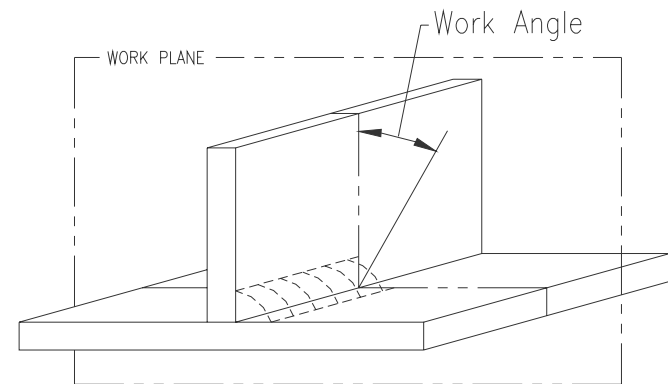
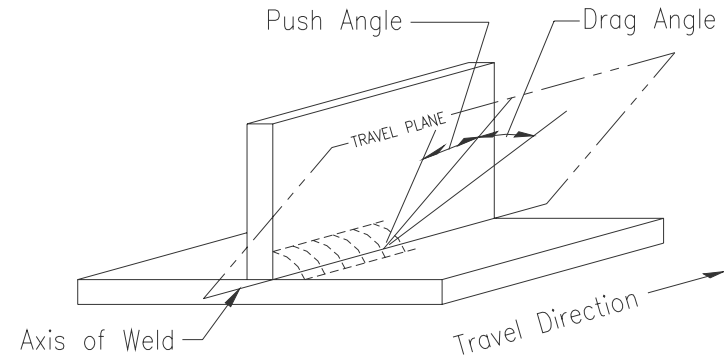
Shipfitting, Cladding,  
Pipe Cutting, Pipe Welding, Crane  
Operations

# How was Welding Simulated?

- Design of Experiment (DOE) with Weld Samples using Electric Boat parameters
- Trained Neural Nets
- Queried Neural Nets in real time to determined weld pool behavior and weld cross sectional area.

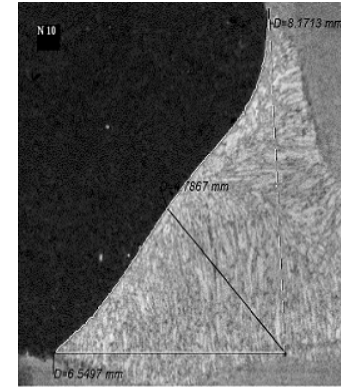
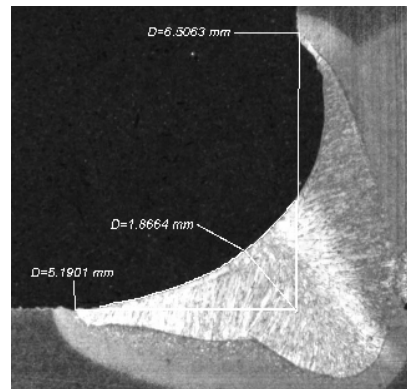
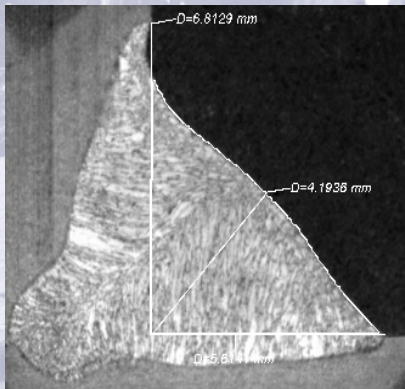
# Welding Parameters

- Welding Angle: 35-55°
- Tip Angle: 70-110°
- Tip-to-Work: 0.6-0.8"
- Travel Speed: 10-20 ipm
- Current: 206-291 Amps
- Voltage: 26-28 Volts



# Welded Samples

No.	WA (deg.)	TA (deg.)	CTWD (Inch)	TS (ipm)	I (A)	V (V)	WFS (ipm)	Arc Power (w)
1	35	110	0.6	10	226.3	26.69	285.54	6041.83
2	55	70	0.6	10	227.6	27.01	283.46	6150.74
3	55	110	0.8	10	213.0	26.99	285.07	5750.42
4	35	70	0.8	10	230.5	26.97	286.27	6216.85
5	55	110	0.6	20	221.1	27.02	285.64	5975.01
6	35	70	0.6	20	260.1	27.05	285.87	7035.77



*EWI generated 43 parameter sets to populate matrix*

# Simulator System Functionality



- Head/torch position determined with a tracker
- Torch position/orientation determined by a haptic control device
- Torch trigger generates the virtual weld bead
- Torch position/orientation is output to the Neural Net which returns weld bead shape
- Stand Alone Computers run Simultaneous Force, Welding Simulation, and Visualization Simulations

their Needs?

the Tools To do The job?

