WISEE Conference - 2017

“Remote Sensing with Spatial Phase Imaging Occam’s Razor”

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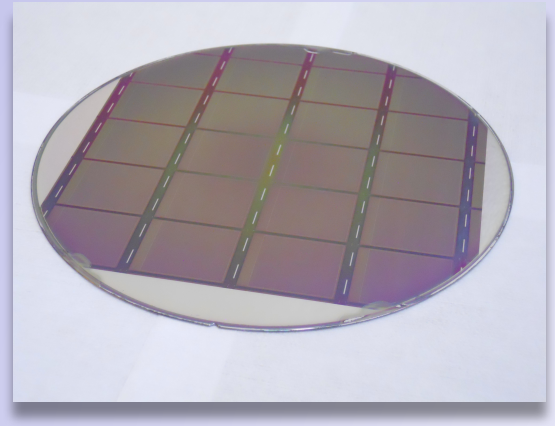
About

- Photon-X designs and builds optical sensors and analytic software applications
- Provide real-time numerical 3D capture and intelligent analytics of the physical world using the proprietary measurement of emitted electromagnetic energy (light).
- We call our technology ***Spatial Phase Imaging (SPI)***
- 16 years of technology growth
- Primarily a US Military contractor

Photon-X Technology

- Single Sensor (Fifteen patents (Patented, Patent Pending, or Provisional)
  - Detect targets at nearly any distance from less than 1 foot to over 15 kilometers
  - Perform target acquisition in challenging environments and weather conditions
  - Measures at the ¼ pixel level to produce images in the micron range
  - Identify and provide **real-time** data on either still or **targets in motion**
  - Produce volumetric, full color 3D imaging content for real-time use or for storage to be used at a later time

- Analytic Software
  - 3D – Unique capture
  - 4D – Compares past & present
  - 5D - Predictive analytics
  - Customizable per customer's requirements



Client Sampling

- Government clients include: DoD, Intel Agencies, DARPA, OSD, JIEDDO, DOT, DoJ, NASA, DARPA/JIEDDO
- Private industry clients including large media companies and international oil companies

Occam's Razor

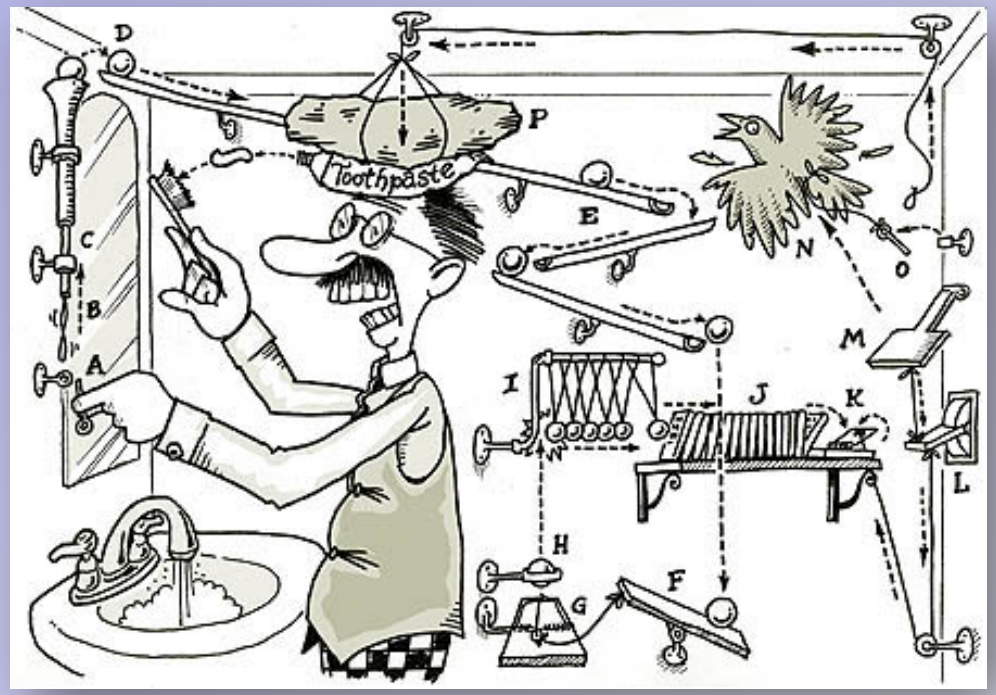
- William of Ockham (or Occam) was a 14th century logician and Franciscan friar.
- Ockham was the village in the English county of Surrey where he was born.
- His principle states that "Entities should not be multiplied unnecessarily."
- There are many loose translations, but for today …

"If you have two equally likely solutions to a problem, choose the simplest."

The Problem with Sensors

Common optical technologies do not have the ***simplicity*** and accuracy that today's world demands.

