Maximizing Data Quality for In-Service Tank Inspections – Calibrations to Confirmations

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Advanced Robotics

State of the Art Sensors

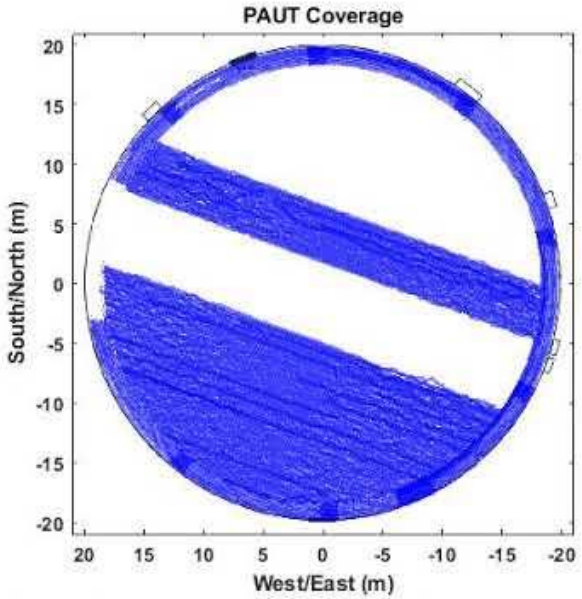
High Density Data Acquisition

Tank Inspection - The Traditional Approach

- ❑ PROJECT LASTS WEEKS OR MONTHS
- ❑ DRAIN, VENT, CLEAN, WASTE DISPOSAL
- ❑ INSPECT WITH MAGNETIC FLUX LEAKAGE (MFL)
- ❑ VALIDATE WITH SPOT ULTRASONIC (UT)
- ❑ REPAIR *"SINCE IT IS OUT OF SERVICE"*

square ROBOT

Square Robot's Tank Inspection Capability



- ❑ **Critical 130' Diameter Demineralized Water Tank**
- ❑ **Tank flowing 5000 gpm in/out during inspection**
- ❑ **5 days inspection**

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Robotics Enable Safe, Informed Efficiency

Environmental, Social, Governance

- Zero confined space entry
- Reduced work at heights
- *Carbon Equivalent releases contained per average tank:
  - Diesel > 5 Tons
  - Gasoline > 20 Tons

*Source - Third Party Verified for 100’ diameter tank

Big Data Solutions kBytes to tBytes

- Hi confidence / hi resolution data
- Big data feed/ advanced processing
  - API 653/ EEMUA 159
  - RBI / EVA / Digital Platforms

Capital Efficiency

- *$300,000 - +$2M savings per average out-of-service tank operation
- Proactive risk vs time based inspections

*Source - Solomon Associates 2018 Fuels Study

Operational Efficiency

- In- Service Inspection
- Tank utilization
- Extended out of service dates
- Extended tank life
- Predictive repair & maintenance

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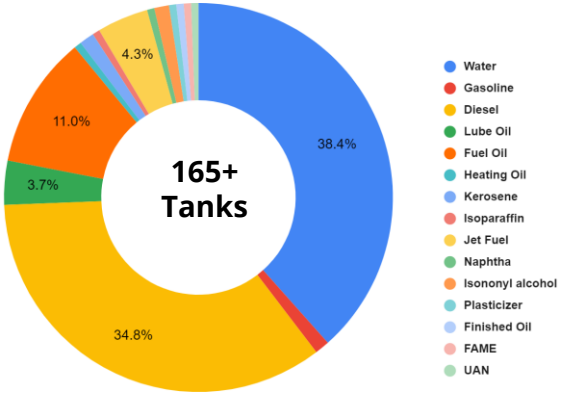
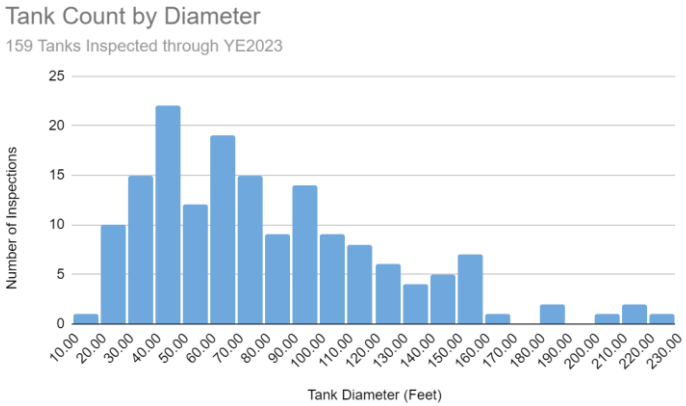
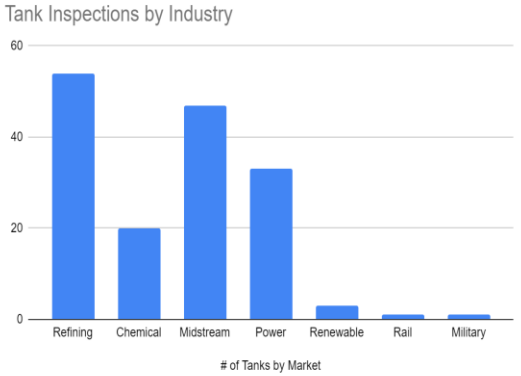
Square Robot Inspection Track Record

