# TECHNICAL FINAL REPORT

***TECHNOLOGY INVESTMENT AGREEMENT 2011-462 (ASE-09-01)***

[ADVANCED TECHNOLOGY INTERNATIONAL (ATI) & SERVO-ROBOT CORP.]

## 21ST CENTURY SMART WELD INSPECTION SYSTEM TO IMPROVE SHIP PERFORMANCE

### PROJECT OVERVIEW

The prime objective of this proposal was to develop a portable weld inspection tool that is optimized for shipyard weld joints, applicable weld quality standards and the specific use pipe and hull fabrication. The basis for this development is the existing new Servo-Robot WikiScan portable weld inspection tool introduced to the market in November 2010. The biggest improvement for the shipbuilding new construction and repair industry that will be realized with the successful completion of this program is a significant reduction in unnecessary repairs. These are due to the redundant inspection cycle employed where multiple levels of people inspect the same weld. The time saved will be especially relevant for the LCS and JHSV ships which have an aggressive build schedule requiring time saving innovations.

### TABLE OF CONTENTS


| SECTION | PAGE |
|---|---|
| 0.0 EXECUTIVE SUMMARY | 2 |
| 1.0 ACKNOWLEDGEMENTS | 2 |
| 2.0 INTRODUCTION | 2 |
| 3.0 SCOPE AND APPROACH | 3 |
| 4.0 TEAM ROLES AND ACTIONS | 3 |
| 5.0 PRIOR RELATED WORK | 3 |
| 6.0 HARDWARE DEVELOPED | 3-4 |
| 7.0 SOFTWARE DEVELOPED | 4 |
| 8.0 STATUS AND FURTHER WORK | 5-6 |
| 9.0 REALIZED BENEFITS TO INDUSTRY AND NAVY | 6 |
| 10.0 TECHNOLOGY TRANSFER | 6 |
| 11.0 APPENDICES 1 & 2 | 7-13 |

## 0.0 – EXECUTIVE SUMMARY

The following report summarizes the work done by Servo-Robot Inc. and the Team to develop a 21st Century Smart Weld Inspection System to Improve Ship Performance.

The WiKi-SCAN/Ship weld inspection system developed in this project demonstrates the basic functionality required by the three supporting shipyards with respect to capabilities, ease of use and high performance to improve the effectiveness and efficiency of their visual weld inspection.

Recommendations for future work include continuing to develop new functionality that would increase the percentage of features the WiKi-SCAN/Ship can measure compared to present methods and to support Carderock with their project called "Testing and Verification of an Advanced Visual Testing inspection Tool".

## 1.0 – ACKNOWLEDGEMENTS

The three sponsoring shipyards are HII-Ingalls, HII-NNS and Fincantieri (Marinette Marine). The technology advisor is Thurston Gore of HII-NNS and Madeleine Davis was our Project Advisor from SCRA. Note Jim House stepped in for the last couple months after Madeleine Davis took another assignment within SCRA. Thanks to them for their valuable input at the start of the project and for their helpful feedback along the way.

## 2.0 – INTRODUCTION

### 2.1 PROJECT IDENTIFICATION

Both the United States Navy and commercial shipyards have continually expressed the need for a less subjective more precise system to inspect both structural and pipe weld joints and welds. One very specific example of this is the P15 socket/flange outside weld which is very difficult to properly inspect and there is a great amount of over welding and over repair. In the case of Fincantieri there is also sometimes the need to perform RT inspection if no sound conclusion can be made as to the acceptability of the weld. Therefore this project was defined to develop a portable handheld weld inspection system which could fill this identified void.

### 2.2 CONCEPT DESCRIPTION

The goal of this program is to develop a new weld inspection system for submarines and surface ships fabrication for both structural and pipe welding. This system is based on Servo Robot's previous experience with both automated and handheld weld inspection for general industry.

## 3.0 – SCOPE AND APPROACH

### 3.1 SCOPE

This WiKi-SCAN/Ship portable handheld weld inspection system is being designed to be used by inspectors, supervisors and even welders themselves to assess more accurately and consistently the conformance of the welds to applicable standards. The overriding goals reflect the need to make this system easy to use, reliable and repeatable.

### 3.2 APPROACH

The first thing done to clearly define the needs of each of the participating shipyards (HII-ingalls, HII-NNS and Fincantieri) was to survey each shipyard. A combination of phone calls and onsite visits were used to further refine and clarify the needs.

## 4.0 – TEAM ROLES AND ACTIONS

The team consisted of Servo-Robot Inc, Servo Robot Corporation (Milwaukee, WI) and the three participating shipyards. Thurston Gore from HII-NNS was designated the National Shipbuilding Research Program (NSRP) Technical Representative (PTR) and monitored the technical work and reviewed the quarterly reports for compliance with the technical requirements of the Subcontract. Beyond establishing the initial "wish list" information and helping to refine the prioritized wants and needs, the actual development was done by the Servo-Robot team. This team consisted of personnel in disciplines including project management, software, mechanical and electrical control as well as welding.

**The outside contact people involved included:**

- Daniel Roland → Fincantieri
- John Ranager → HII-Ingalls
- Jeremy Nichols → HII-NNS (Later Tony Buckley)
- Madeleine Davis → SCRA (For the last quarter it was Jim House)

## 5.0 – PRIOR RELATED WORK

This project built on previous Servo-Robot Inc. work and R&D associated with portable weld inspection done in a NIST program back in the 1990's and a NSRP project done in the mid 2000's with a previous generation weld inspection Tool that involved EWI and GD- Bath Iron.

## 6.0 – HARDWARE DEVELOPED

The hardware developed and interfaced in this program includes the laser vision sensor, 2D color camera, Smart Tablet (developed by Servo Robot) and ancillary components. See Figure 1 showing an overall picture of the WiKi-SCAN/Ship and a review of all what is included in the system in Figure 2. Specific key developments completed for Phase 1 include:

6.1 5X magnification viewer which will allow the improvement in detection of small defects like pinholes.

6.2 Variable speed cooling fan

6.3 WiKi-SCAN guide roller with built-in encoder to facilitate maintaining the orientation and standoff of the system more consistent for certain part geometries as well as provide distance traveled. (See Figure 3)

## 7.0 – SOFTWARE DEVELOPED

### 7.1 APPLICATION SOFTWARE

**7.1.1 DYNAMIC SCAN CAPABILITY** - This new capability allows for the ability to detect multiple defects over a specific length of scan. This level of capability does not allow for a length of defect to be measured but instead it concentrates on the number of occurrences. It is essentially a series of snapshot s that are combined together to give an overall result. .

**7.1.2 PART LIBRARY EDITOR** – This allows one to program multiple WiKi-SCAN/Ship systems from a PC and in turn be able to upload any changes to settings on the WiKi-SCAN/Ship systems out in the field. See Figure 4.

**7.1.3 REMOTE VIEWER** – This allows one to display the recorded inspection onto a PC or tablet PC for remote viewing within the distance allowed by the wireless network.

**7.1.4 PASSWORD PROTECTION** – An administration level password protection is available to restrict the WiKi-SCAN/Ship programming to authorized individuals.

