



# Understanding In-Service AST Inspection Robotics and using auxiliary techniques:





# History and Technology Background

- Petroleum and Petro-Chemical Industry
  - Economic concerns, and
  - Environmental and safety impact concerns associated with tank inspections
  - Industry looking for options





# How to Select Candidate Tanks for In-Service Inspections

- Tanks believed to be in fair-to-good or unknown condition:  
Condition
- Tanks where leakage of stored contents is unacceptable  
- Terminals and chemical plants: Unacceptable leakage
- Tanks tied to process unit operation where removal would  
cause unit shutdown/slowdown: Service Interruption
- Tanks with high costs associated with tank entry or waste  
disposal: Waste Cost
- Tanks with a high commercial incentive to seek short  
extension before traditional out-of-service inspection:  
Extensions

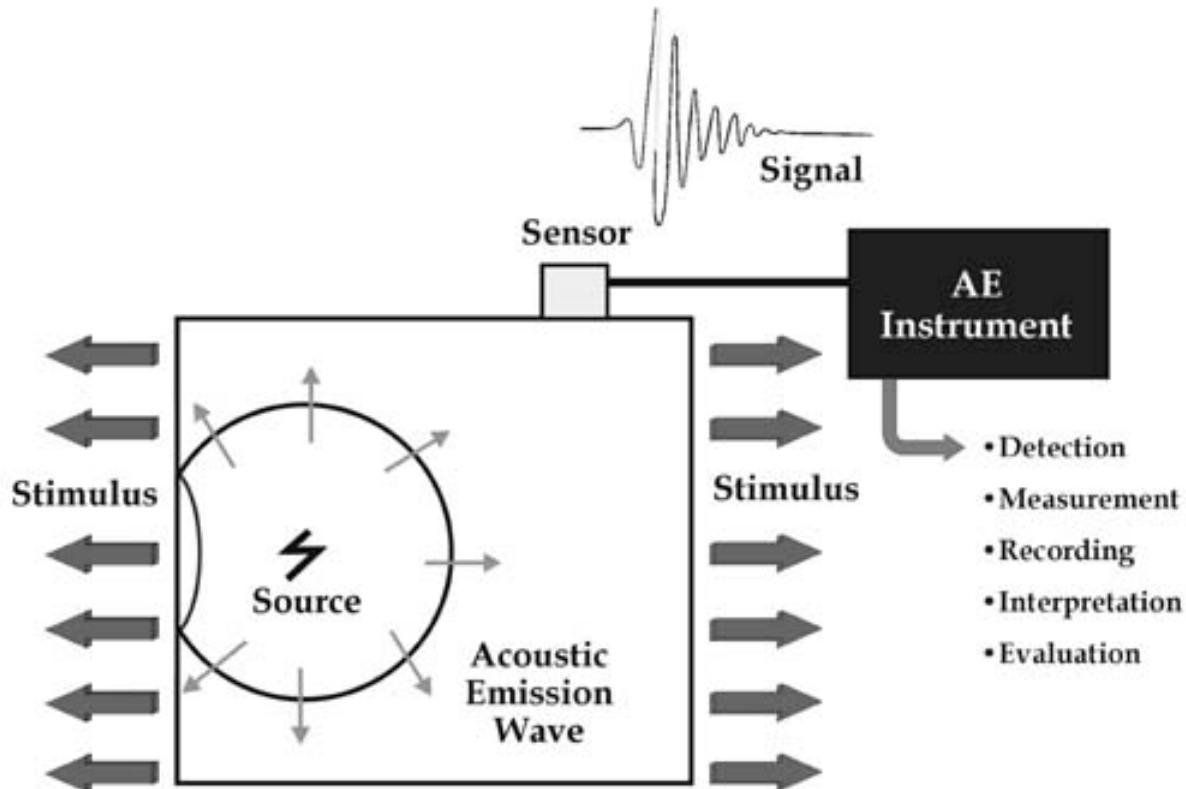




# Auxiliary NDT methods for selecting AST's

## Acoustic Emission:

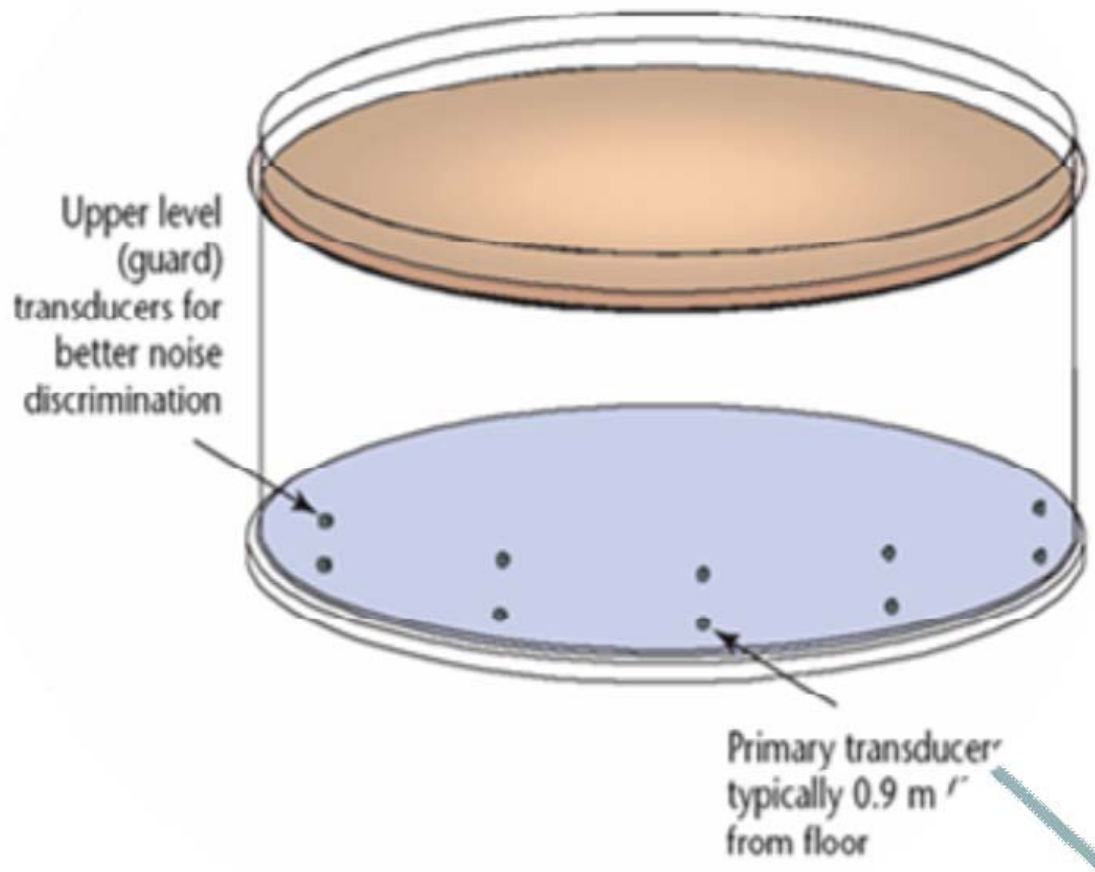
- Can be used to detect Active corrosion in the complete tank
- Tank needs to be full to provide stress





# Auxiliary NDT methods for selecting AST's

## Acoustic Emission:





# Auxiliary NDT methods for selecting AST's Acoustic Emission:





## Auxiliary NDT methods for selecting AST's

<b>Rank</b>	<b>Color code</b>	<b>AE Energy Levels</b>
Category A	<b>Green</b>	No Energy
Category B	<b>Blue</b>	Low Energy
Category C	<b>Orange</b>	Low to Medium
Category D	<b>Red</b>	Medium to High
Category E	<b>Red</b>	High to Very High