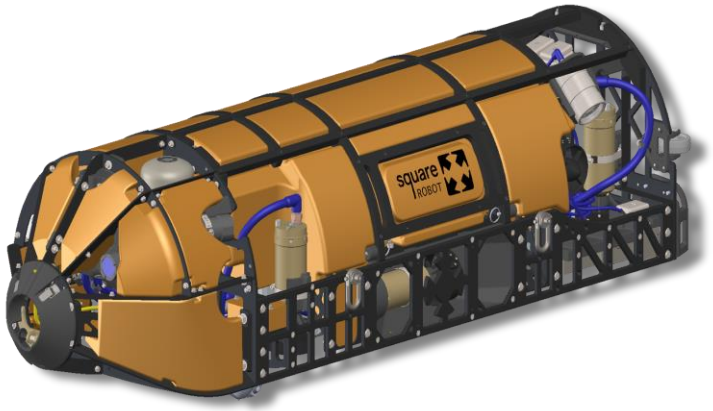






KPI	Count
API 653 Tanks Inspected	>165
PAUT Bottom Coverage (includes obstacles)	60% average (95% max)
Confined Space Labor Hours Saved	100,110 hours (630/tank avg)
CO2 Emissions Equivalent Contained	825,600 lbs(7,800/tank avg)
Tank Utilization	95% - 99%
Cost Savings (assume $300k x 165 tanks)	$49 million

Square Robot's Inspection Capability



SR-3
Autonomous Submersible Tank Inspection Robot

	Applications
Launch/Recovery Method	Side Shell or Roof Launch
Communications	Fiber Optic Tethered
Tank Type	Fixed, External or Internal Floating Roof
Product Compatibility	Low/High Flashpoint Products
PAUT Bottom/Coating Thickness	Active
Bottom Settlement Under Load	Active
Visuals of Bottom, Shell, Internals	Active
PAUT Internal Shell Inspection	Active
PAUT Fiberglass Liner Bottoms	Active
Internal Roof Seal Inspection	In Development
Sediment Thickness Mapping	In Development

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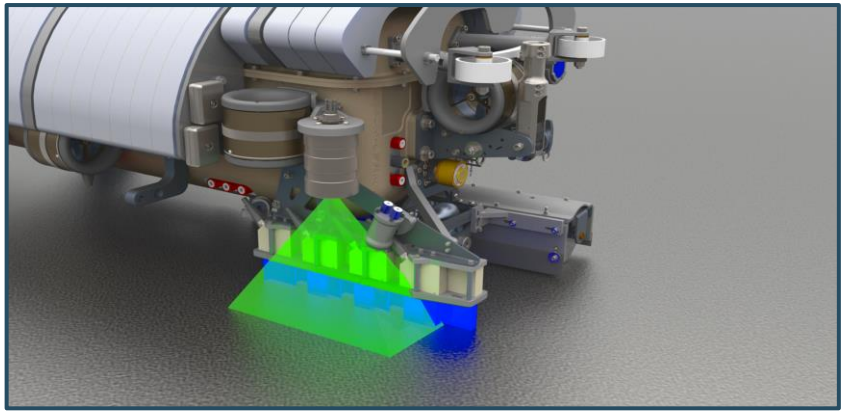
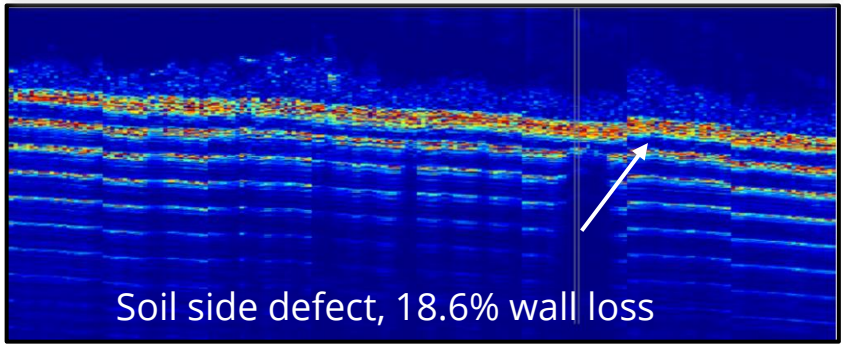
High Resolution Sensors and Navigation