**7.1.5** – The socket flange P15 pipe weld is able to be measured by incorporating a new feature that allows one to integrate the 3D profile semi-automatic mode onto the 2D view from which the distance from the scribe mark to the original edge can be accurately determined. This will then allow for a much more accurate weld measurement to be taken. This capability applies to both pipe socket flange type fillet welds as wells as any structural lap fillet weld. See Figures 5-6.

**7.1.6 WELDER FEEDBACK** – The first capability will be to output an “over welding” value which will help tell the welder and supervisors how well the deposited weld is matching the requirements. In addition there is a Height/Width metric present for groove welds. See Figure 7 for the over welding metric..

### 7.2 GRAPHICAL USER INTERFACE

The key to the successful implementation of this WiKi-SCAN/Ship system into the shipyards is the ability for users to quickly learn how to use it and also to be able to use it after a period of non-use. The interface is completely icon based and has been developed keeping in mind that the users will be welders, weld inspectors, Trainers and supervisors.

### 7.3 EXCEL SPREADSHEET REPORT

The report form needs to be customizable by each shipyard because of the different formats that are present and also the different quality systems that the weld data goes into. The data format and form itself were thus designed to be as flexible as possible and with as much power to allow optimum identification of the inspector, weld, joint, and part. See Figure 8.

## 8.0 – STATUS & FURTHER WORK

### 8.1 STATUS

The goal was to produce a prototype WiKi-SCAN/Ship weld inspection system that could be tested in the shipyards that are part of this project to determine how well it met the original goal. The demo at Fincantieri July 17, 2012 showed that each of the new developments listed above in Section 7.1 were successful thus confirming the new software and hardware as well as the integration of both, was completed. Samples with typical examples of a "burned away edge" were provided by Dan Roland from Fincantieri during the visit in late May so that testing can be done ahead of time.

**8.1.1** HII-Ingalls has been able to use their existing WiKi-SCAN to do their own evaluation. Their results are shown below. What was learned during the testing of the WiKi-SCAN on structural welds includes:

- Great for auditing of weld size to determine conformance to requirements. 10X faster than traditional gauges.
- Measurements with the WiKi-SCAN/Ship agree with standard measuring and inspection methodology based on Flaw-Tech workmanship samples used for inspector training.
- Presently the WiKi-SCAN can measure or inspect 74% (17 out of 23) visual weld inspection attributes listed in Table 278-1 of Mil-Std 278. Those not measurable include: Cleanliness, Oxidation, Slag, Base Material Surfaces, Intersecting welds and incomplete insert melt. What these attributes all have in common is that they do not have an objective tolerance that can be set. These were never thought to be inspectable automatically within the scope of this project.
- The socket flange software developed to allow for both structural and pipe weld inspection worked well but it was found in the opinion of the inspectors that tried it to be no faster or accurate than the manual methods presently used.
- Difficulty with measuring welds on bulb tees and (pipe) socket joints. Note new socket flange software was never tested on this and may in fact handle this situation.
- Ingalls Training Dept. has concluded that the requirements for training related to the WIKISCAN are the same as those for other inspectors. Consequently, a specific "training package" is not needed.

**8.1.2** Fincantieri (MMC) has the following to report as activity.

- Initial use for the WiKi-SCAN will be for auditing the ever growing number of pipe and structural component suppliers. The WiKi-SCAN will be used to audit a percentage of parts being welded and will offer the benefit of making this faster to do and will provide the documentation in an easily stored format.
- The socket flange software developed for both structural and pipe weldi inspection worked well in testing at the yard and suppliers and is seen as being both faster and more accurate by removing subjectivity.
- Plan is to buy one WiKi-SCAN in the first half of 2013. PO is going through approval.

**8.1.3** HII_NNS has decided to wait until the Carderock Testing and Verification Panel project is complete so the full approval of NAVSEA and SupShip will be in place. Note that onsite demonstrations on representative structural component was overall successful with the prime interest being in the ability to "buyoff" modules prior to their installation into bigger "chunks" of the ships.

### 8.2 FURTHER WORK

Recommended Further Work

During the project a variety of ideas came up for additional development outside the scope of this project which would solve problems within each shipyard. Some were related to welding and a few were non-welding. The top 5 requests are listed below and should be considered for a future Panel or Full NSRP project.

**8.2.1** While a continuous snapshot mode was developed for this project, the full continuous scanning ability like is present with the Servo Robot full automatic ArcScan would bring further advantages to the use of the WiKi-SCAN/Ship because then the length of defects could be assessed.

**8.2.2** The 8.2.1 development could be employed either manually or in conjunction with a mobile tractor (RTT style), mechanized tractor (Gullco, Bug-O), or mobile robot (Servo Robot MWR) all utilized extensively in the shipyards now for welding. Integration to one or more of these systems would need to be facilitated.

**8.2.3** In a variety of sections of a ship or submarine there were areas identified that could not be easily reached with the length of handle on the present WiKi-SCAN/Ship. Innovative extensions need to be developed.

**8.2.4** The correct orientation (angle of the WiKi-SCAN/Ship to the weld or weld joint) and the standoff (distance from the WiKi-SCAN/Ship camera to the weld surface) need to be maintained within a specific window, which is in fact quite large and forgiving. However, for smaller pipe (under 6" diameter) this ability to maintain consistency gets more difficult. Discussions were held pointing to a need for a cradle or other support of some kind that would allow for easy rolling around the pipe.

**8.2.5** The most exicting non welding need identified was for the measuring across adjacent panels the flatness and fairing of the joints. We already can do this but only in a very small area but to be effective we would need to go from a 2" wide laser line to a 2' laser line. This would require new hardware and some small software changes. If the true demand in quantities that would be bought per year at a specific price could be quantified, this could be a great project.

## 9.0 – REALIZED BENEFITS TO INDUSTRY AND NAVY

It is still early in the program but we have seen interest from other Defense Industry commercial shipyards in this technology. One example is Nassco where Mike Sullivan told me after my presentation at the SP-7 Panel meeting that the WiKi could prove to be a huge advantage on aluminum where PT is now used and our new 5X magnification could be used and save millions of dollars. Ingalls reported that the WiKi-SCAN is almost ten times faster than their traditional measuring techniques. No specific savings to the Team members by virtue of using the WiKi-SCAN has occurred yet because it is still under evaluation at Ingalls and neither Fincantieri nor HII_NNS have one in house.

## 10.0 – TECHNOLOGY TRANSFER

1. Attended, exhibited and presented at a variety of navy related events including Navy Days in Washington DC (twice), NSRP All Panel Meetings (twice), SP-7 Welding Panel meetings (4 times) and the AWS 2013 Shipbuilding Conference.
2. Created WiKi-SCAN/SHIP brochure that has been sent out to all navy and commercial shipyards.
3. Contacted all Army Depot's and provided them information about the standard WiKi-SCAN as well as what the /SHIP version will do. TARDEC purchased on for their development and prototyping area as well as to share with depots.
4. Created a WiKi-SCAN Wordpress website for easy access to information by all industry.