- Complicated solutions with a multitude of equipment and software processes
- Cannot accurately measure moving objects
- Cannot see in bad weather
- Single application solutions
- Billions invested to make incremental changes to 19th Century photography
- **Not Occam's Razor**



Current Optics: Rube Goldberg complexity

Physics Behind SPI

- All objects emit Electromagnetic Radiation (EM) at all times
- Electromagnetic radiation, is a form of energy emitted by moving charged particles. As it travels through space it behaves like a wave, and has an oscillating electric field component and an oscillating magnetic field. These waves **oscillate** perpendicularly to and in phase with one another.
- Objects emit radiation over a wide range of wavelengths; the amount of energy emitted at each wavelength is not the same
- This EM is emitted at right angles to the surface of the object

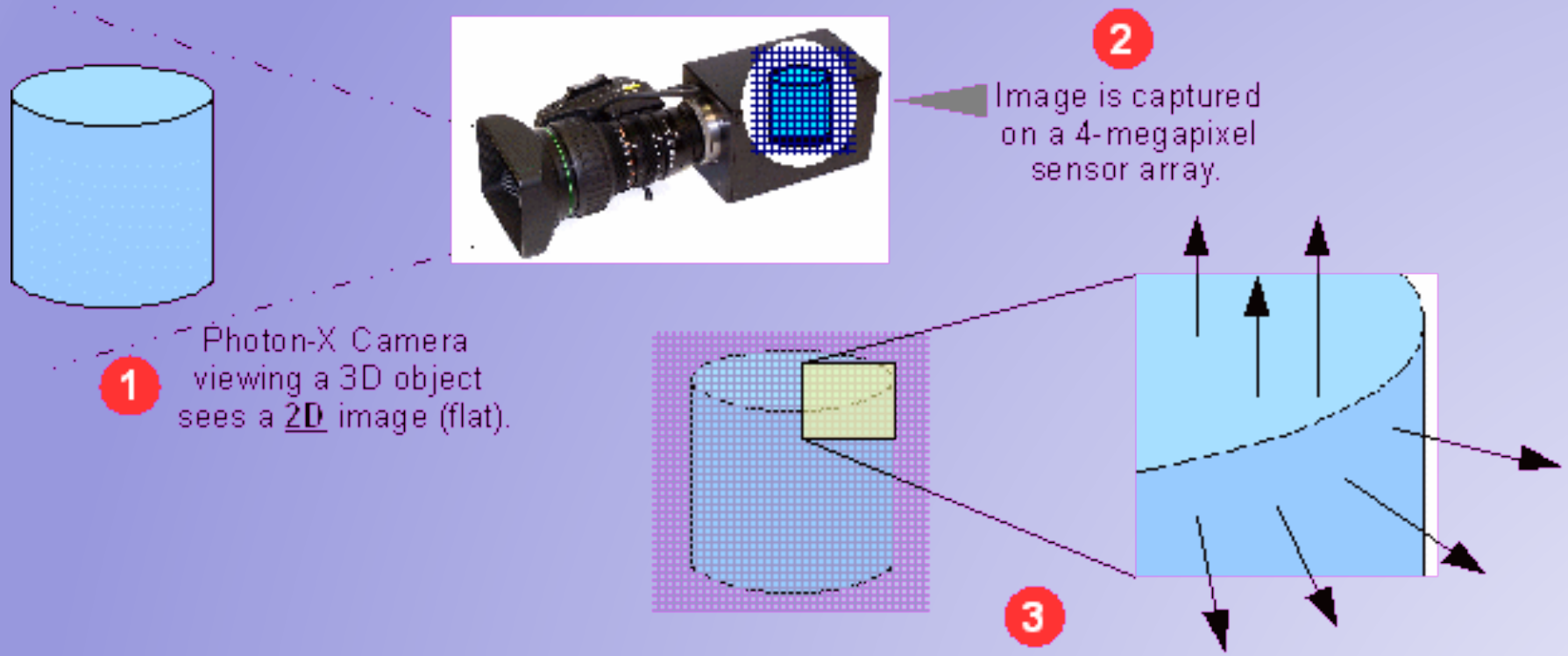
SPI- Spatial Phase Imaging

- There are three characteristics of light: **frequency**, **intensity**, and **spatial phase**
- The **spatial** phase state of a beam of light characterizes the degree to which the electric field vectors of individual waves are aligned.
- When unpolarized light reflects off the surface of an object it is polarized so the surface orientation can be detected
- Pixel intensity values corresponding to 0, 45 and 90 degrees of linear spatial phase are captured simultaneously, data can be converted to a set of Direction Cosines for that surface area
- Knowing the surface normal at each projected pixel on the target object allows for its surface data to be computed

SPI Sensor

- The Photon-X SPI optical sensor capture this energy and produces a data set for interpretation and analytics
- Energy capture is available beyond the visible range of the EM spectrum
- Captured pixel-level dimensional target surface data permits tracking as it moves through space
- “Normals” are captured by the SPI Sensor
- **Single sensor, single lens**
- **Passive - no lighting; no energy source needed**
- **Stills or video in real-time**

Simple Process – Simple Tool



Competitive Grid

- The Photon-X SPI optical sensor is versatile as it is unique!