PAUT L-Scan Plate Thickness



Critical Zone and Water Puddling

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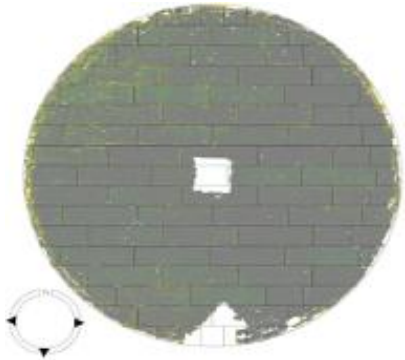
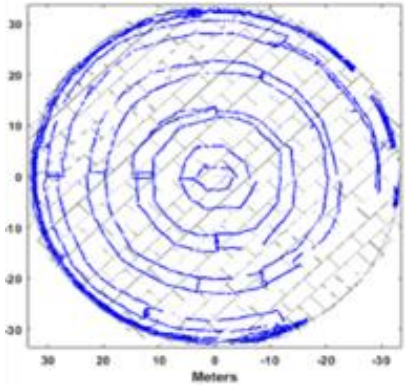
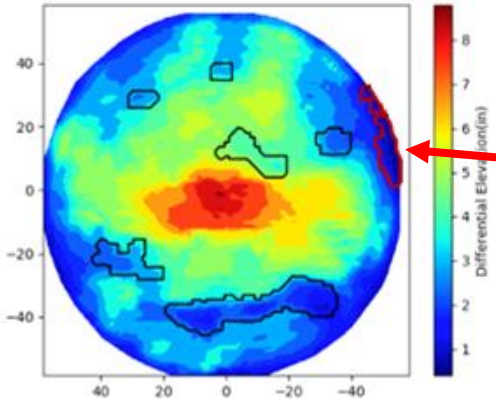
API, EEMUA, and Risk Based Inspections

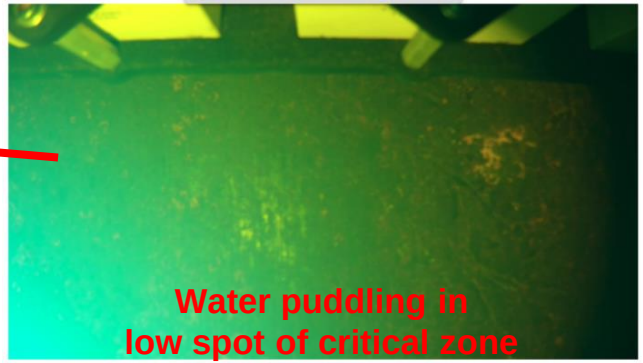
- ❑ Tank Bottom Thickness using Phased Array UT
  - ❑ Differentiate Product and Soil Side
  - ❑ Variety of Epoxy and Fiberglass Liners
- ❑ Tank Shell Thickness using Phased Array UT
- ❑ Internal Visual using 2 onboard video cameras
- ❑ Tank Bottom Settlement *under loaded conditions*





PAUT COVERAGE INCREASES CONFIDENCE





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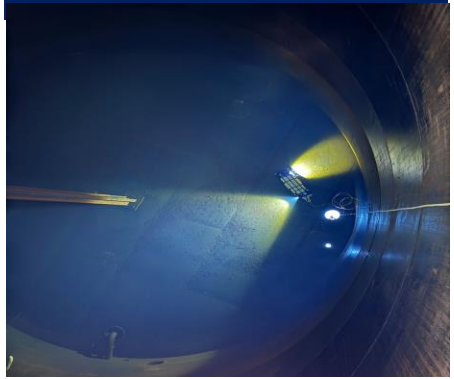
SR-3 Robot Roof Launch Approach