ING TRAINER USE TIPS

CONTROL BAR IN USER'S PALM.  
FOCUS SHOULD BE OVER  
FOR GOOD VISUAL FOCUS.  
ON CHINA BACK TO HOLD IT UP  
WHAT YOU SEE THROUGH.

CORNER OF PL  
D AND LOOK AT  
ANGLES.

AN ARC.

D. RES

LOWER



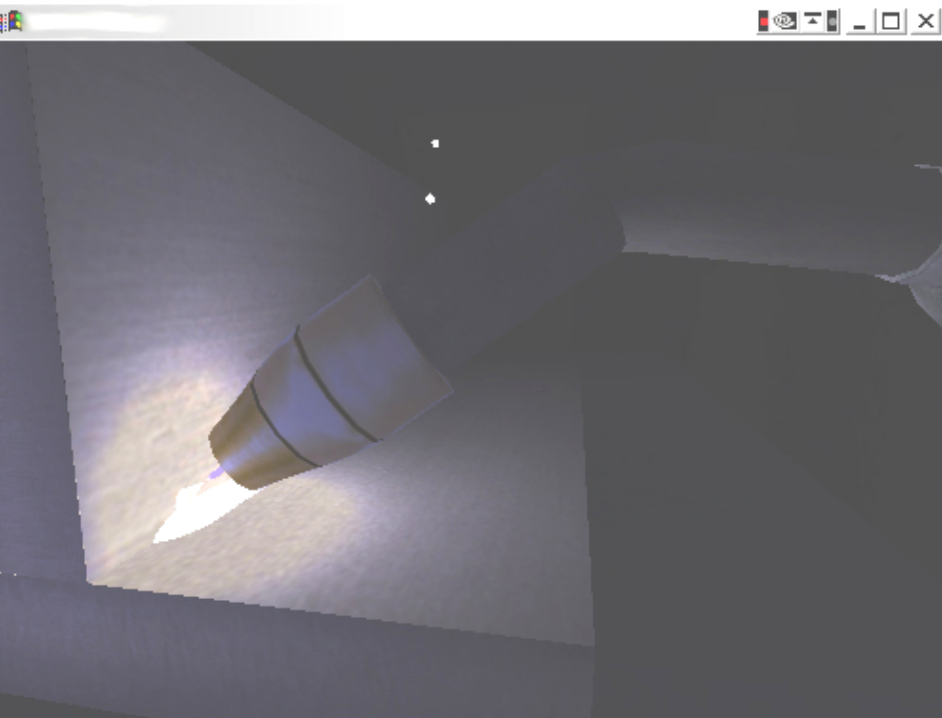
# Simulation Scenario



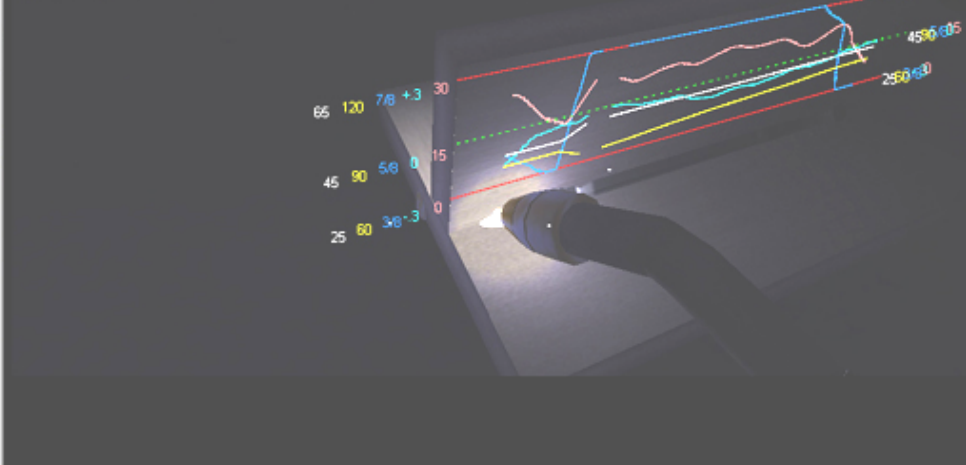
Welder Training Booth

Weld Typical of Training





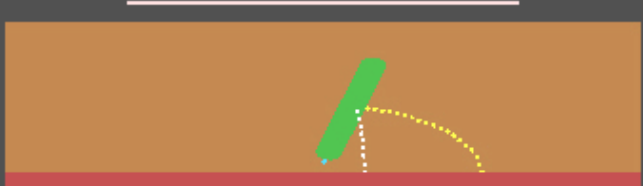
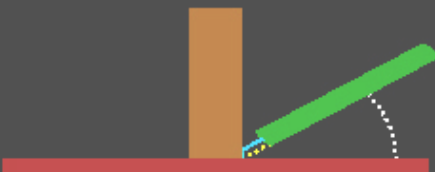
Head -> Torch = 12.6 in  
WA = 36.5 TA = 70.0  
CTW = 0.51 AE = -0.23  
TS = 18.4