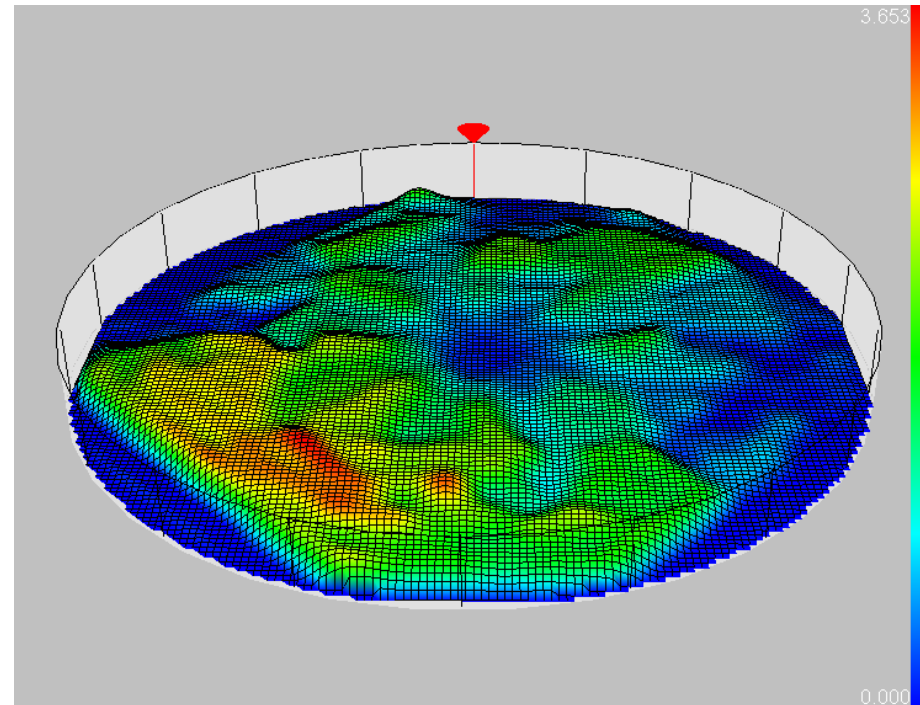
# Auxiliary NDT methods for selecting AST's

## 3D Sludge profiler:

Quick 3-Dimensional Sludge Profiling Technique to precisely measure and calculate the total volume of sludge within a tank.

Many tank operators may have an idea how much sludge is within the tank however are never very accurate. When bidding out cleaning projects many times the final cost of the project exceed what was budgeted as the amount of sludge within the tank is not known or significantly underestimated. The sludge profile precisely measures and provides volumetric visualization of the sludge within the tank.

- Precise to within 3 Percent
- 3 Dimensional Imaging Provided
- Extremely Quick (1 to 2 tanks / day)



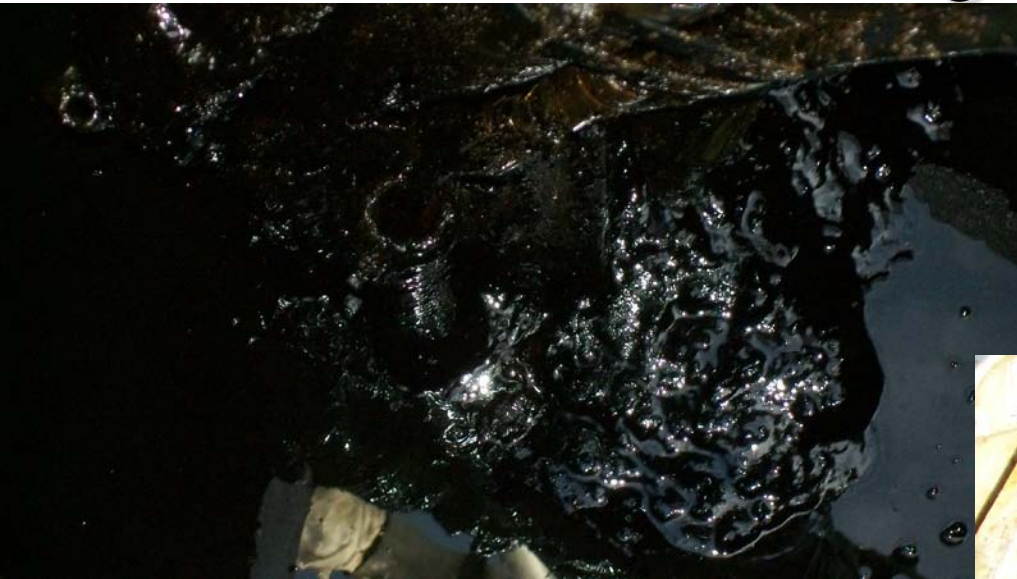




# Auxiliary NDT methods for selecting AST's

3D Sludge profiler:

Why we like to know  
the sludge level



After a lot of cleaning

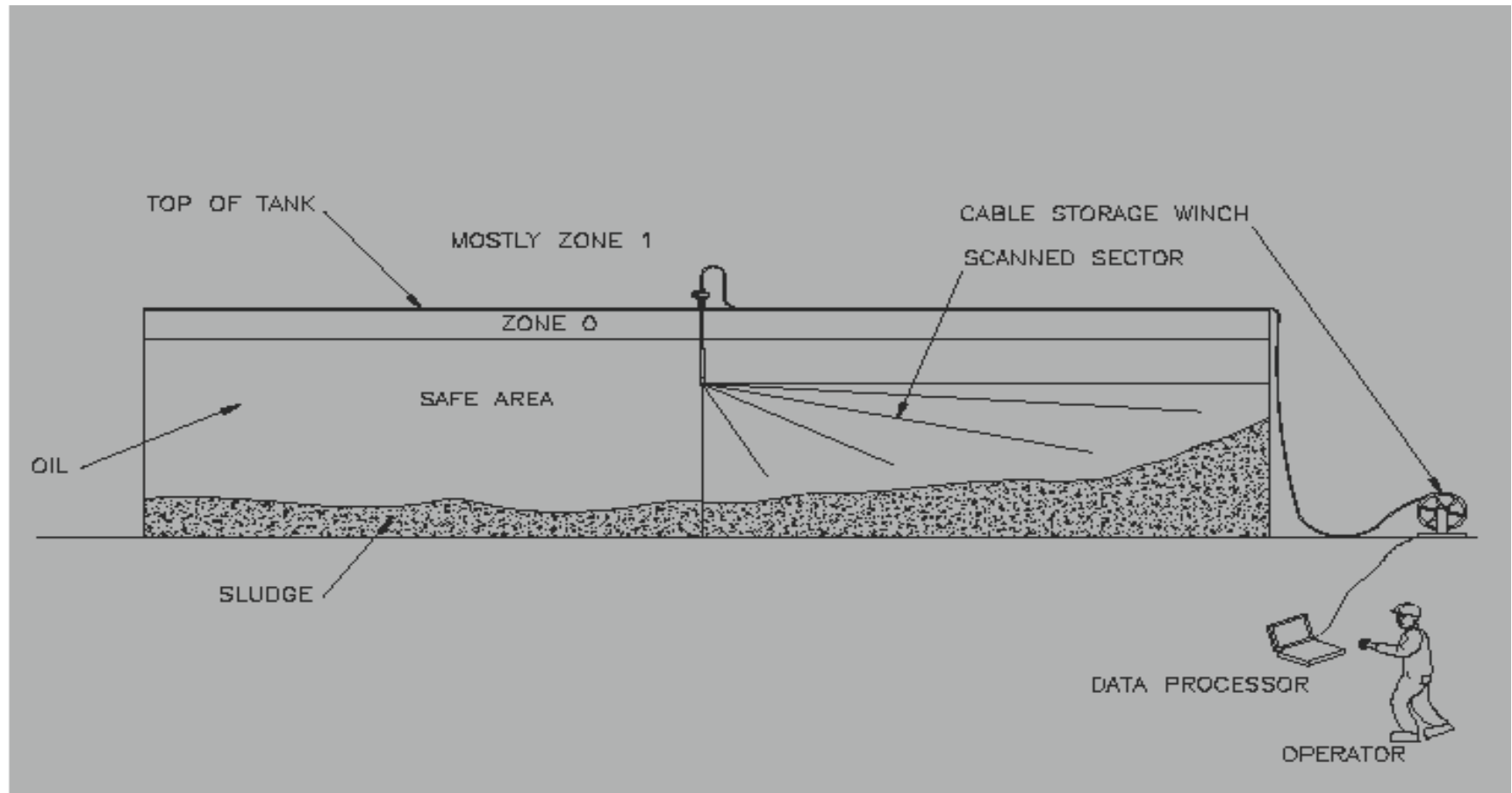
## Storage Tank Types

- Tank Floor
  - Cone Up
  - Cone Down
  - Sloping
- Tank Roof
  - Floating
  - Fixed
- Diameter up to 350'