## 11.0 APPENDICES

### 9.1 FIGURES

FIGURE 1 – OVERVIEW OF WIKISCAN-SHIP SYSTEM

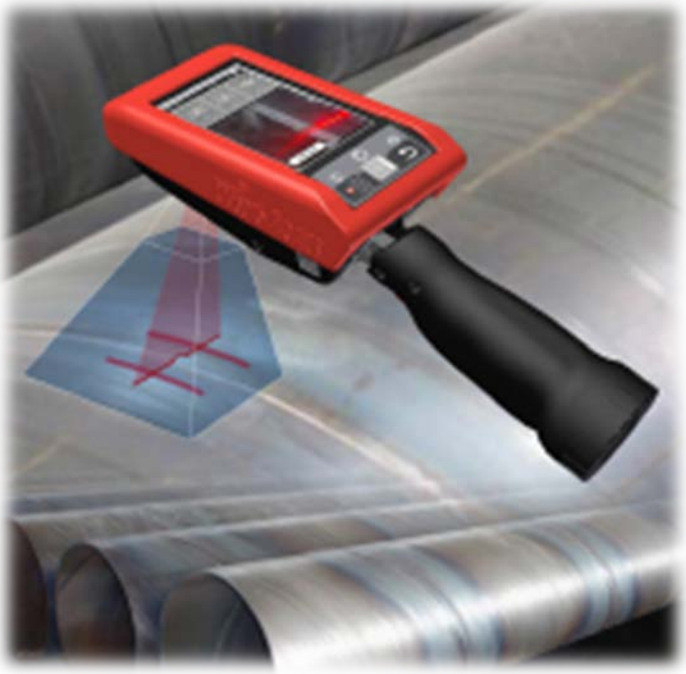


FIGURE 2 – DETAILS OF WHAT IS INCLUDED IN WIKI-SCAN/SHIP