	TECHNICAL FEATURES								
CURRENT 3D TECHNOLOGY	3D Model	Dynamic and Targetless	Emitted or Reflected Energy	Wide Dynamic Range	Line of Sight	High Resolution	Simultaneous Multi-Function	Very Long Distances	Automated Analytics
Photon-X	✓	✓	✓	✓	✓	✓	✓	✓	✓
Time of Flight	✓	✗	✗	✗	✓	✗	✗	✗	✗
Stereopsis	✗	✗	✗	✗	✓	✓	✗	✗	✗
Stereo Correspondence	✓	✗	✗	✗	✗	✓	✗	✗	✗

Client Example

SURFACE INSPECTION EXAMPLES USING SPI IMAGING

Non-slip Surface and Topside Equipment Inspection

Equipment:

- 1 Single lens SPI camera with a visible light sensor
- Ambient lighting

Project:

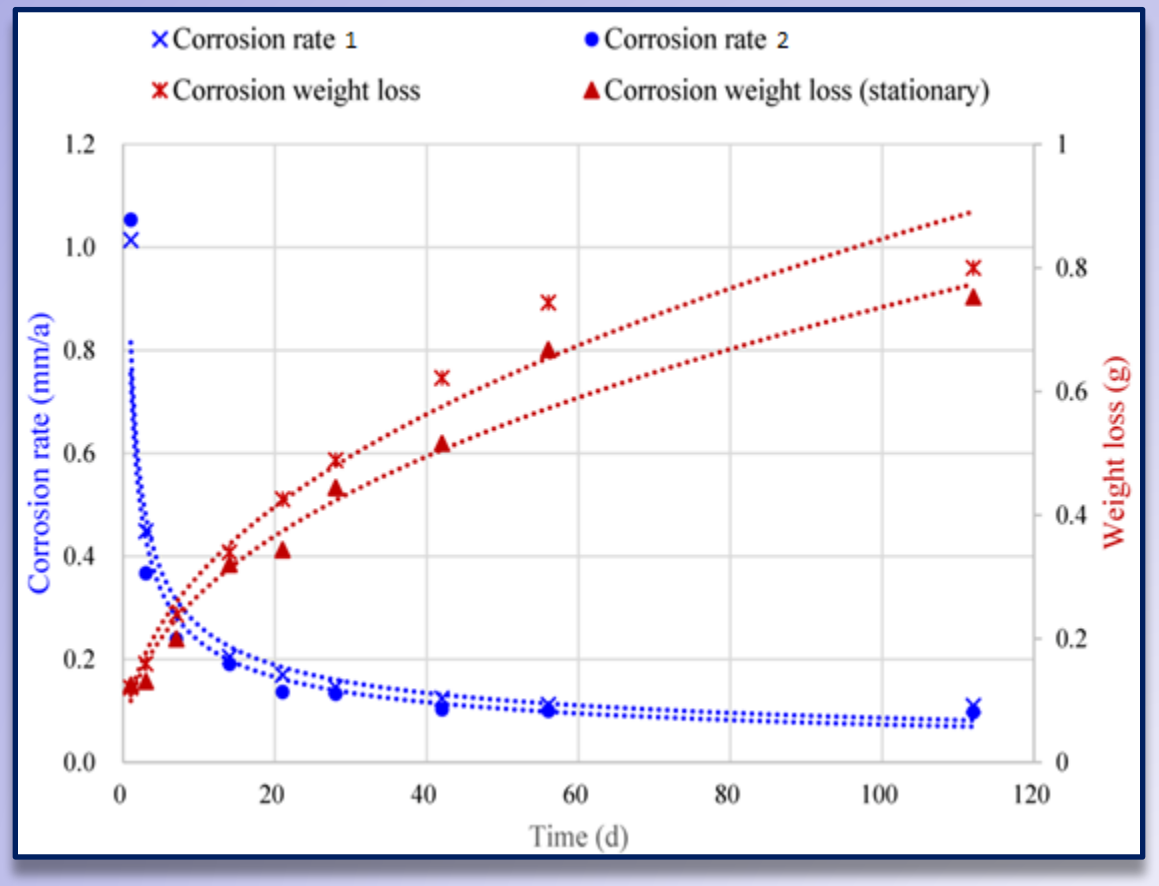
- Automate remotely quantifiably all visual Inspections to ISO or Self-Certifying requirements

- Visual Inspections tested include;
  - ✓ Blistering & Cracking
  - ✓ Rust
  - ✓ Flaking
  - ✓ Chipping,
  - ✓ Stress/Strain
  - ✓ Volumetric Metal Loss