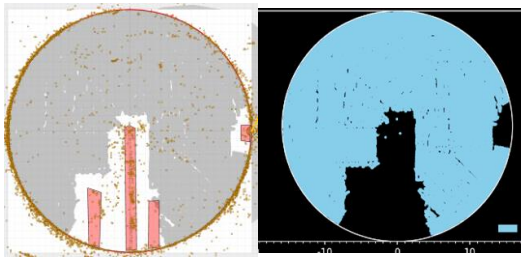
1. Mobilize

2. Lift

3. Submersion

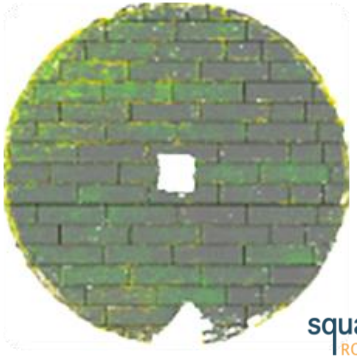


4. Inspection



5. Recover

6. Report



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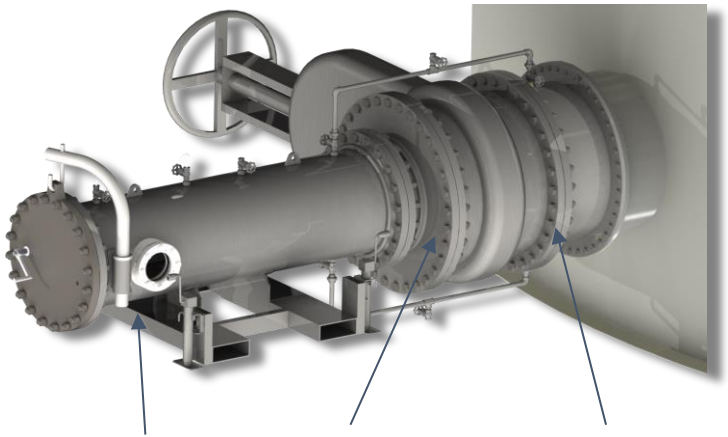
SR-3 Robot Side Launcher System



Vehicle Chamber

24” Gate Valve

Manway Adapter

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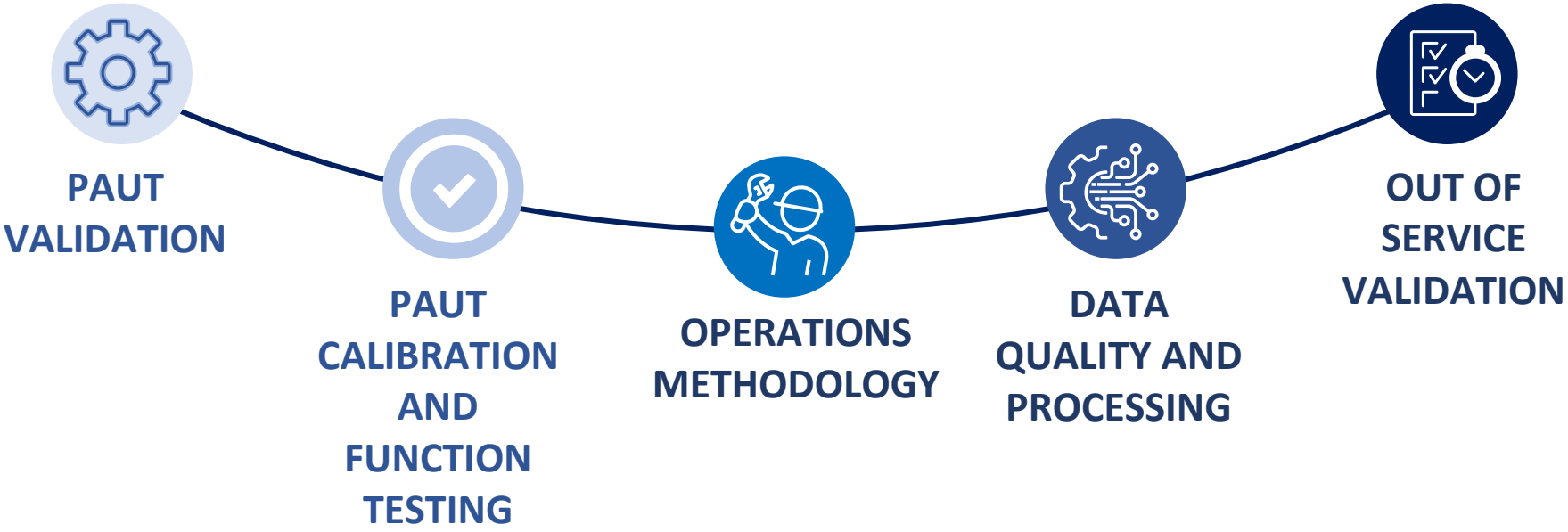
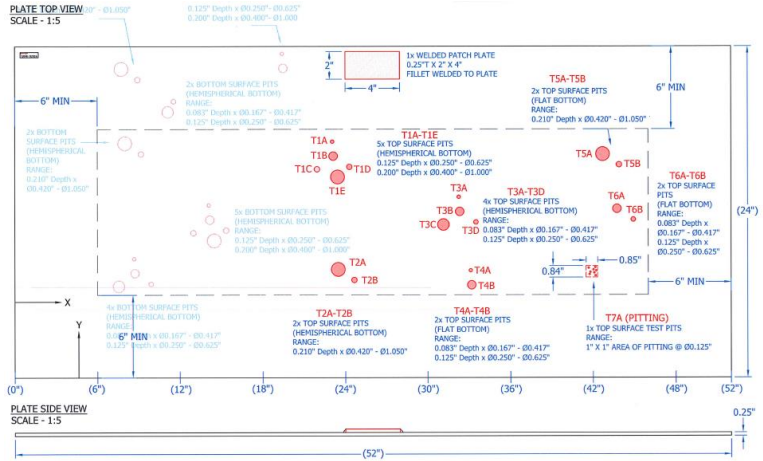
Maximizing Data Quality