# 3-D Sludge Profiler







# Tank Deployment

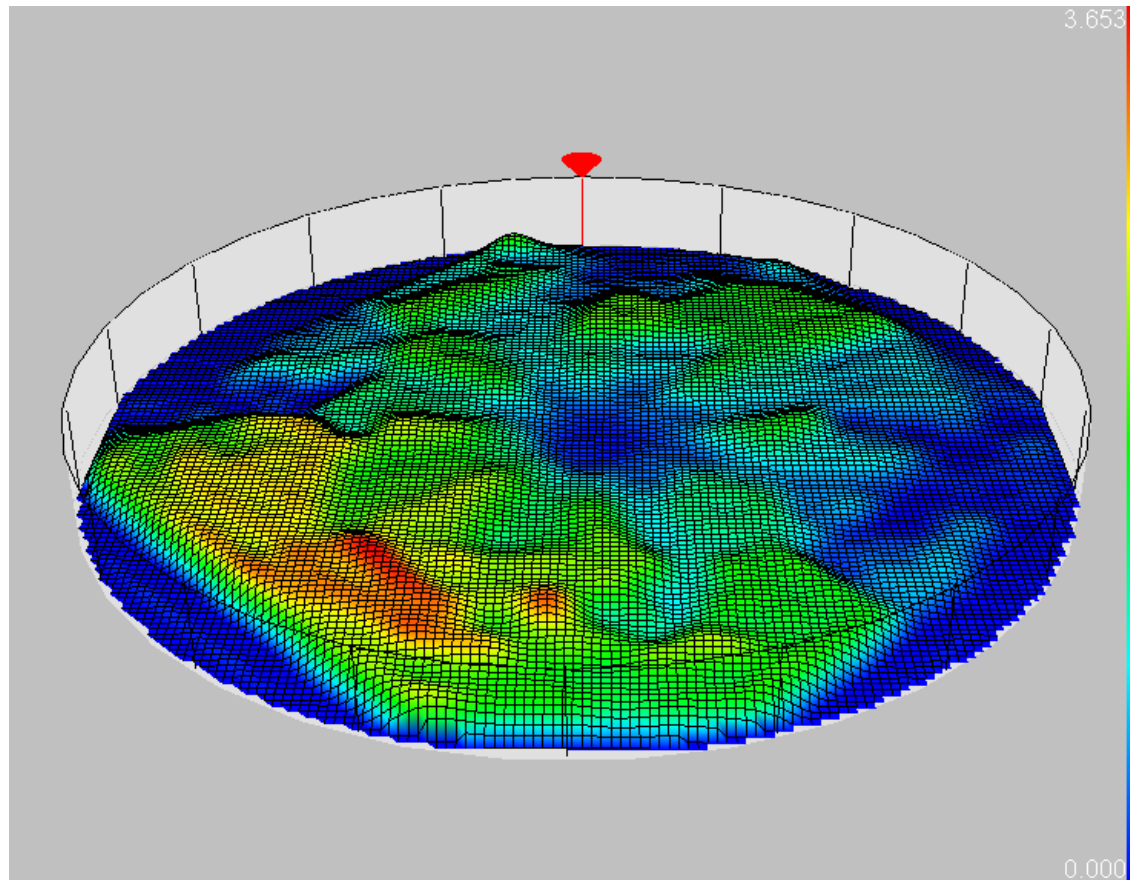






## User Interface

- Sludge 3D Display
- Merged Display from Multiple Entries
- Tank Wall Mimic Shown
- Volume Calculation
- Topology Display
- Accuracy  $\pm 3\%$

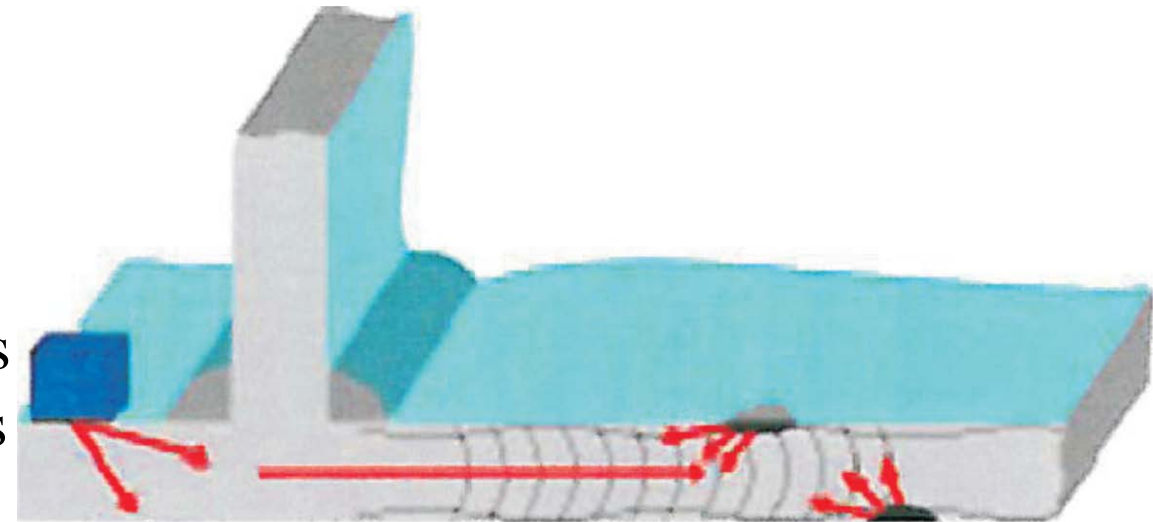




## Auxiliary NDT Methods for selecting AST's

### Short Range Guided Wave:

- Tank Floor Annular Plate Testing
- Testing Concrete Coated Interfaces
- Testing Under Pipe Supports
- Tank Dyke Piping Interfaces
- Scan Under Vessel Supports

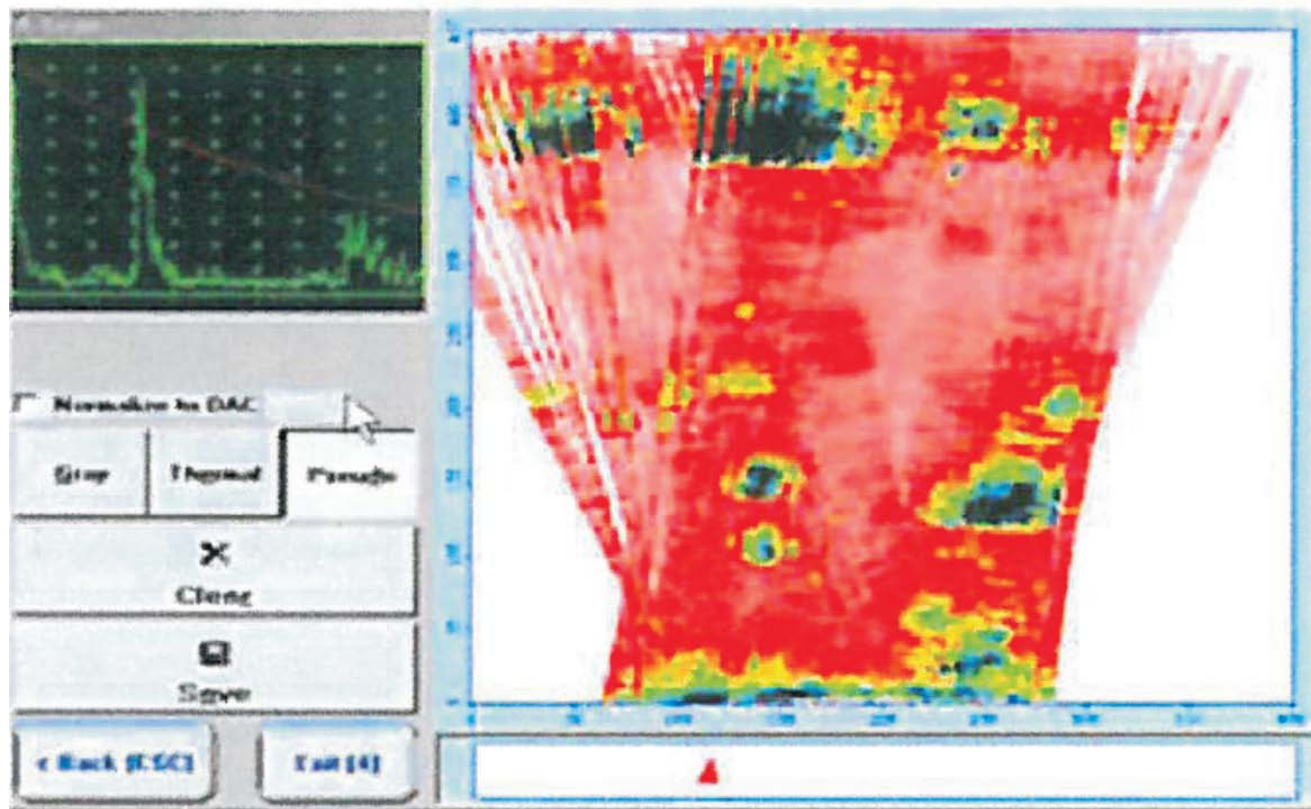


Some limitations exist when using this technique including:

- Top or Bottom Side Differentiation
- Must Have 2" Space for Probe Placement



## Data collection:







## Inspecting the annular ring :







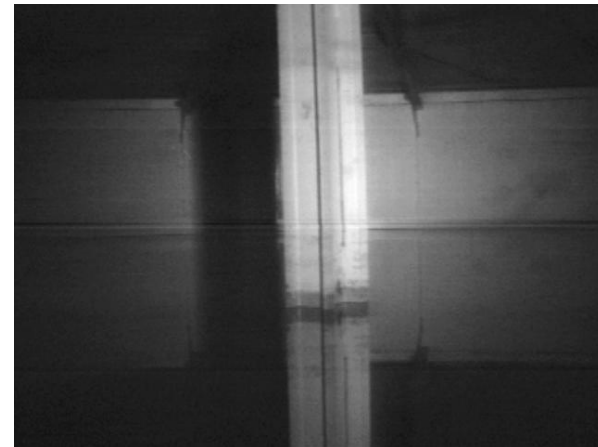
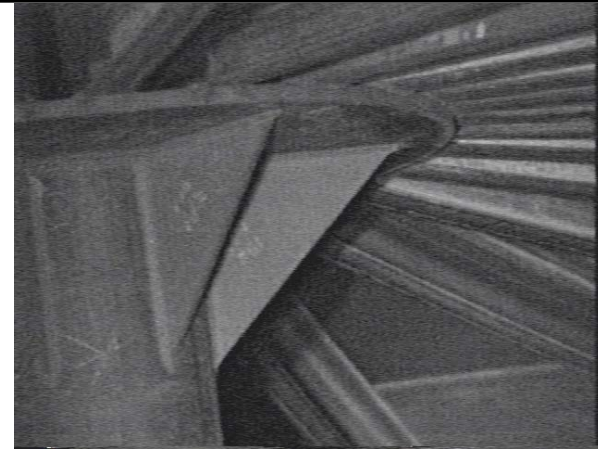
# Major Elements of a Robotic On-Stream Cleaning and Inspection System

- Robotic Vehicle (300 lbs)
- Umbilical (350 – 500 feet)
- Roof Top Staging Equipment
- UT Subsystem
- Video/Sonar
- Navigation/Control
- Transport Vehicle
- Data Analysis Center





# Tank Vapor Space Inspection



## Quik-Look™ Seal Inspection

System consists of:

- Intrinsically-safe light system
- Pan/Tilt/Zoom Camera System

Quik Look system inserted through roof  
Manway

- System can be used to view condition  
of roof/rafters



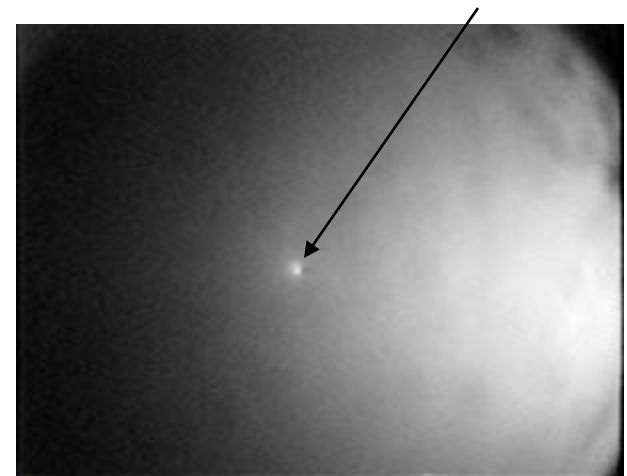




# Quik-Look (Qualitative Visual of Primary Seal)



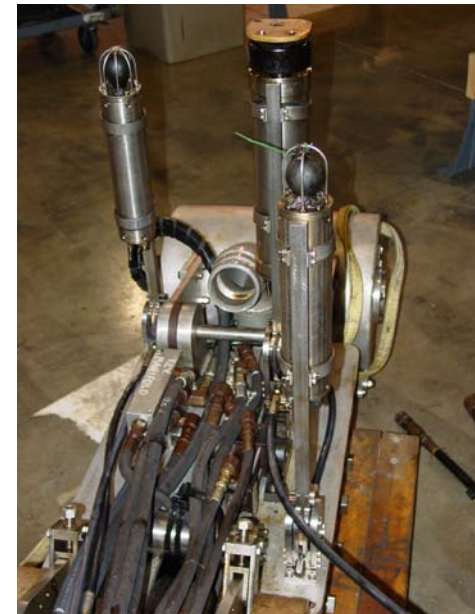
Internal Column  
and Light from  
Hatch