Onsite Test Facility

SPI Surface Inspections - Software

- Historical Data Comparison
- Predictive Trending
- Geo-positioning
- Analysis tools for all relevant ISO Standards:
  - ✓ ISO 4628-2 Blistering
  - ✓ ISO 4628-3 Rusting
  - ✓ ISO 4628-4 Cracking
  - ✓ ISO 4628-5 Flaking
  - ✓ ISO 4628-6 Chalking by tape
  - ✓ ISO 4628-7 Chalking by velvet method
  - ✓ ISO 4628-8 delamination and corrosion around a scribe
  - ✓ ISO 4628-10 Filiform Corrosion



Non-slip Surface and Topside Equipment Inspection

Process:

- Objective, remote, accurate, repeatable, and automated
- Eliminates the subjective variance in inspections
- Can be accomplished in real-time and on moving targets

BENEFITS

- Reduced labor cost by De-manning inspection operations
- Environment can be captured digitally, algorithmically analyzed, and its output quantified
- Frequency of inspection is virtually free
- Predictive Modeling – maintenance calculated based on degradation rates
- Simple, elegant solution

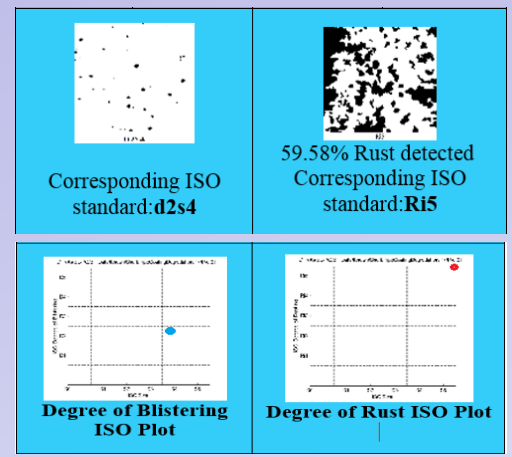
Non-slip Surface and Topside Equipment Inspection

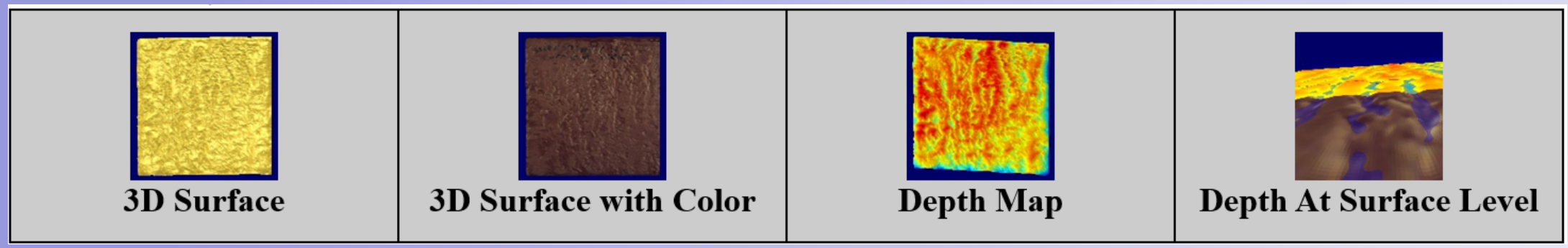
Phase I Findings:

Non-slip Surface and Topside Equipment Inspection
TEST REPORT: Wednesday 4th of March 2015 06:51:20 PM
Pipe Coating Degradation **Known Samples / Short Range Optics** Samples with known data are imaged with a Short distance lens.
Data is then placed in the corresponding folders for analysis.

BP Results->Known->Short->PipeCoatingDegradation->P7

Original Image	Region of interest	Detected Blisters image	Detected Rust image
2 **Blister ISO Density Score**	4 **Blister ISO Size Score**	5 **Rust ISO Density Score**	5 **Rust ISO Size Score**





Pipe Coating Degradation

Volumetric Metal Loss Inspection

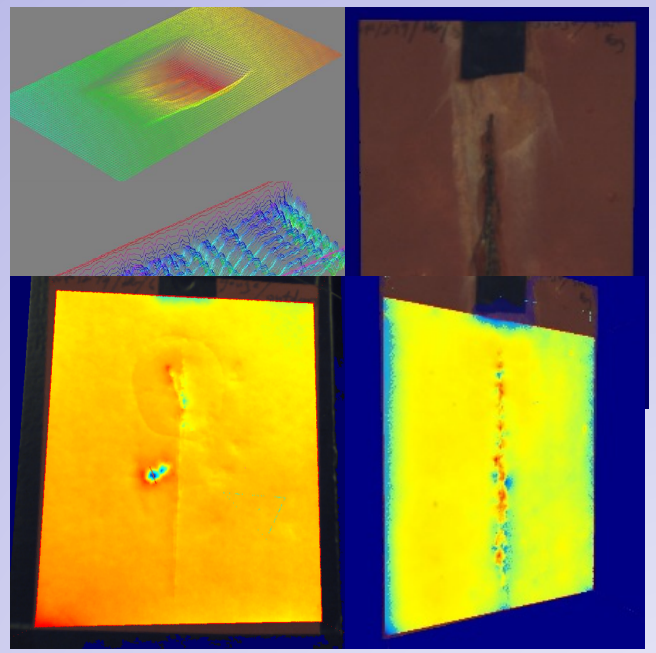
Equipment:

- 1 Single lens SPI camera with a visible light sensor
- Ambient lighting

Project:

- Automate remotely quantifiably all visual Inspections to ISO or Self-Certifying requirements

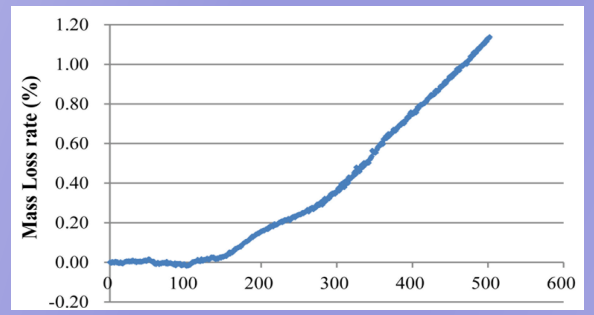
- Benefits include;
  - ✓ Sub-millimeter accuracy
  - ✓ Less space and faster than traditional LASER scanners
  - ✓ Increased Defect Detection

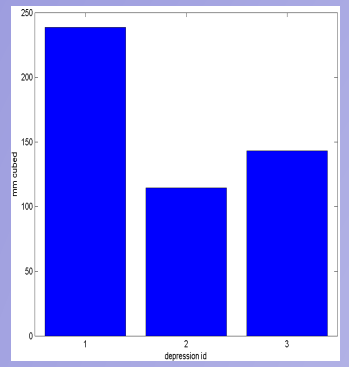


Metal Loss

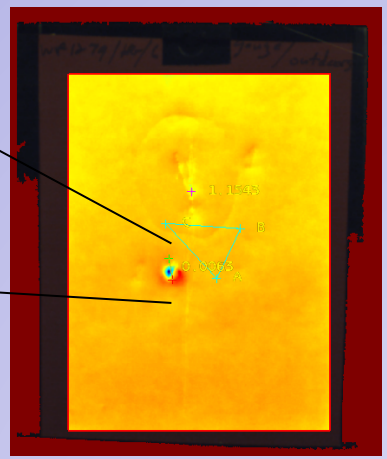
Volumetric Metal Loss Inspection