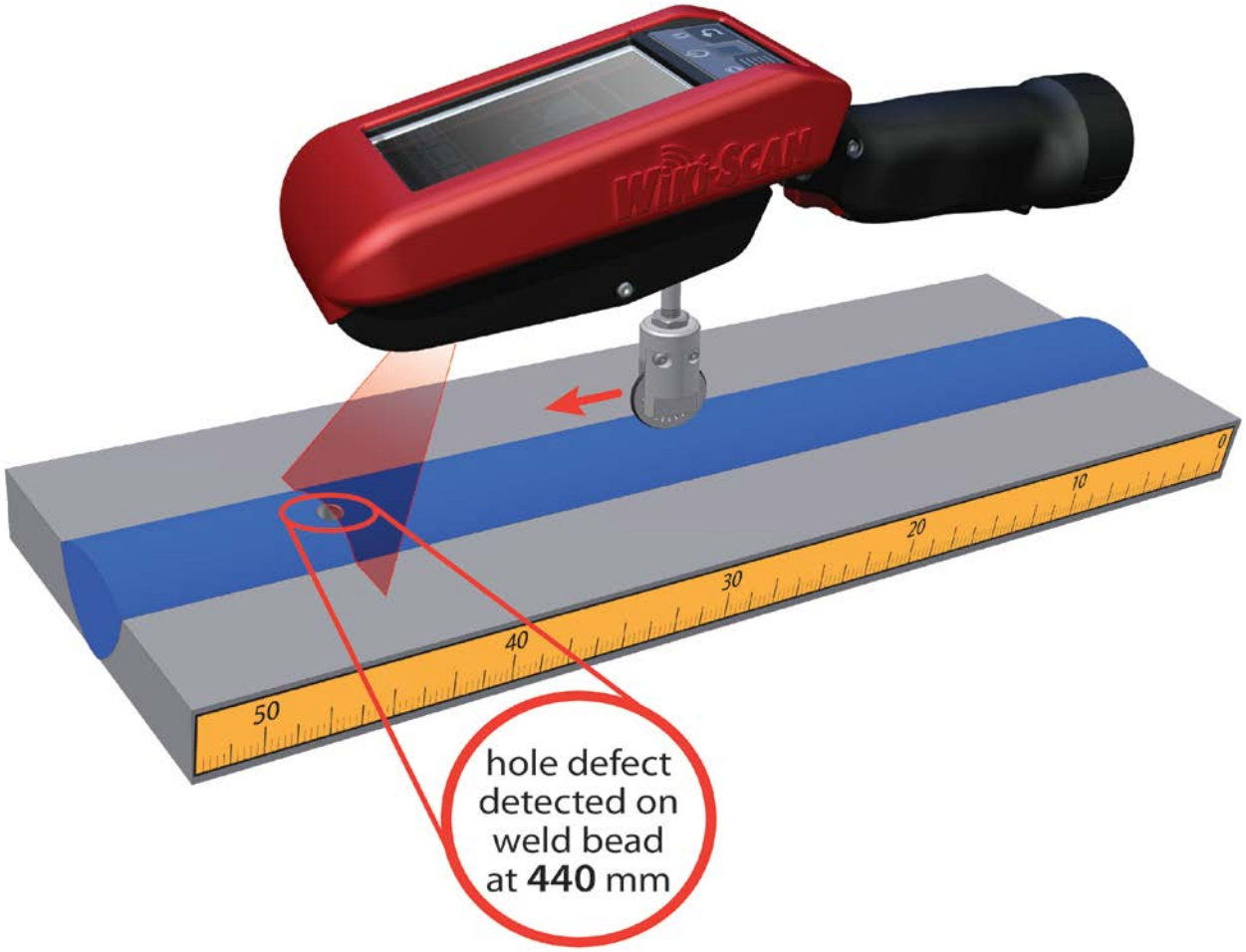



FIGURE 3 – DYNAMIC SCAN RECORDING OF DEFECTS

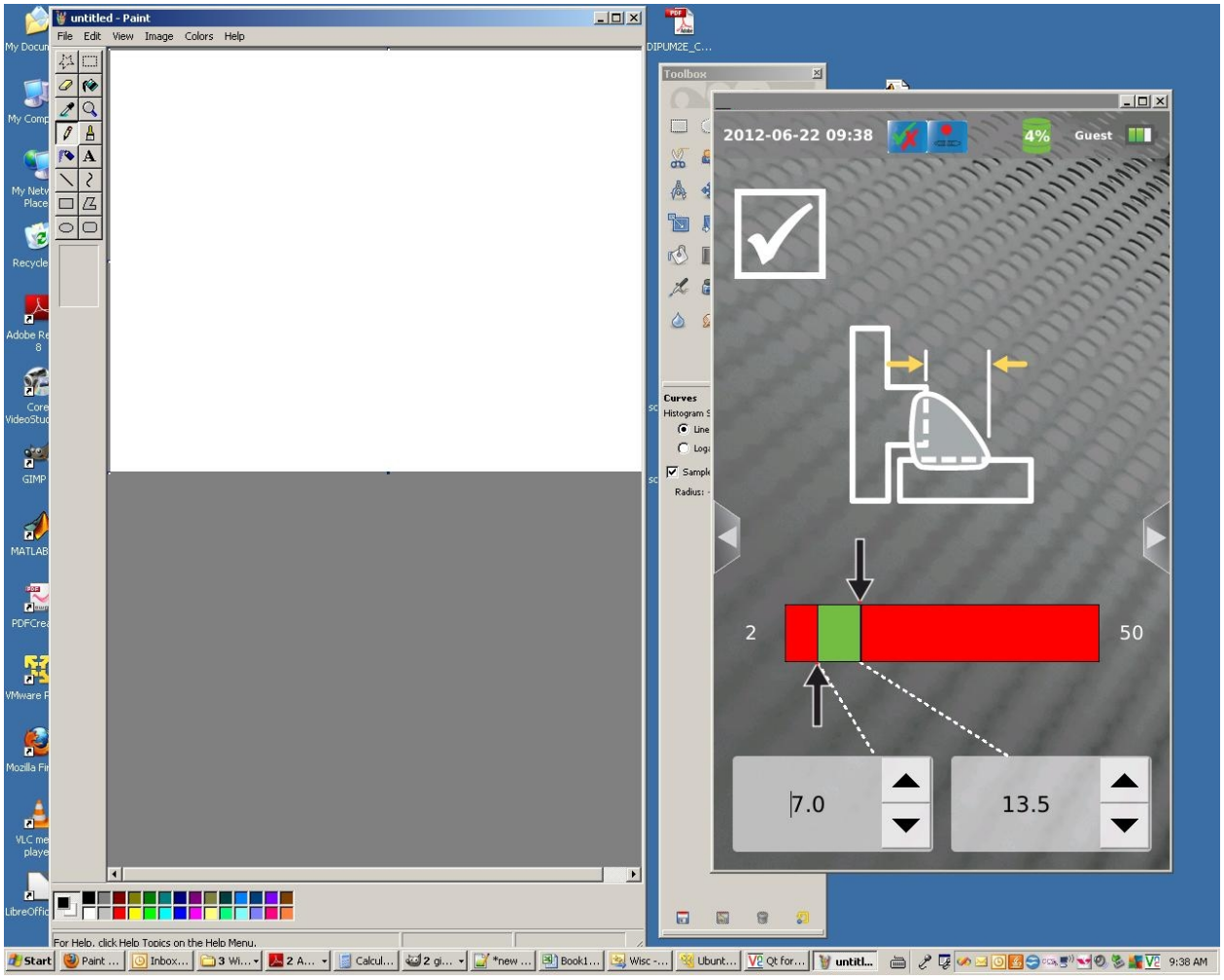
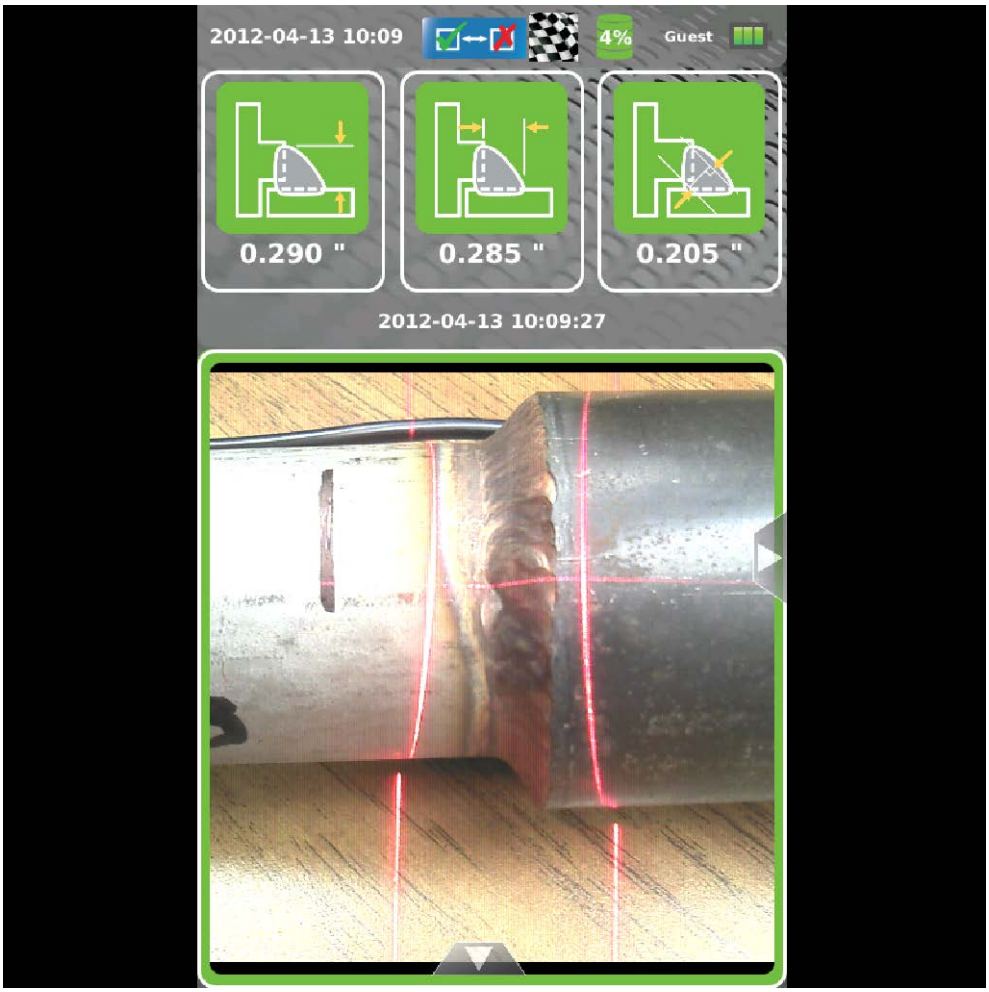