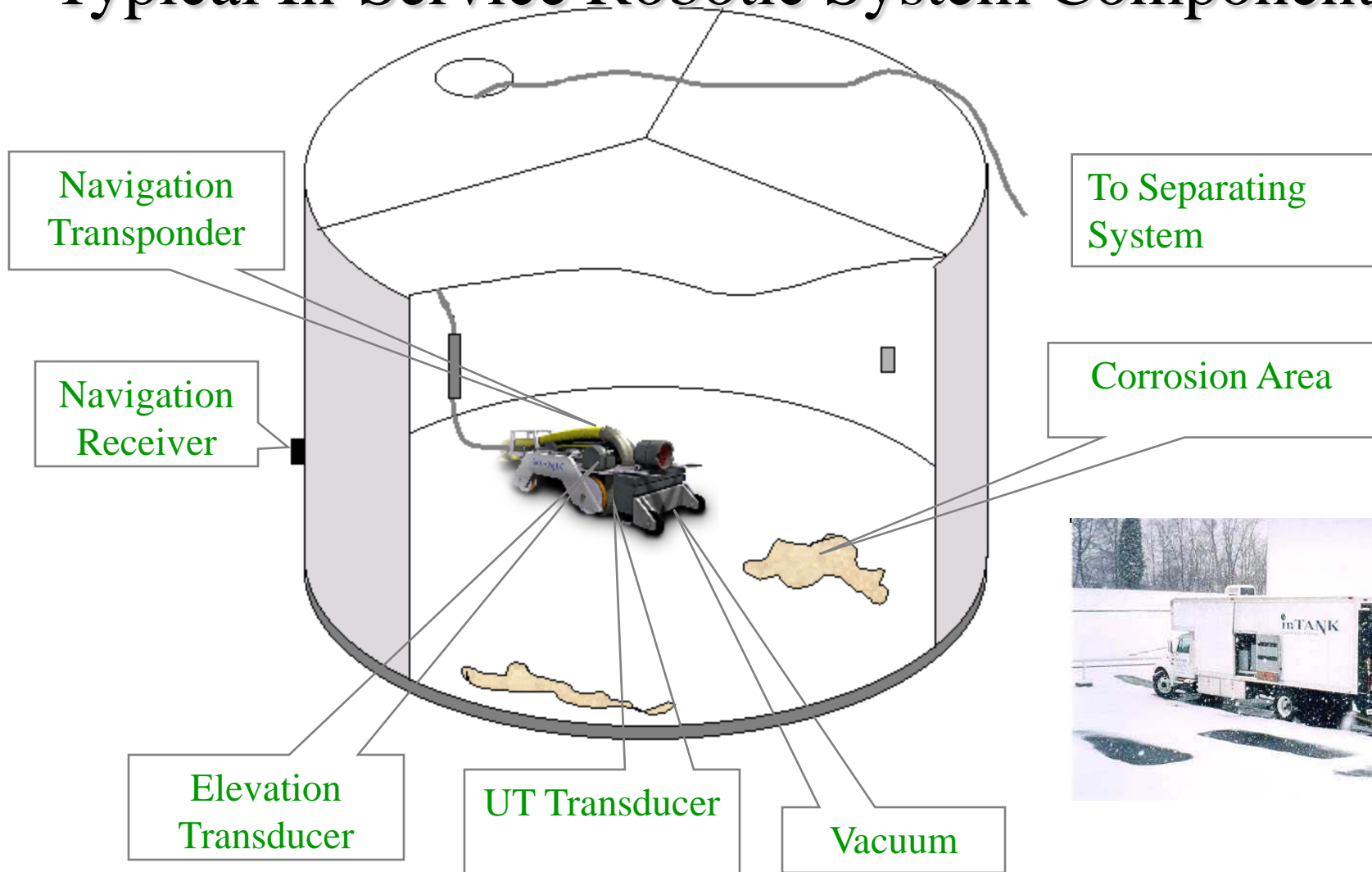


# Tank Desludging and Filtration



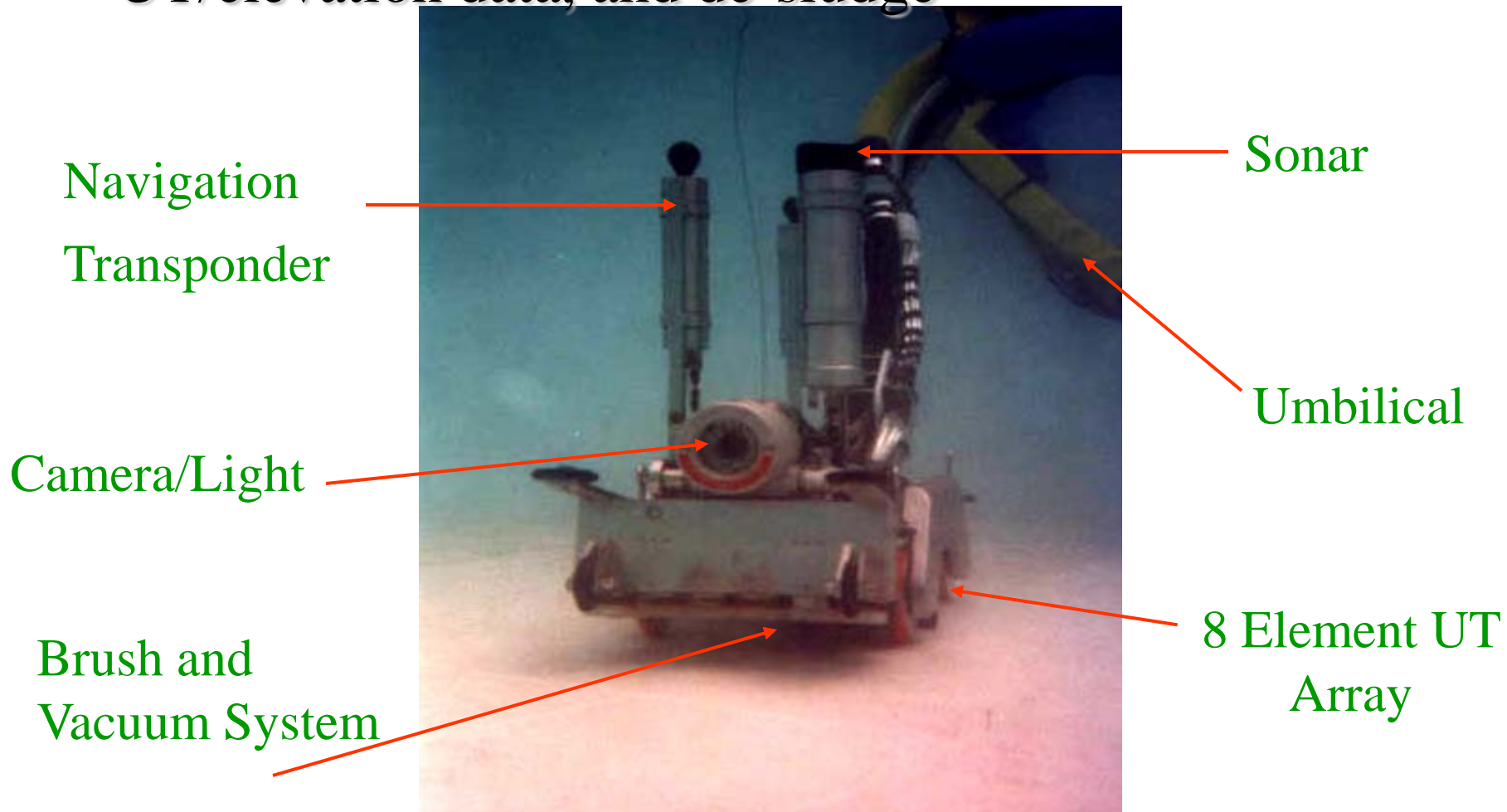


# Typical In-Service Robotic System Components





The Robot is fully equipped to navigate, collect UT/elevation data, and de-sludge







# Robot Deployment Through Roof Manway

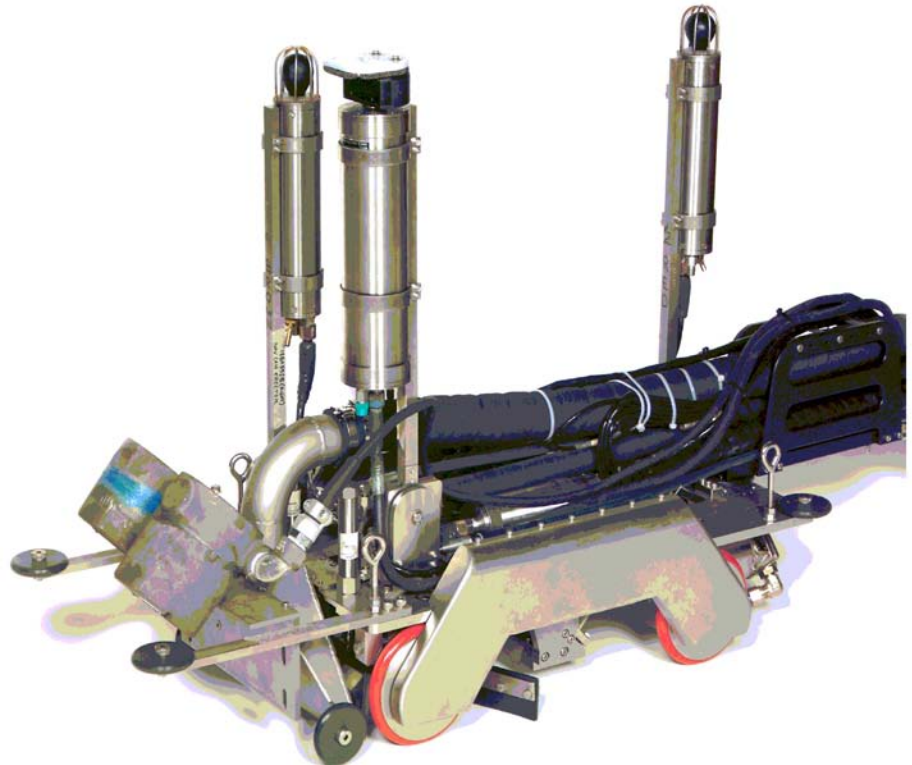




## OTIS (H/E) Robot

### System consists of:

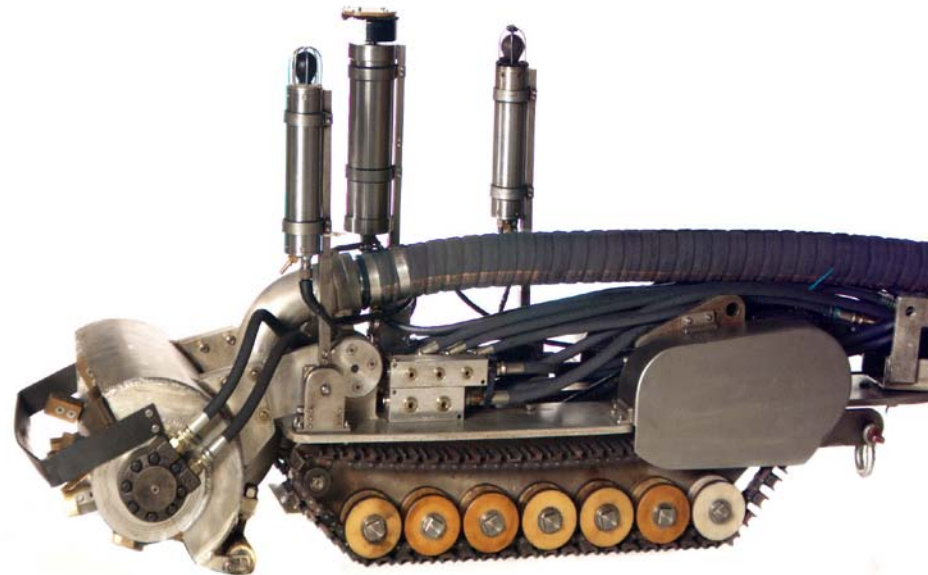
- 8 UT transducers
- Video and sonar systems
- 2 active sonar location pingers
- 6-12 passive sonar location receivers
- Cleaning system