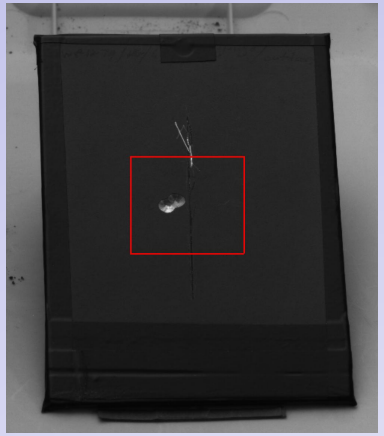
Metal Volume loss Algorithm





Processed image





High Confidence Detection of degree of Volume Loss

Rate of Volume loss can be predicted

Divot Depth Measurement = 0.86mm
Depth at Point = 0.26mm

Spatial Phase 3D Image

Acquired Image

Volumetric Metal Loss Inspection: Findings

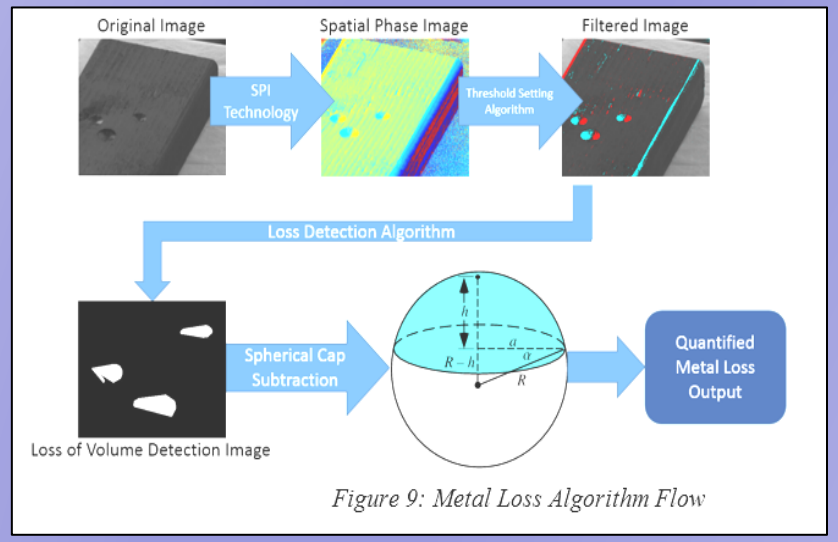


Figure 9: Metal Loss Algorithm Flow

Metal Loss Algorithm

Ground truth framework

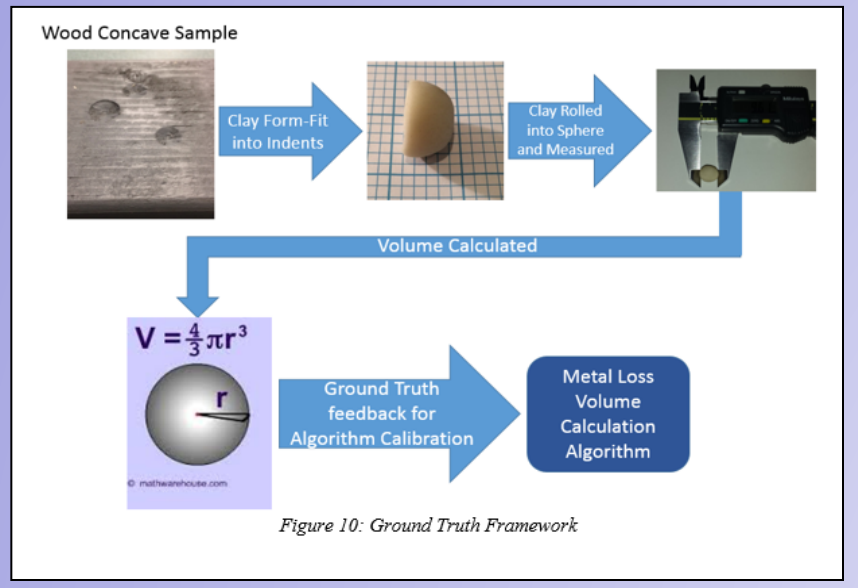
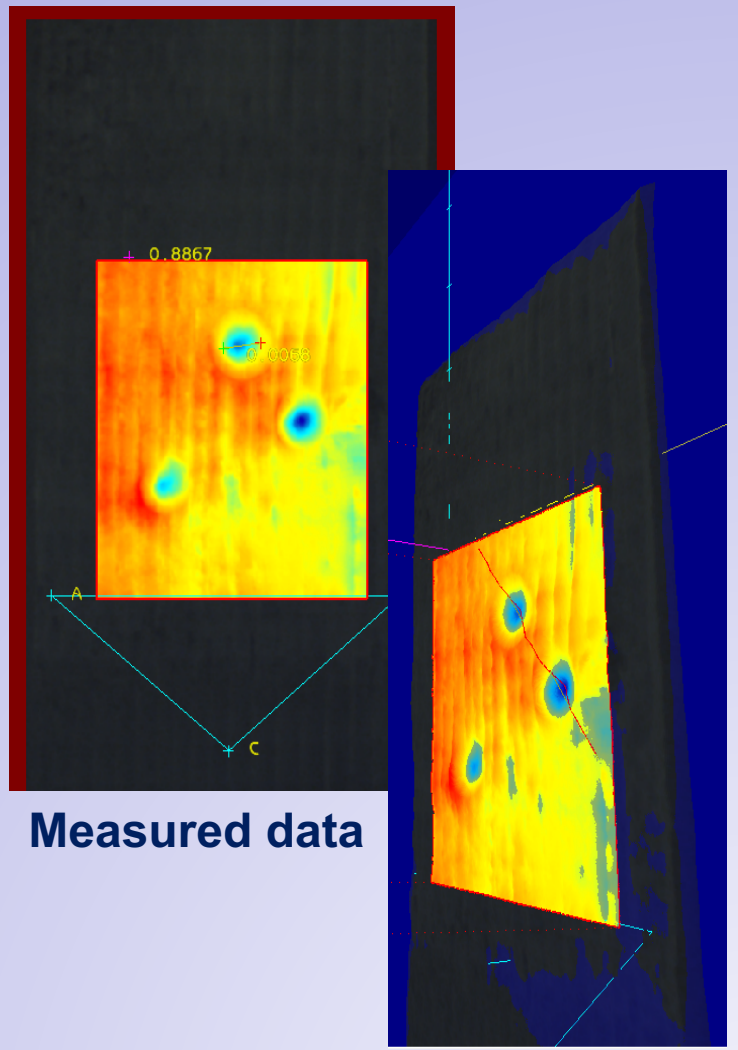