FIGURE 4 – PART LIBRARY EDITOR

FIGURE 5 – SOCKET /FLANGE 2D/3D




MEASUREMENT RESULT SCREEN - ORIGINAL

FIGURE 6 – SOCKET FLANGE – ENHANCED CAPABILITY

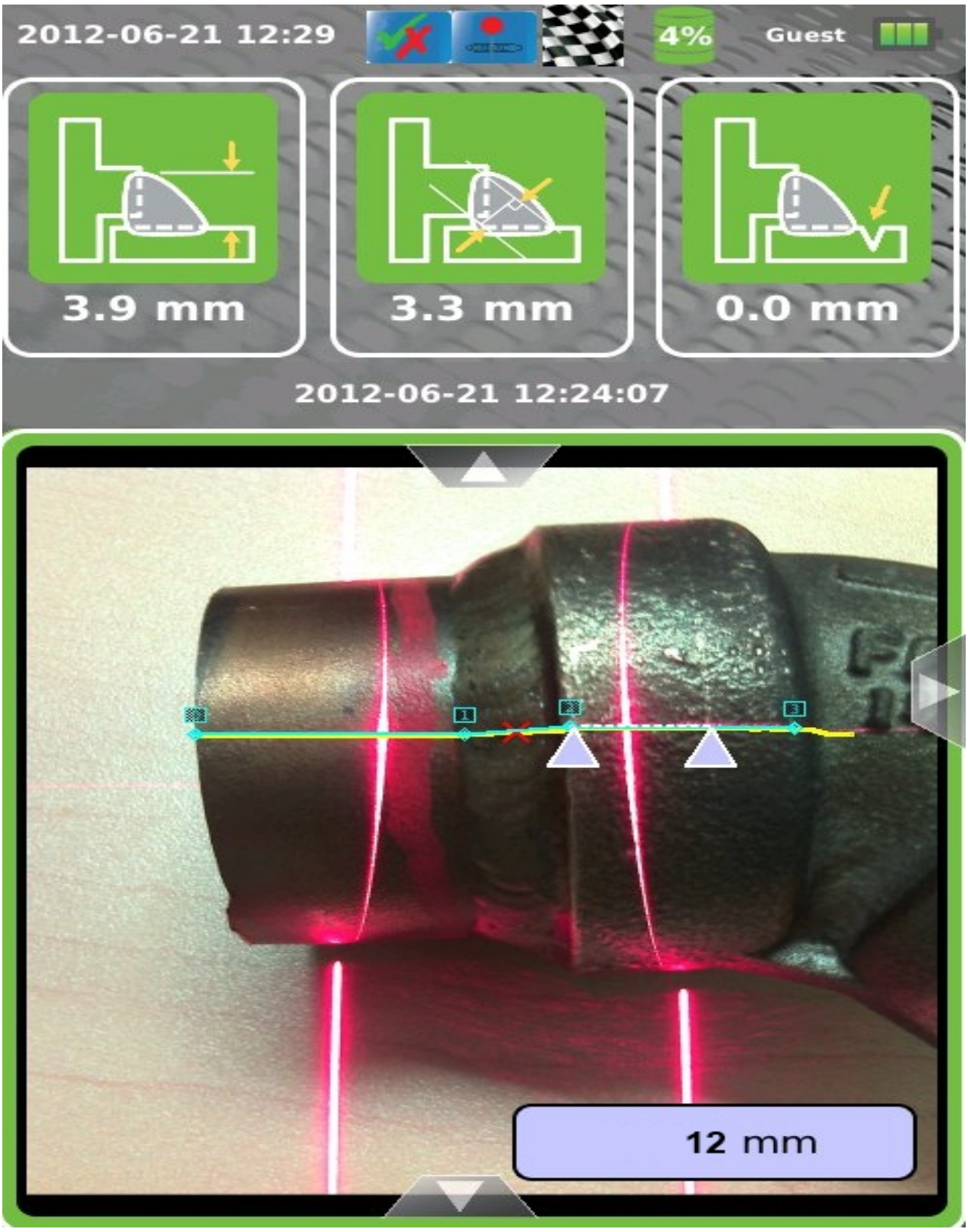



FIGURE 7 – TRAINING OVERWELDING METRIC

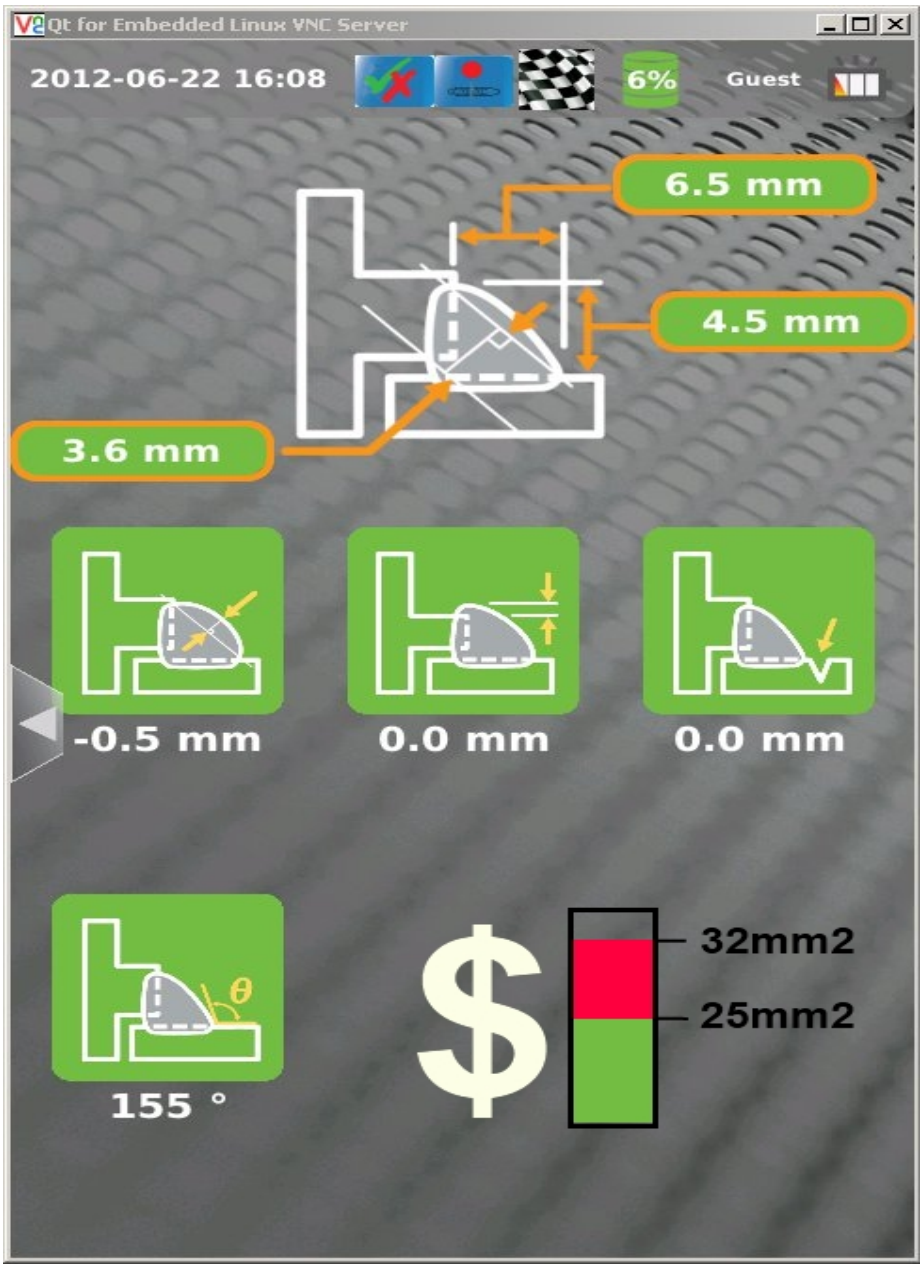

Qt for Embedded Linux VNC Server
2012-06-22 16:08
6%
Guest
6.5 mm
4.5 mm
3.6 mm
-0.5 mm
0.0 mm
0.0 mm
θ
155 °
$
32mm2
25mm2

FIGURE 8 – ENHANCED REPORT

| Welding test on part C38 | | TEST CONDITIONS | | | | | | | TEST RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 11/06/2012 | | | | | | | | | | | | | |
| Report #: | 4 | | | | | | | | | | | | | |
| Serial number: | 1120 | | | | | | | | | | | | | |
| Measurement unit: | mm | | | | | | | | | | | | | |
| Language: | English | | | | | | | | | | | | | |
| | | | Welding parameters | | | | | Wiki-Scan joint inspection | | | Wiki-Scan weld inspection | | | | |
| Part# | Test ID and result | Current (A) | Voltage (V) | Wire speed (m/min) | Torch orientation (°) | Alignment (mm) | Root opening | Beta angle | Leg1 | Leg2 | Throat | Convexity | Undercut 1 | |
| C38-410-28 | Test1-12 | 290 | 26 | 8 | 35 | -0.3 | 1 | 85 | 32 | 2.2 | 32 | 32 | 2.2 | |
| | Test1-13 | 295 | 26 | 7 | 35 | -0.3 | 2 | 85 | 32 | 2.2 | 32 | 32 | 2.2 | |
| | Test1-14 | 300 | 26 | 8 | 35 | +0.3 | 3 | 86 | 25 | 2.2 | 32 | 32 | 2.2 | |
| C38-410-29 | Test1-15 | 290 | 22 | 8 | 35 | -0.3 | 1 | 90 | 32 | 2.2 | 32 | 32 | 2.2 | |
| | Test1-16 | 295 | 22 | 7 | 35 | -0.3 | 2 | 92 | 32 | 2.2 | 32 | 32 | 2.2 | |
| | Test1-17 | 300 | 22 | 8 | 35 | +0.3 | 3 | 92 | 25 | 2.2 | 2.2 | 2.2 | 2.2 | |