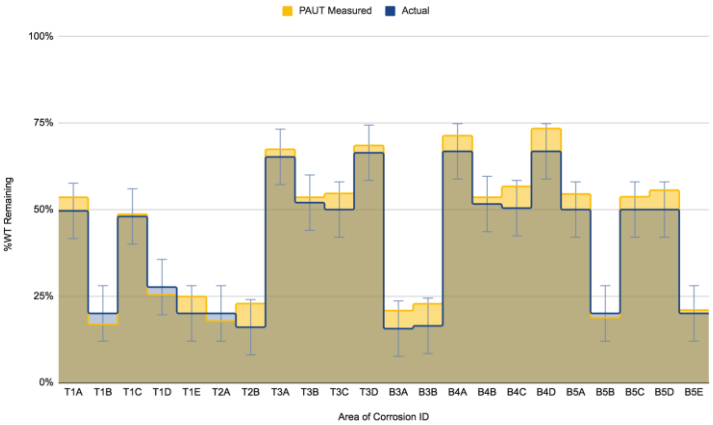


Phased Array UT Validation

API 653 Test Plates



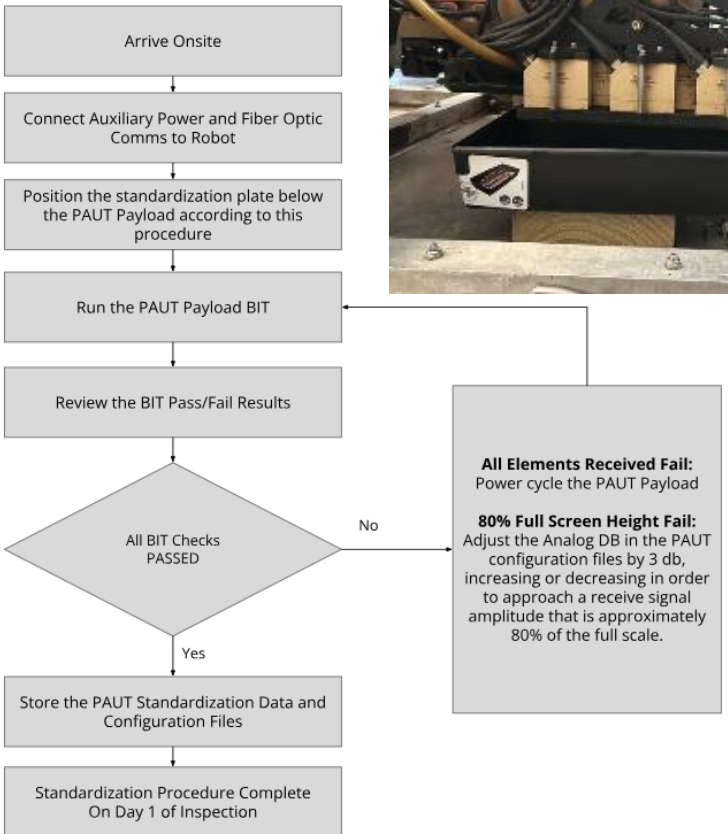
Allowable Measurement Range Shown

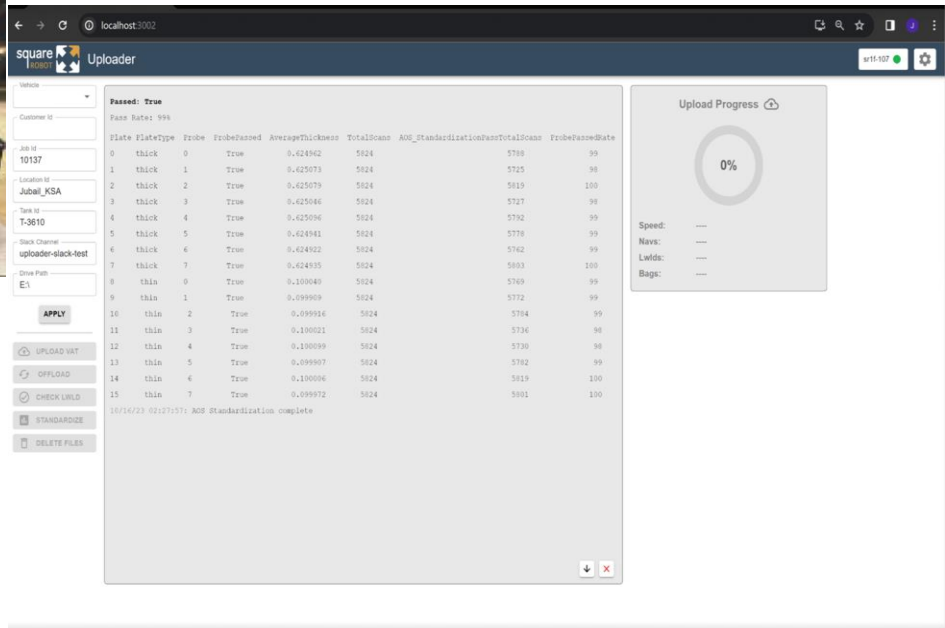


Phased Array UT payload
Meets API 653 - Annex G Requirements

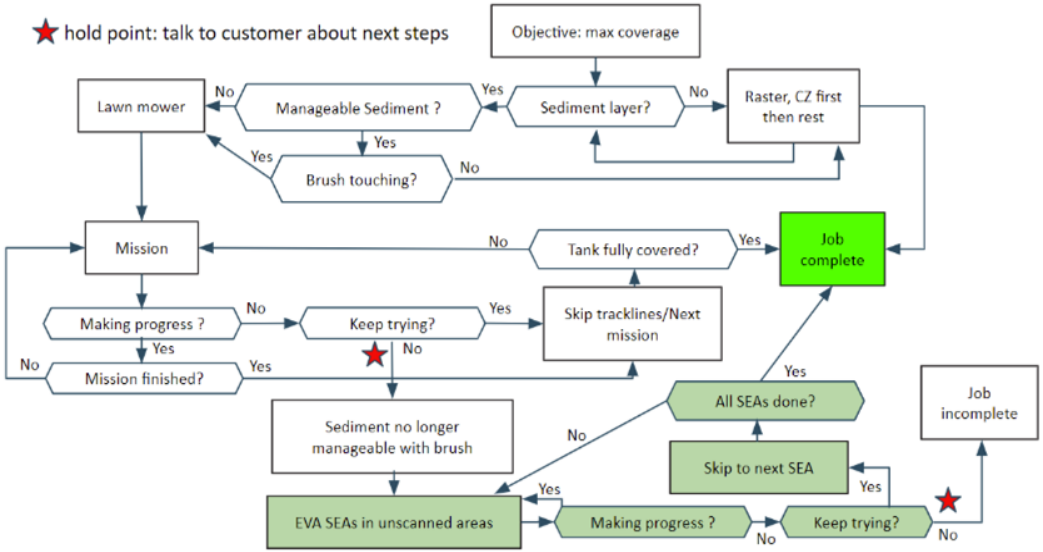
PAUT Calibration/ Function Testing

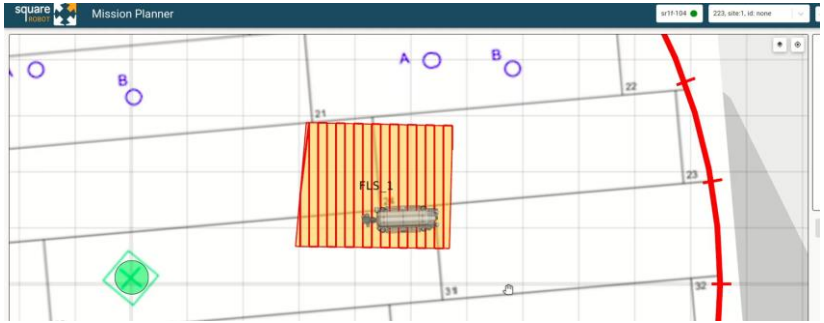
Flow Chart - On-Site

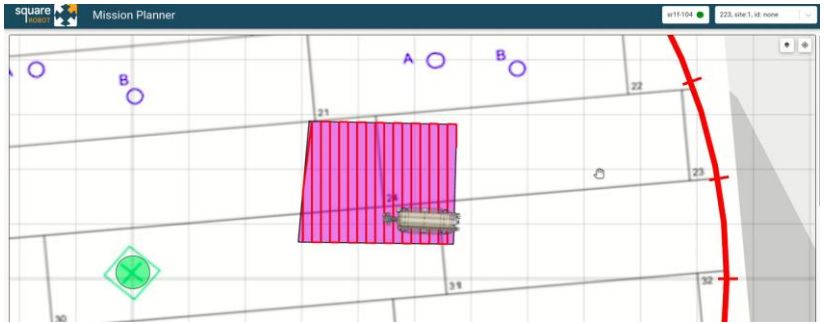




Operations Methodology - Onsite



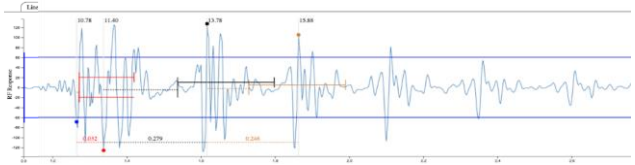




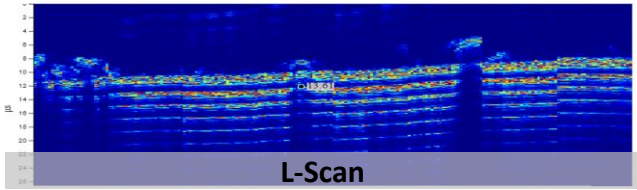
Data Quality and Processing

Heavily attenuated signals