iWeldAngle = 36.5  
iTravelAngle = 70.0  
iCupToWorkDistance = 0.51  
iAimError = -0.23  
iTravelSpeed = 18.4  
iVoltage = 0.00  
iWireFeed = 0

iWeldAngle = 36.5  
iTravelAngle = 70.0  
iCupToWorkDistance = 0.51  
iAimError = -0.23  
iTravelSpeed = 18.4  
iVoltage = 0.00  
iWireFeed = 0

# System Reportage During Weld



# System Reportage After Weld

Head -> Torch = 26.0 in

WeldAngle = 37.2

TravelAngle = 84.4

CupToWorkDistance = 0.86

AimError = -0.07

TravelSpeed = 18.4

Voltage = 27.33

WireFeed = 300

65 120 7/8 +3 30

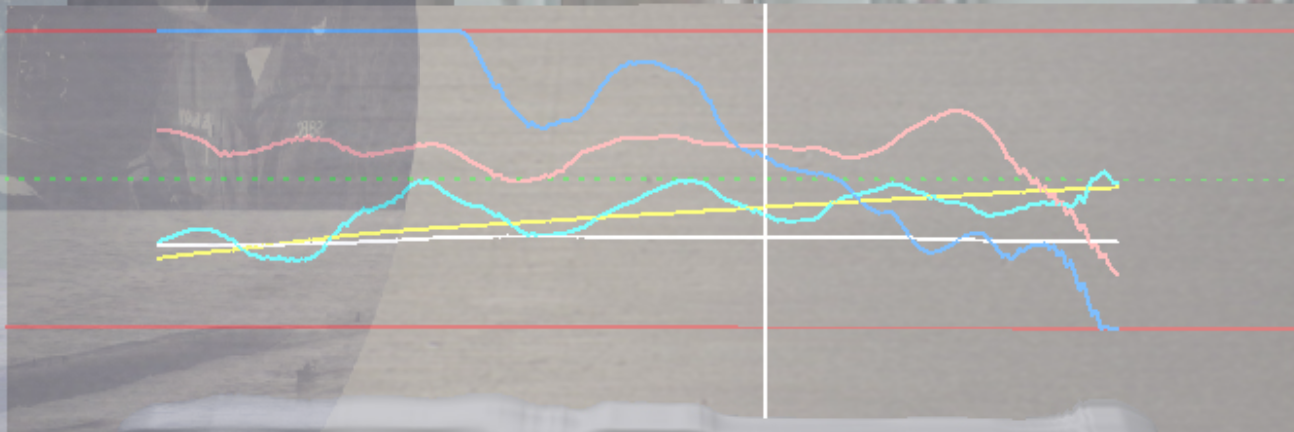
45 90 5/8 0 15

25 60 3/8 -3 0

65 120 7/8 +330

45 90 5/8 0 15

25 60 3/8 -3 0



# Evaluation Trials @ EB

- 100+ People Tested System over 3 weeks at Quonset Point Welding School
  - Seasoned Welders 20+ Years Experience
  - People with 0 Experience
- The majority of users liked the experience and recommended future development of the system.

# Year 2 Technology Plan

- Improve Graphics of Weld Pool and Sound as Torch Orientation Changes in 3-D Space.
- Add Real-Time Audio/Visual Feedback to Help Welder Correct Torch Orientation or Travel Speed Errors During Simulation.
- Develop implementation plan for use in GDEB Welder Training Program

# Current Status

- EWI used FLUENT software to develop an advanced GMAW weld pool model for year 2 enhancements. Turned over to VR SIM for use.
- EWI Drafted Curriculum for VR GMAW training at GDEB
  - GDEB Reviewing & Modifying
- VRSim Integrating SGI Components and Creating Mocked-Up Welding Equipment for System

# Electric Boat Point of Contact

Allan Cote

860-433-2011



# The Navy Joining Center

*Over a Decade - Serving Navy Needs*



Operated by **EWI**  
THE MATERIALS JOINING EXPERTS