## 9.2 HII-INGALLS PHASE II REPORT

NATIONAL SHIPBUILDING RESEARCH PROGRAM (NSRP)

21ST CENTURY SMART WELD INSPECTION SYSTEM TO IMPROVE SHIP PERFORMANCE

PHASE II REPORT ON HII-INGALLS EVALUATION OF SERVO-ROBOT INC. WIKISCAN/SHIP SYSTEM

In June 2011, National Shipbuilding Research Program (NSRP) funding was provided for further development of the WikiScan/Ship system manufactured by SERVO-ROBOT Inc. to meet the needs of visual weld inspection in the shipbuilding industry. Ingalls Shipbuilding was contracted to evaluate the current version of the system (scanner) and provide feedback as to improvements needed in order for the scanner to provide maximum value as an inspection tool in the shipyard. The 21st Century Smart Weld Inspection System to Improve Ship Performance NSRP project was broken into two phases. Phase I transpired from June 2011 through July 2012. Phase II transpired from August 2012 through May 2013. This report mainly covers the Phase II project activities. If the reader is interested in the Phase I activities he is referred to the Phase I report submitted to the NSRP.

## 2.1. PHASE I PROJECT ACCOMPLISHMENTS

During Phase I of the NSRP 21st Century Smart Weld Inspection System to Improve Ship Performance project, these things were accomplished:

- Ingalls Shipbuilding purchased a scanner from SERVO-ROBOT Inc.
- SERVO-ROBOT Inc. delivered the scanner to Ingalls Shipbuilding and provided initial user training.
- Initial evaluation of the scanner was performed by Ingalls Shipbuilding Quality and Process Excellence Department and Operations Department personnel.
- Ingalls Shipbuilding provided feedback to SERVO-ROBOT Inc. concerning Ingalls Shipbuilding observations gathered during use of the WikiScan/Ship device.
- SERVO-ROBOT Inc. worked to correct deficiencies via software updates.

A final report was generated at the end of Phase I by Ingalls Shipbuilding personnel. The Phase I report details a number of functional deficiencies of the WikiScan/Ship system, as well as areas where it might provide value to the shipbuilder.

## 2.2. PHASE I EVALUATION OBSERVATIONS PROVIDED TO SERVO-ROBOT INC. ABOUT THE WIKISCAN/SHIP DEVICE

Phase I of the 21st Century Smart Portable Weld Inspection System to Improve Ship Performance NSRP project transpired from June 2011 to July 2012. Ingalls Shipbuilding's role in Phase I of the project was to evaluate the current version of the WikiScan/Ship device and provide feedback to SERVO-ROBOT Inc. for desired improvements in the system. Ingalls Shipbuilding personnel used the WikiScan/Ship device to perform some weld inspections and evaluate some of the extended capabilities of the device and the software. Following is the list of issues that resulted from Ingalls Shipbuilding personnel's Phase I evaluation of the WikiScan/Ship scanner as a production inspection tool:

- Battery charge life and sourcing challenges
- Need for offline programming capability
- Need ability to input name for each inspection site (shot)
- Need ability to download the pictures with the data - for quick reference
- The scanner cannot recognize a significant number of flaws in the structural welds expected to be encountered by shipyard inspectors
- Difficulty with measuring welds on bulb tees and (pipe) socket joints
- Inconsistent accuracy of measurement dependent on positioning of the scanner

Improvements in some, or all, of these areas were planned to be made by SERVO-ROBOT Inc. during Phase II of the 21st Century Smart Portable Weld Inspection System to Improve Ship Performance NSRP project.

The initial software upgrade (Phase I) provided power management features which extended battery charge life to approximately 3.5 hours during Ingalls evaluation activities. Although useable, the Ingalls team does not consider this an adequate life for production inspection use. The batteries themselves are of a unique type and rather expensive. SERVO-ROBOT has expressed no intention of further addressing the battery related issues although they do now inventory the batteries in their Milwaukee facility rather than users having to order them from the manufacturer.

The goal of Phase II of the NSRP 21st Century Smart Weld Inspection System to Improve Ship Performance project was to correct the deficiencies of the system to the greatest degree possible, with Ingalls Shipbuilding personnel performing evaluation and providing feedback on these improvements.

## 3.1. PHASE II EVALUATION OBSERVATIONS PROVIDED TO SERVO-ROBOT INC. ABOUT THE WIKISCAN/SHIP DEVICE

Following is the subset of the areas for improvement that SERVO-ROBOT Inc. addressed during Phase II of the 21st Century Smart Portable Weld Inspection System to Improve Ship Performance NSRP project, and that were evaluated by Ingalls Shipbuilding using the WikiScan/Ship device:

- Need for offline programming capability
- Need ability to download the pictures with the data - for quick reference
- Difficulty with measuring welds on (pipe) socket joints
- Inconsistent accuracy of measurement dependent on positioning of the scanner

In addition to the improvements listed above, some other improvements made to the WikiScan/Ship device were evaluated by Ingalls Shipbuilding personnel during Phase II of the 21st Century Smart Portable Weld Inspection System to Improve Ship Performance NSRP project. These additional functionalities included:

- Functionality to measure a 3D profile with toolbox arrows to enable measuring multi-pass features, such as peak to peak distance
- Circle functionality added to measuring toolbox to enable measuring bead peak to valley distance
- Magnifier viewing capability to better see porosity and cracks in the weld.
- Functionality to save 3D profiles in the report

During Phase II of the 21st Century Smart Portable Weld Inspection System to Improve Ship Performance NSRP project, Ingalls Shipbuilding personnel performed the following additional activity:

- Conducted a comparison between the time required to perform an inspection using the WikiScan/Ship scanner and the time required to conduct the same visual weld inspection using the traditional approach involving hand tools.

Evaluation of the scanner was accomplished by Ingalls Shipbuilding personnel who were experienced in visual inspection of both structural and pipe welds. Some were representatives from the Quality and Process Excellence Department who have responsibility for final judgment of weld quality. Others represented supervision that has an interest in insuring “first time quality” by immediately inspecting the craftsperson’s work and providing feedback.

## 3.2. EVALUATION SUMMARY

### 3.2.1 OFFLINE PROGRAMMING CAPABILITY

SERVO-ROBOT Inc. personnel developed a software application to address a specific Phase I produced request for an offline programming capability. This requested functionality was motivated by the desire to have a set up method whereby multiple WikiScan/Ship devices could be configured with specific weld inspection parameters, other than by using the touch screens on the devices themselves. Ingalls Shipbuilding personnel had theorized about an operating environment where multiple personnel would use multiple WikiScan/Ship devices to inspect shipbuilding welds. Interactively setting up the WikiScan/Ship devices (all to the same parameters) one by one would become an onerous task when setting up multiple devices. The desire was to have a personal computer (PC) based set up application where the inspection parameters could be set, and then the

parameters could be "pushed" to multiple WikiScan/Ship devices so they would all be configured with the same weld inspection setup.