## OTIS-HD Robot

### System consists of:

- Auger sludge removal system
- Sonar/camera system
- 4 UT immersion transducers
- Flushing system
- 2 active sonar location pingers
- 6-12 passive sonar location receivers
- Tracked vehicle for up to 1.2 m (4 feet) sludge

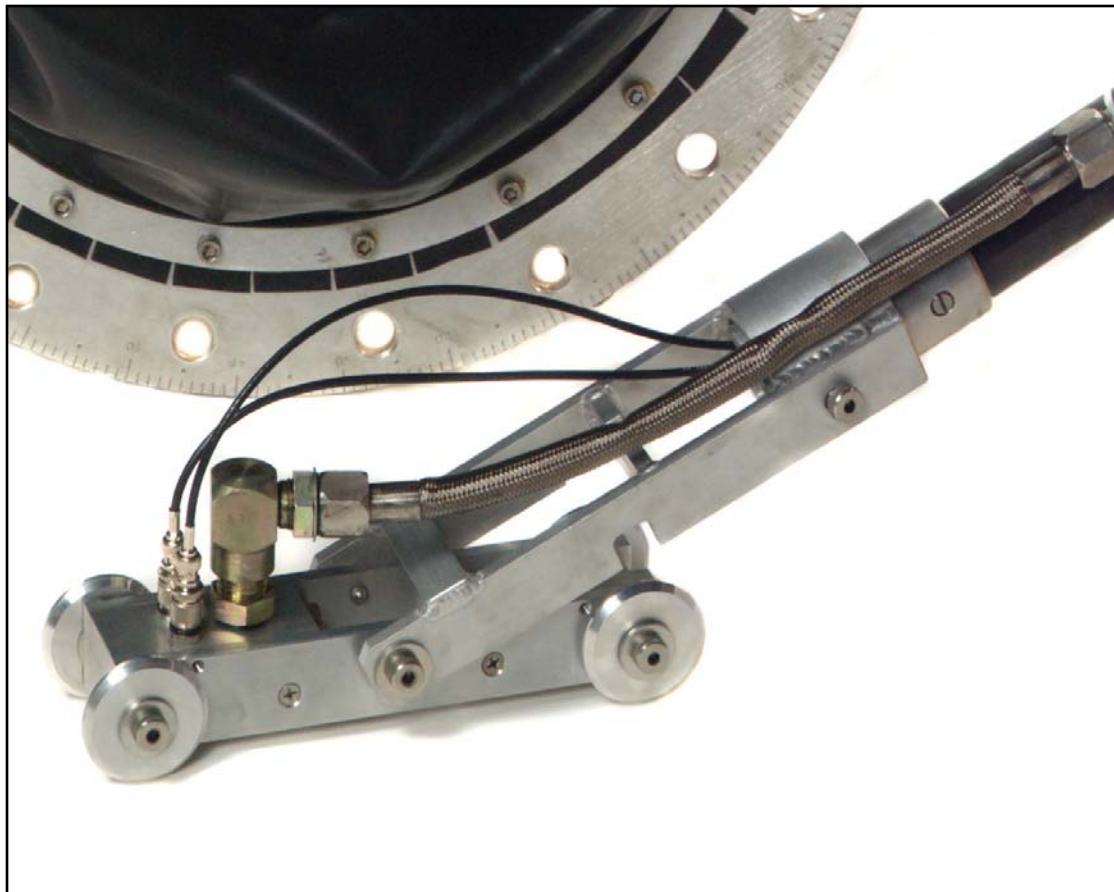




## OTIS Probe

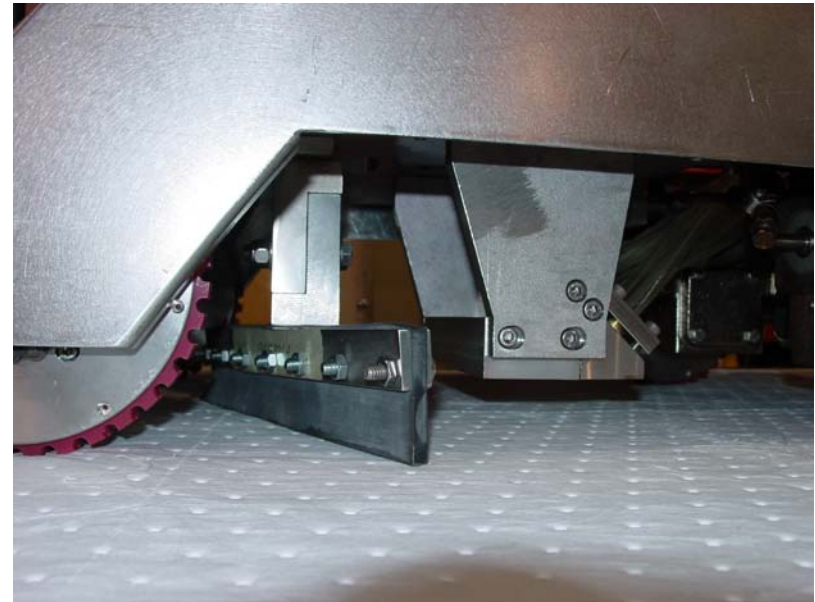
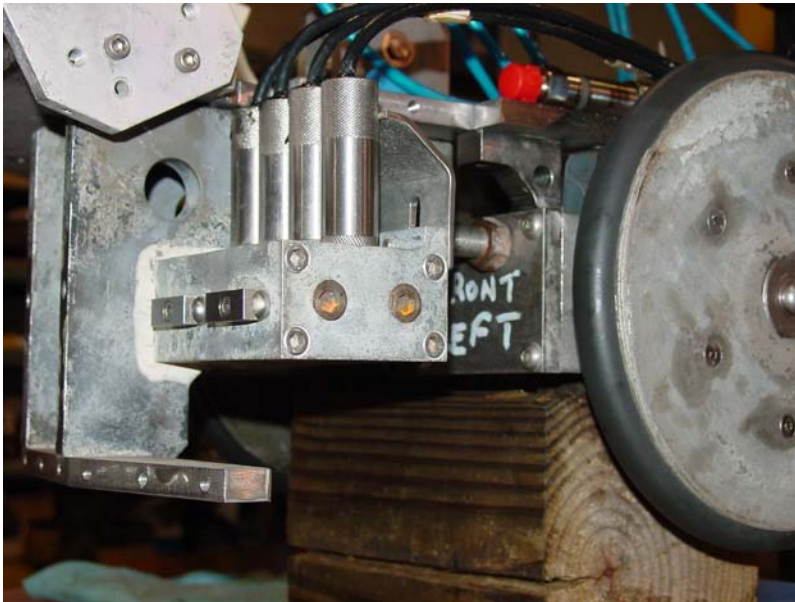
### System consists of:

- 2 (4) UT immersion transducers
- Flushing system
- Pole assembly
- Gimballed manway seal (optional)
- Products < 200 C (400 F)