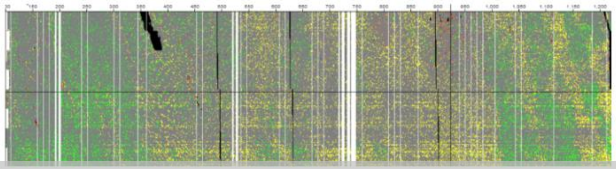
Heavily attenuated signals



A-Scan

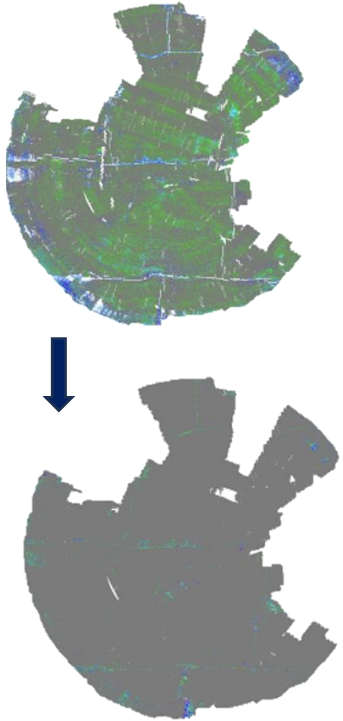


L-Scan

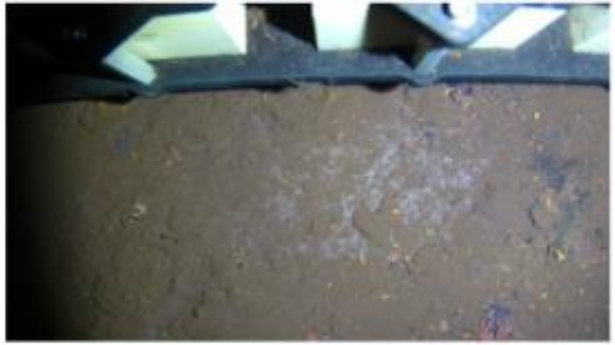


Linear View

Post processing thickness computation



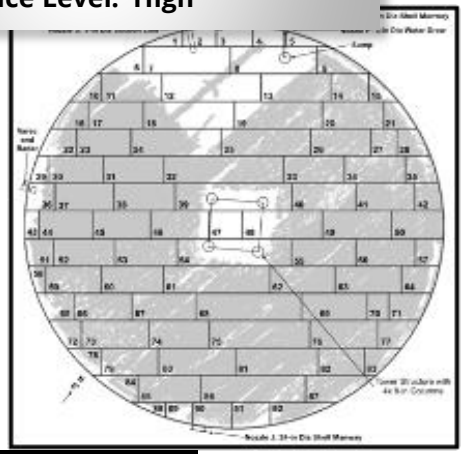
PAUT Data Confirmation

Visual Observations	Magnetic Flux Leakage	Saturated Low Frequency Eddy Current
		
IN-SERVICE VIDEO/CAMERA FOOTAGE	**OUT-OF-SERVICE MFL SCANNING**	**OUT-OF-SERVICE SLOWFEC SCANNING**

Continuous Improvement Feedback Loop

Case Study: 114’ Diameter Diesel Tank

- **Inspection Time: 3 DAYS**
- **UT Tank Bottom Coverage: 81%**
- **UT Plate Coverage: 90/94 plates**