SERVO-ROBOT Inc. personnel developed the WikiForPC software application to address the desire for offline programming capability. In early March 2013, Ingalls Shipbuilding personnel obtained the WikiForPC software application from SERVO-ROBOT Inc. Ingalls Shipbuilding personnel installed the software on an Ingalls Shipbuilding owned Microsoft Windows XP configured laptop computer. Observations were that the installation was straightforward and typical of similar software installation procedures. Ingalls Shipbuilding personnel exercised the WikiForPC software during the last week of March. Observations included:

- The WikiForPC software mimics the onboard software of the WikiScan/Ship device; all the screens are the same, with the exception of two buttons for import/export of data.
- Using the software is not intuitive, including the process of saving the configuration data.
- The WikiforPC software lacked a User Manual.

Notwithstanding the usability observations, Ingalls Shipbuilding personnel were able to use the WikiForPC application to create a file containing the setup data. This setup configuration file was stored in a specific directory on the laptop computer. It was known beforehand that the WikiScan/Ship device doesn't support standard computer networking capabilities. Therefore, a memory stick was the designed transport mechanism that had to be used to move data between the laptop computer and the WikiScan/Ship device. The setup configuration file was successfully exported to a memory stick plugged into a port on the laptop computer. The memory stick was then removed from the laptop, plugged into the port on the WikiScan/Ship device, and the configuration data was successfully imported into the WikiScan/Ship device. The device was correctly configured using this setup file and was used for later weld inspection activities.

### 3.2.2 ABILITY TO DOWNLOAD PICTURES WITH THE DATA

SERVO-ROBOT Inc. added a capability to the WikiScan/Ship software whereby pictures of the weld inspection could be saved. Ingalls Shipbuilding personnel's observations include the statement that a weld inspector can now save measuring tool values for 2D pictures, both in inspection mode and history mode on the device. Ingalls Shipbuilding personnel also observed that the device can better measure pinholes, etc., in the welds using the picture functionality. It was observed that the weld inspector can record several pictures for the same inspection and this is a desired capability.

### 3.2.3 DIFFICULTY WITH MEASURING WELDS ON (PIPE) SOCKET JOINTS

During Phase I of the 21st Century Smart Portable Weld Inspection System to Improve Ship Performance project, Ingalls Shipbuilding personnel made the following observation: "In inspecting socket welds for pipe joints it is difficult to obtain an accurate measurement of weld size due to the loss of required reference points when the weld extends too far onto the "shoulder" of the socket." SERVO-ROBOT Inc. delivered a WikiScan/Ship software update to Ingalls Shipbuilding in September 2012 that included a potentially improved functionality for (pipe) socket weld inspection. Ingalls Shipbuilding personnel's evaluation of the (pipe) socket joint weld inspection improved functionality was that it provided a potential solution for measuring socket welds, although a question remains as to whether it will be of practical benefit to the inspector as compared to using the traditional approach involving hand tools.

### 3.2.4 INCONSISTENT ACCURACY OF MEASUREMENT DEPENDENT ON POSITIONING OF THE SCANNER

During Phase I of the 21st Century Smart Portable Weld Inspection System to Improve Ship Performance project, Ingalls Shipbuilding personnel made the following observation:

> "Another important issue that was identified by all users is that it is difficult to obtain repeatable measurement results of unwelded butts with any degree of accuracy. This seems to result from different instrument handling from operator to operator and the fact that a measurement reading depends on the position at which the scanner is held.

The laser projection provided as an alignment indicator, although quick and easy to use, does not seem to adequately position the scanner for an accurate, repeatable measurement."

To address this, SERVO-ROBOT Inc. delivered a WikiScan/Ship software update to Ingalls Shipbuilding in September 2012 that included an improved functionality for improving the accuracy of measurements taken with the WikiScan/Ship device. Evaluation of this improved functionality yielded the opinion that the new software provided an improvement in the accuracy issues observed during Phase I of the 21st Century Smart Portable Weld Inspection System to Improve Ship Performance project.

### 3.2.5 FUNCTIONALITY TO MEASURE 3D PROFILE WITH TOOLBOX ARROWS TO ENABLE MEASURING MULTI-PASS FEATURES, SUCH AS PEAK TO PEAK DISTANCE

During Phase II of the 21st Century Smart Portable Weld Inspection System to Improve Ship Performance project, SERVO-ROBOT Inc. added a capability to the WikiScan/Ship software that enables the device to measure a 3D profile to enable measuring a feature such as a peak to peak distance. Ingalls Shipbuilding personnel's observations were that this functionality performed satisfactorily. It was observed that this capability is the same as what is available in the 2D mode. Ingalls Shipbuilding preferred to use the 2D measurement mode so this functionality was nice to have, but not particularly useful.

### 3.2.6 CIRCLE FUNCTIONALITY ADDED TO MEASURING TOOLBOX TO ENABLE MEASURING BEAD PEAK TO VALLEY DISTANCE

During Phase II of the 21st Century Smart Portable Weld Inspection System to Improve Ship Performance project, SERVO-ROBOT Inc. added a capability to the WikiScan/Ship software that enables the device to use a circle when measuring a bead peak to valley distance. Ingalls Shipbuilding personnel's observations were that this functionality performed satisfactorily. It was observed that this capability is the same as what is available in the 2D mode. Ingalls Shipbuilding preferred to use the 2D measurement mode so this functionality was nice to have, but not particularly useful.

### 3.2.7 MAGNIFIER VIEWING CAPABILITY TO BETTER SEE POROSITY AND CRACKS IN THE WELD

During Phase II of the 21st Century Smart Portable Weld Inspection System to Improve Ship Performance project, SERVO-ROBOT Inc. added a capability to the WikiScan/Ship software that enables the device to display a real time 5X magnified view of the weld under inspection. Ingalls Shipbuilding personnel's observations include the statement that this now gives the weld inspector a much improved ability to see porosity and cracks in the weld. It was observed that this capability is very useful when measuring to find accurate measurement points, and this is a highly desirable capability.

### 3.2.8 FUNCTIONALITY TO SAVE 3D PROFILES IN THE REPORT

During Phase II of the 21st Century Smart Portable Weld Inspection System to Improve Ship Performance project, SERVO-ROBOT Inc. added a capability to the WikiScan/Ship software that enables the device to save 3D profiles to a report. Ingalls Shipbuilding personnel's observations were that this functionality performed satisfactorily. It was observed that this capability is the same as what is available in the 2D mode. Ingalls Shipbuilding preferred to use the 2D measurement mode, and save 2D profiles in a report, so this functionality was nice to have, but not particularly useful.

### 3.2.9 TIME COMPARISON BETWEEN USING THE WIKISCAN/SHIP DEVICE AND MANUAL INSPECTION METHODS

During phase II of the 21st Century Smart Portable Weld Inspection System to Improve Ship Performance project, Ingalls Shipbuilding personnel conducted a comparison between the time required to perform an inspection using the WikiScan/Ship scanner and the time required to conduct the same visual weld inspection using the traditional approach involving hand tools. The results of this activity are shown in Table 1.