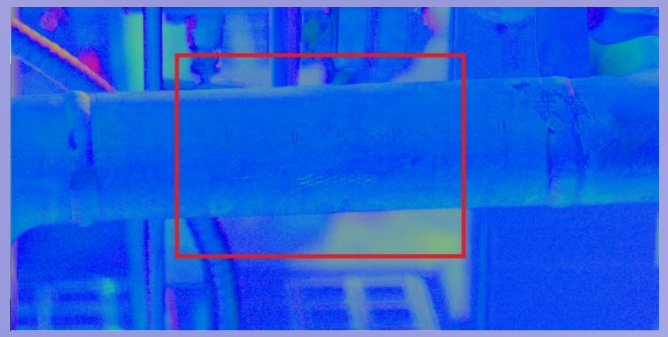
Figure 10: Ground Truth Framework



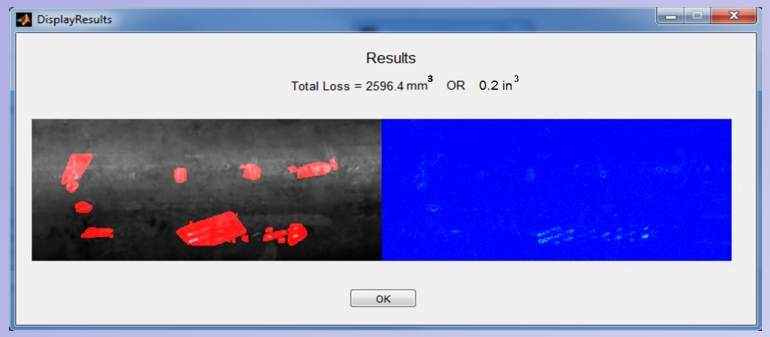
Measured data

Metal Loss Methodology

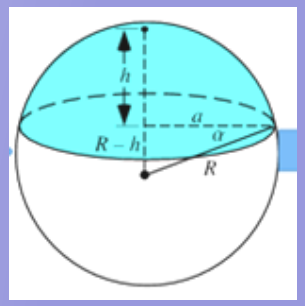
Volumetric Metal Loss Inspection Findings

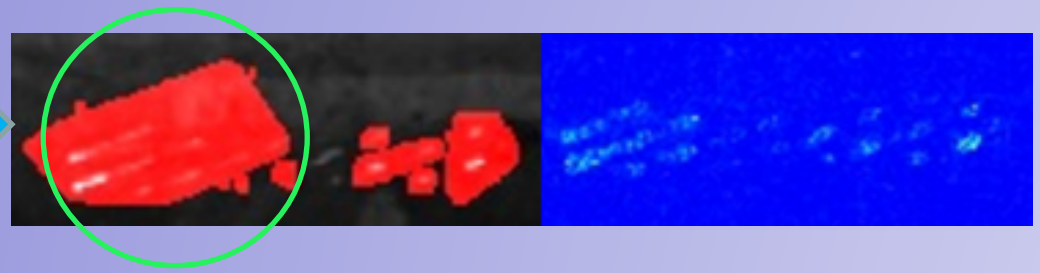


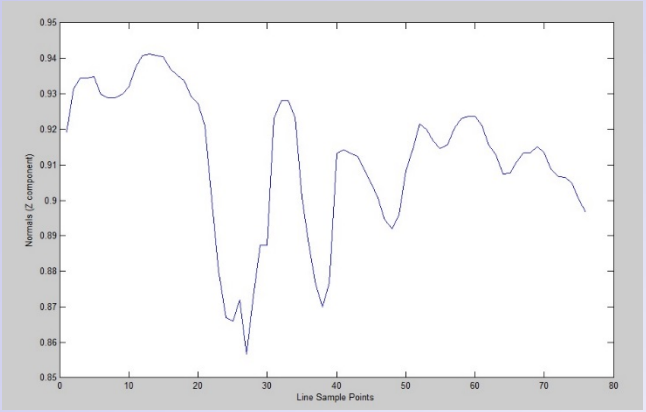
Captured data & Region of Interest (ROI)