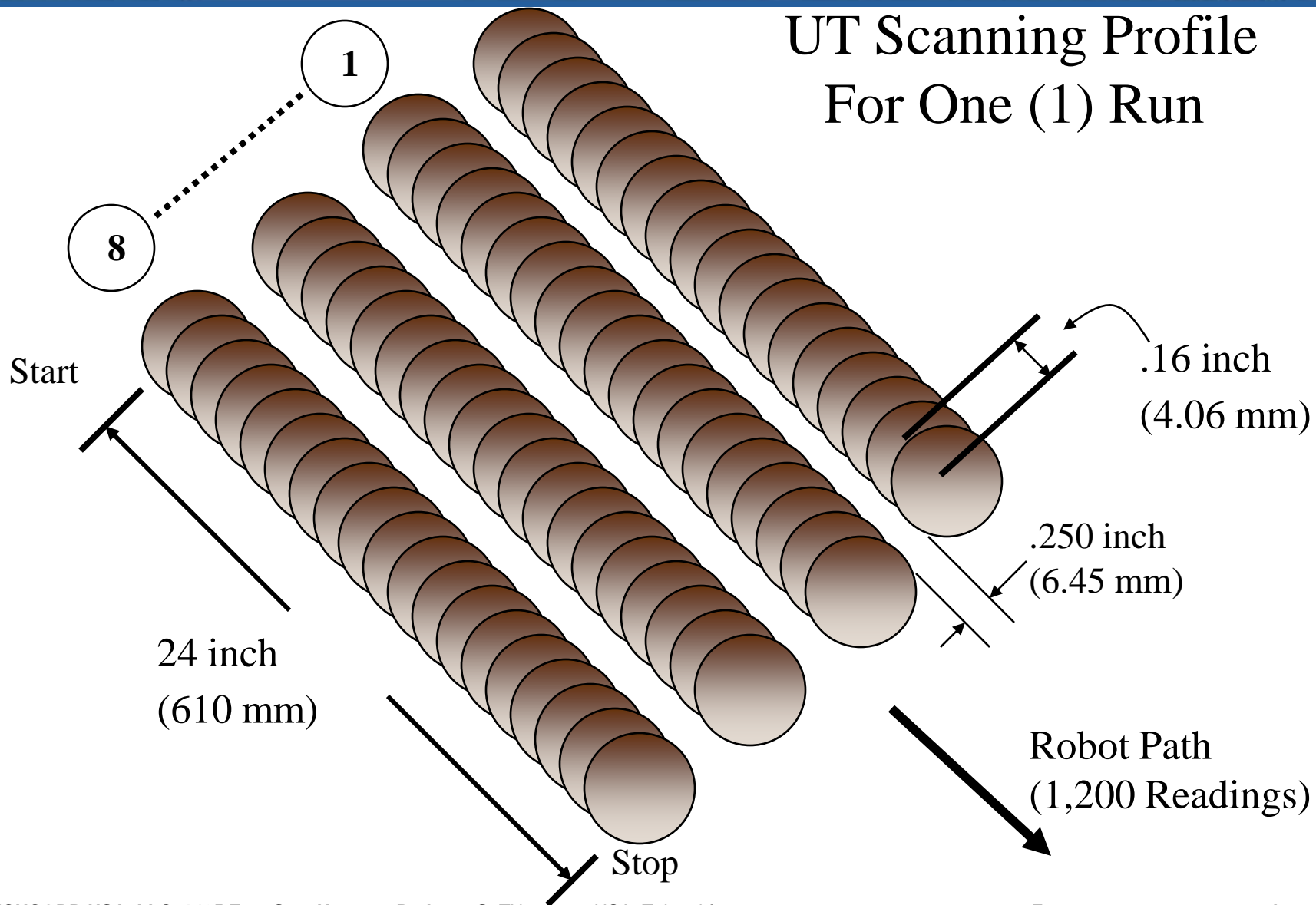


# UT Scanning

## UT Immersion Sensors



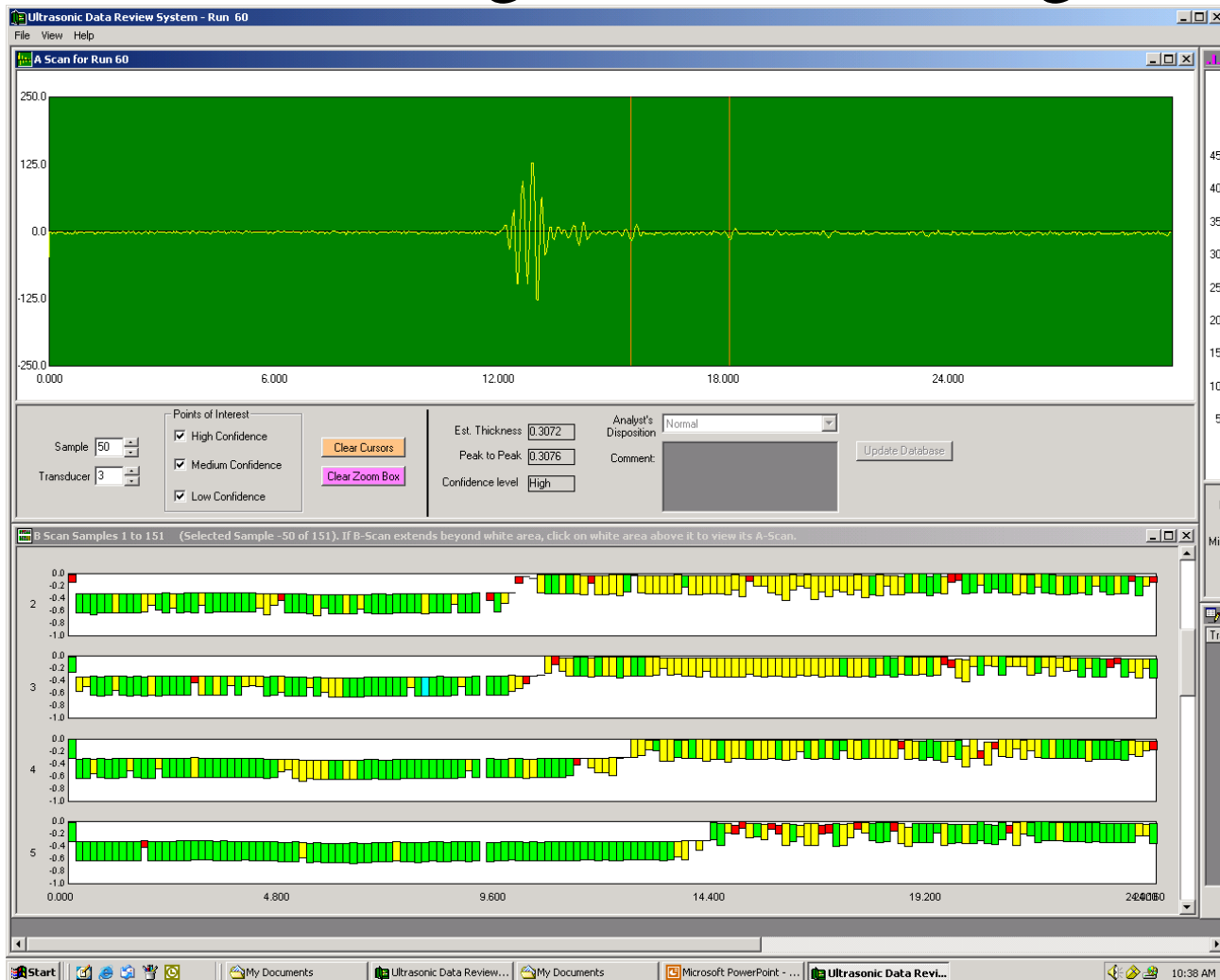
# UT Scanning Profile For One (1) Run



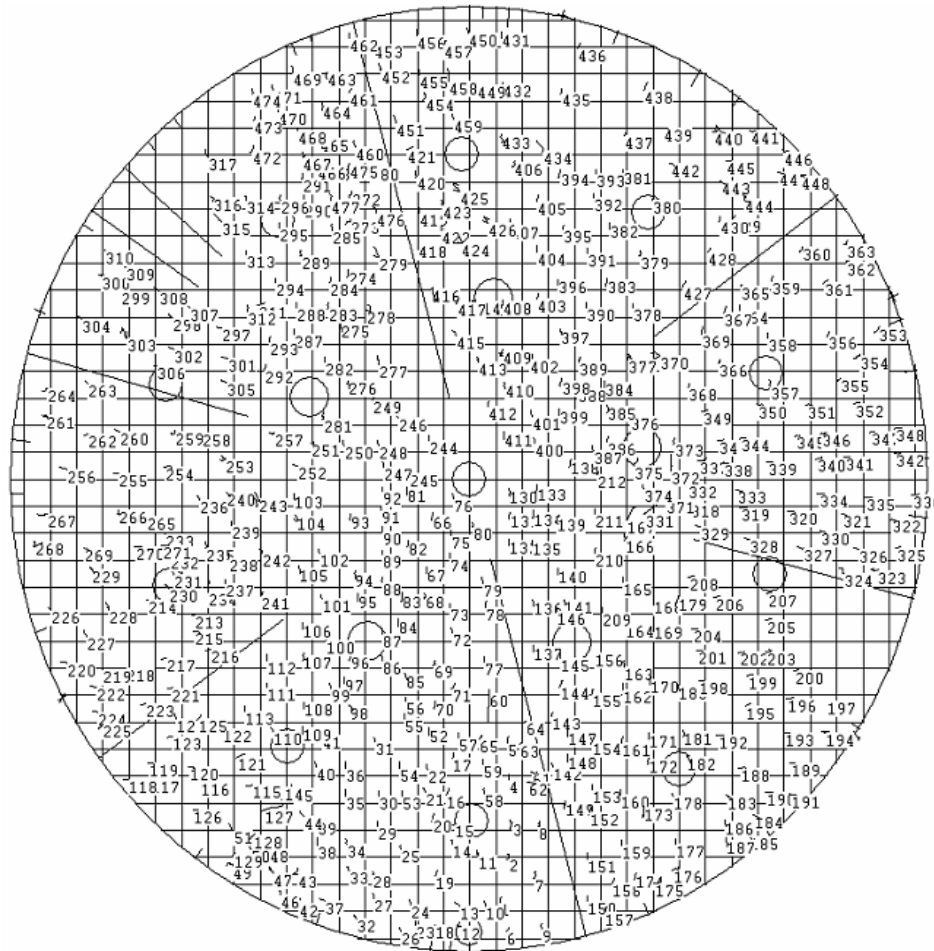




# Robot Crossing Weld At An Angle



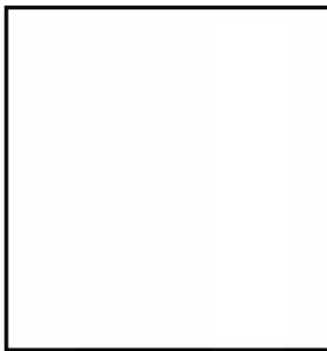