## Table 1. WikiScan/Ship Inspection Time Required Comparison

Ingalls Shipbuilding

### Wikiscan Time Comparison

| Test Plate # | Weld Type | Discontinuity | Manual Time | Wikiscan Time | Remarks |
|---|---|---|---|---|---|
| VTC-24 | Butt | Crater Crack<br>Porosity | 13 seconds<br>12 seconds | 48 seconds<br>3 minutes | Light built on Wikiscan not focus in right area.<br>Had to use flashlight to see porosity. |
| VTC-25 | Butt | Incomplete Root Pentration<br>Underfill | 15 seconds<br>8 seconds | 3 minutes<br>54 seconds | Take 3 attempts and had to use flashlight for incomplete pentration. |
| VTC-29 | Butt | Weld Spatter<br>Chipping Hammer Marks | 5 seconds<br>7 seconds | 40 seconds<br>42 seconds | |
| VTC-30 | Butt | Root Concavity<br>Undercut | 10 seconds<br>12 seconds | 27 seconds<br>3 1/2 minutes | Had to use underfill block to read undercut. |
| CWI-C-32 | Fillet Tee | Undersize Leg<br>Excessive Convexity | 12 seconds<br>1 minute | 20 seconds<br>20 seconds | |
| CWI-C-35 | Butt | Longitudinal Crack<br>Aligned Porosity | 4 seconds<br>12 seconds | 30 seconds<br>32 seconds | |
| CWI-C-36 | Butt | Incomplete Pentration<br>Crater Crack | 4 seconds<br>4 seconds | 36 seconds<br>32 seconds | |
| CWI-C-37 | Butt | Excess Reinforcement<br>Cold Roll | 10 seconds<br>3 seconds | 10 seconds<br>None | Wikiscan could not measure length. |
| CWI-C-38 | Butt | Underfill<br>Undercut (3) | 5 seconds<br>14 seconds (3) | 5 seconds<br>15 seconds (3) | |
| CWI-C-40 | Fillet Tee | Oversize Weld Leg<br>Longitudinal Crack | 25 seconds<br>6 seconds | 30 seconds<br>23 seconds | |

A comparison of the "Manual Time" column to the "Wikiscan Time" column in Table 1 shows that in the majority of the test scenarios, it took the inspector more time to inspect the welded joint using the WikiScan/Ship device than it took him to inspect the joint using the traditional approach involving hand tools. In only one scenario (Fillet Tee, Excessive Convexity), did it take less time using the WikiScan/Ship device. Overall, the man-hour requirement results shown in Table 1 demonstrate that it took the Ingalls Shipbuilding weld inspector more time to inspect each of a wide variety of weld types using the WikiScan/Ship device as compared to performing the same weld inspections using the traditional approach involving hand tools.

The WikiScan/Ship weld scanning system shows potential as a solution for improving the visual weld inspection activities in a shipyard production environment. However, this potential will only be realized when the scanner is made capable of detecting all of the weld flaws contained in the project Phase I report and repeated here.

- Longitudinal crack
- Porosity
- Cold roll
- Accurate measurement of undercut
- Accurate measurement of underfill
- Incomplete penetration
- Crater crack
- Accurate measurement of fillet leg
- Accurate measurement of convexity

The WikiScan/Ship device does have good features that would make it usable in certain situations. The WikiScan/Ship features are not robust enough for everyday inspection at Ingalls Shipbuilding. The device lacks the ability to automatically locate some defects, such as small cracks or overlap. Although the defects can be visually located by a human and then manually measured with the WikiScan/Ship scanner, this defeats the advantage of using the WikiScan/Ship system.

The anticipated advantages of using an automated WikiScan/Ship device were:

- To have 100% repeatability between inspectors on finding all discontinuities present
- Determining the size of discontinuities
- Determining whether the weld is acceptable, or should be rejected
- Increasing the speed of inspection, i.e. reducing the man-hours required to perform the inspection

Each shipyard weld inspector must be able to take any required measurements with a high degree of accuracy. Consistently taking these measurements must not depend on the skill of the operator (whether using the WikiScan/Ship device or not), otherwise disagreement from inspector to inspector will continue. Disagreement between inspectors causes more inspections to be performed than would otherwise be needed. When Ingalls Shipbuilding personnel evaluated the WikiScan/Ship device there was a lack of repeatability between results when different people operated the system. It didn't appear the same results would be produced by different people. This behavior would not reduce the situation of disagreements between inspectors using the WikiScan/ Ship device, resulting in a continued need for additional inspections.

The WikiScan/Ship device was dependable in measuring the size of discontinuities.

The WikiScan/Ship device was not dependable when determining whether the weld was acceptable, or should be rejected. The device would scan past rejectable discontinuities, i.e., cracks, that should have caused the weld to be rejected. But this capability appeared to function differently for different inspectors. This would be another factor leading to a lack of repeatable results between separate inspectors. Also, if the inspector set the mode to "manual" to use the WikiScan/Ship device to interactively measure the discontinuity, it actually took more time to do this than it would have to perform an inspection using hand tools, and the WikiScan/Ship device could not automatically accept or reject the weld.

The time comparison results shown in Table 1 demonstrate that Ingalls Shipbuilding personnel's use of the WikiScan/Ship device did not increase the speed of weld inspection.

Although improvements have been made to the WikiScan/Ship system during the course of the 21st Century Smart Portable Weld Inspection System to Improve Ship Performance project, there are still significant shortcomings that must be overcome for the scanner to be used by Ingalls Shipbuilding Quality and Process Excellence Department personnel for weld inspection and approval purposes. Part of this is the extra time required to make observations when compared to using traditional methods and tools. Another shortcoming is the difficulty of taking measurements and inability of the system to make certain observations. Finally, although some of the new features improve the ability to measure discontinuities and this is a dependable functionality, the WikiScan/Ship device still has shortcomings in the ability to detect discontinuities and provide an automatic determination if the weld is acceptable, or should be rejected.

The extent to which future improvements can be made in the aforementioned areas will determine whether and to what extent the scanner will be incorporated into a production shipbuilding environment. In the meantime, the Ingalls Shipbuilding owned WikiScan/Ship device will be loaned to Huntington Ingalls Incorporated - Newport News Shipbuilding for their

evaluation. This activity may find applicability for the device in Newport News Shipbuilding processes and/or produce additional observations for desired enhancements.

In the 21st Century Smart Portable Weld Inspection System to Improve Ship Performance project Phase I report it was stated that the applicability of the current offering would probably be limited to supporting the degree of overwelding or underwelding of structural fillet welds. Ingalls Shipbuilding currently has some ongoing projects investigating the issues involved with overwelding. With this in mind, once the Newport News Shipbuilding evaluation of the WikiScan/Ship device is complete, the scanner will be provided to Dr. T.D. Huang at Ingalls Shipbuilding for use in the NSRP sponsored “Elimination of Overwelding” projects and/or other projects requiring similar inspection/measurement technology. To facilitate this continued use, a technical support agreement will need to be negotiated with SERVO-ROBOT Inc.

## 9.3 VIDEOS (HYPERLINKED)

1. P15 piping Socket Flange weld inspection

2. Continuous Scan

3. Over Welding % Measurement

4. Marketing & Initial Training