$Total\ Loss = 0.2\ in^3$







Metal Loss Methodology

SPI Surface Inspections - Summary

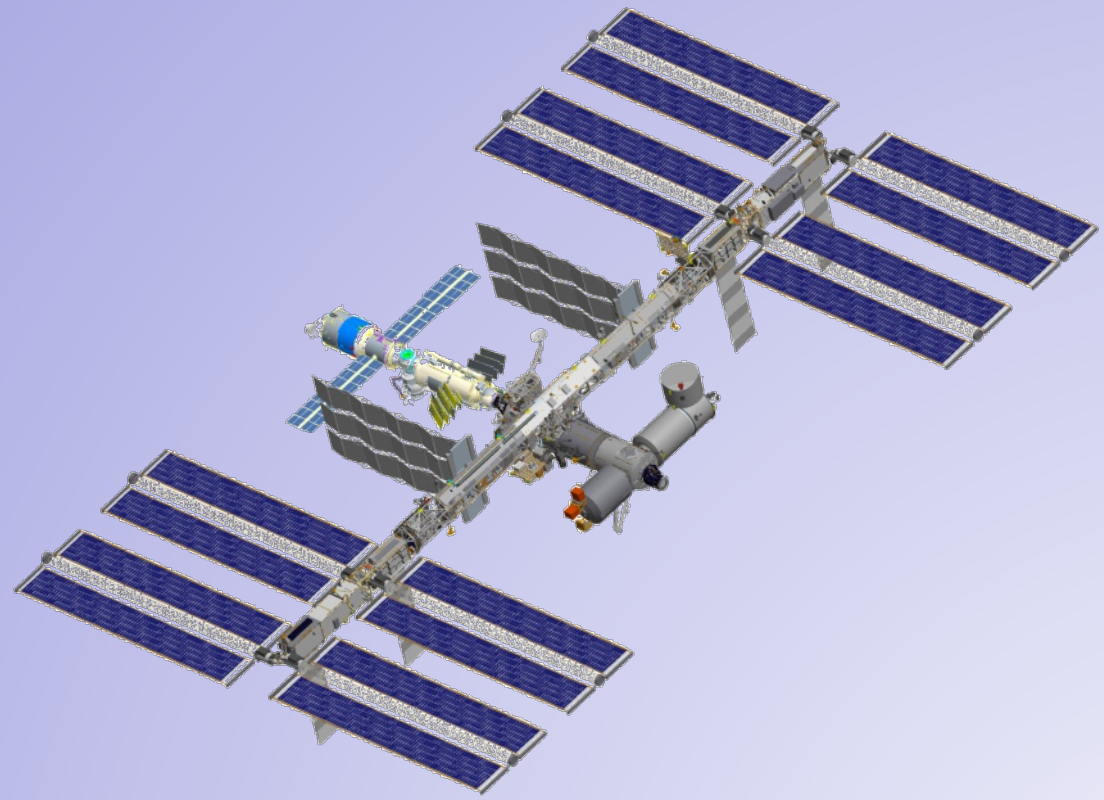
- Automate remotely quantifiably all visual Inspections to ISO or Self-Certifying requirements
- Single lens, single sensor
- Ambient lighting
- Real-time capabilities
- Accurate to microns

OTHER PHOTON-X CAPABILITIES:

- SPI: 3D Volumetric Measurements
- NIR: Immunity to Day/Night lighting Conditions
- LWIR: Thermal Imagery
- COLOR: Colorized depth map
- HYPERSPECTRAL: Advanced Contaminant and Identification
- SOFTWARE: Volumetric Historical Analytics

SPACEFLIGHT APPLICATIONS

- Inspections
  - Corrosion detection external
  - Corrosion detection internal
  - Real-time stress analysis
- Human Factors
- Automation
  - Robotics
  - Auto navigation
- 3D Mapping & Modeling
- Virtual reality



Volumetric Robotic Vision

Volumetric Robotic Vision →

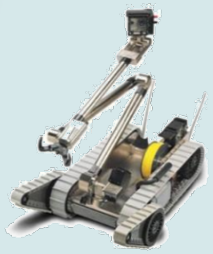
Robot Eye to Hand Coordination ▶

(Autonomous Robotics)

Human Understanding →

National Robotics Technology Center

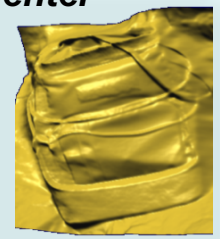
EOD – Robotic Vision



Robotic IED Testing

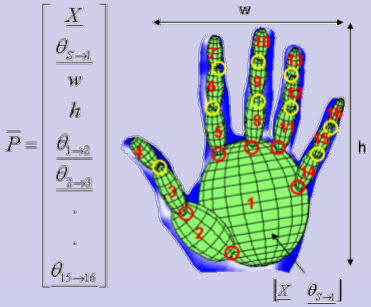
Roadside object

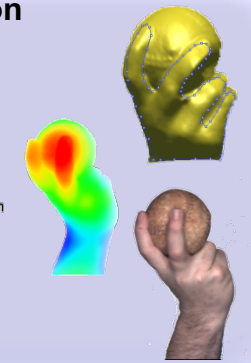
Scene of interest



3D Image

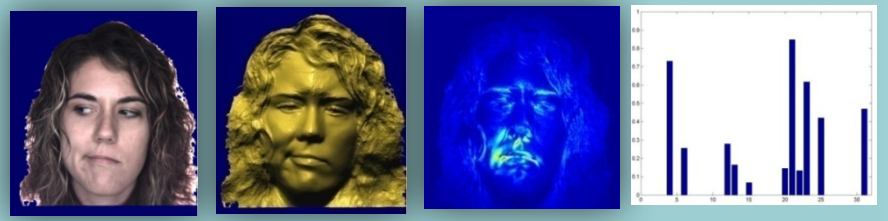
Dexterous Robot Manipulation





Segmentation of Structures (wires, etc)

Human Machine Interface (HMI)



Emotion and Gesture Recognition

QUESTIONS

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