- **Confidence Level: High**



In-Service Robotic Inspection

- Tank built 1978 with repairs in 2003
- Inspected while fueling train locomotives every 4 hours
- Water puddling
- Detected unknown double bottom

Savings: In-Service Robotic vs Traditional Inspection

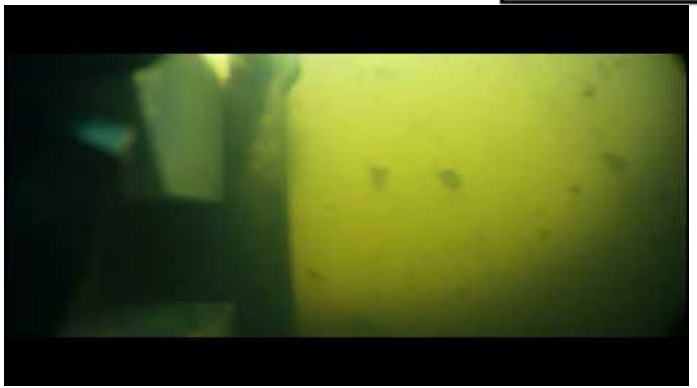
~$1.2 million USD vs Out of Service Inspection

+ ~40 days out of service time/temp storage

+ 6.6 tons of CO_2 emissions contained

+ 670 confined space labor hours

+ Extended API 653 compliance 18 years with minor external repairs



Case Study: 92’ Diameter Diesel Tank

- **Inspection Time: 3 DAYS**
- **UT Tank Bottom Coverage: 78%**
- **UT Plate Coverage: 29/31 plates**
- **Confidence Level: High**

In-Service Robotic Inspection

- Similar tanks nearby suggested repairs required
- Obtain API 653 compliant report
- Robotic inspection in 2022 to plan for 2025 repairs

Savings: In-Service Robotic vs Traditional Inspection

> $400k vs Out of Service Inspection cost

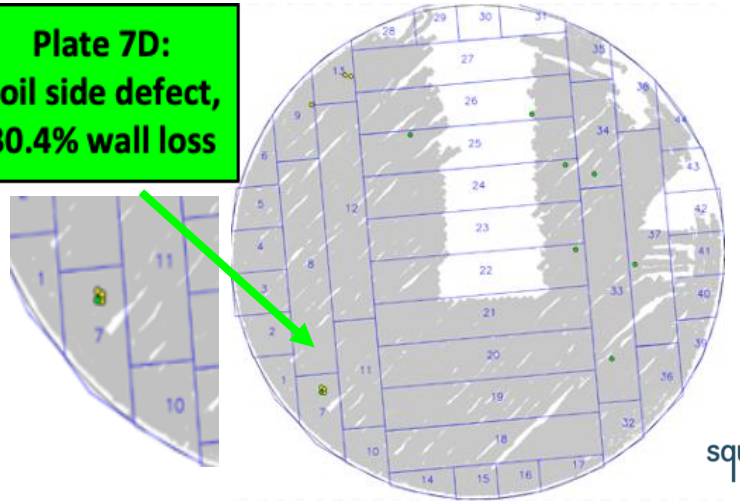
+ 27 days of out of service time

+ 5 tons of CO2 emissions contained

+ 550 confined space labor hours

+ Extended API 653 compliance > 20 years

Plate 7D:
Soil side defect,
30.4% wall loss



Questions?

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