# Data acquisition: location of UT runs





# Tank Lining Illustration

Transducer

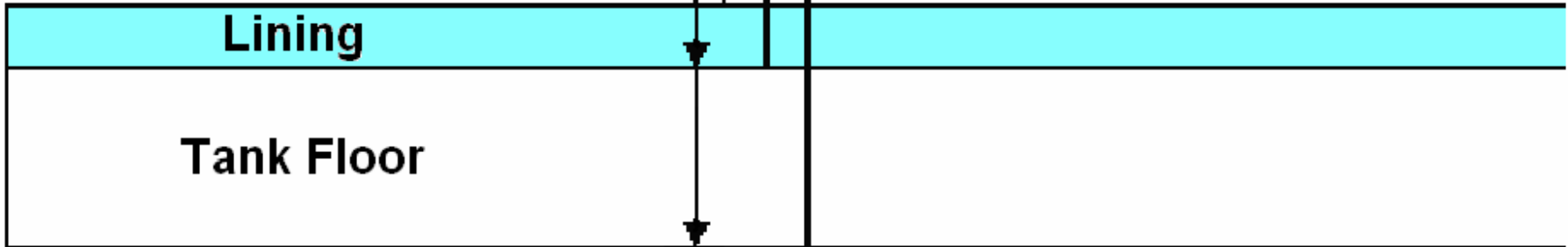


Transmitted Signal

Transmitted Signal

Lining

Tank Floor





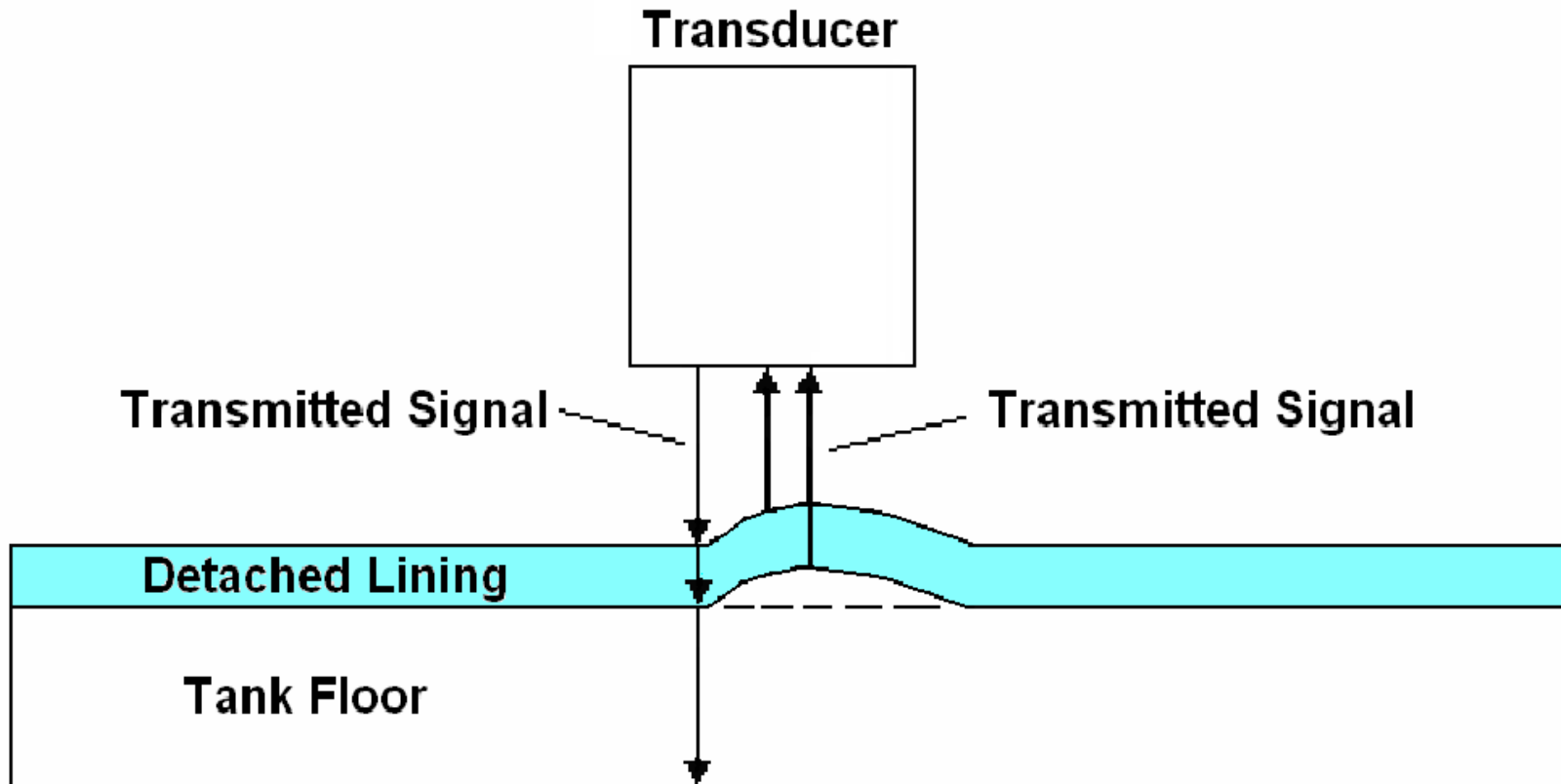


# Tank Lining Example



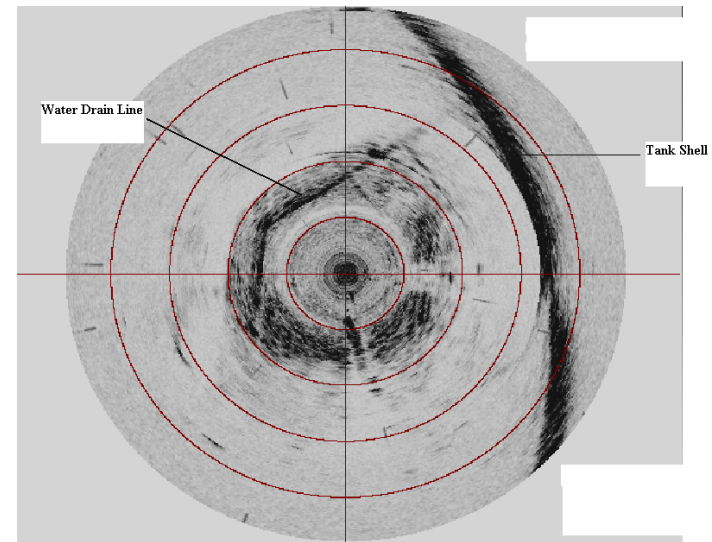


# Detached Lining Illustration



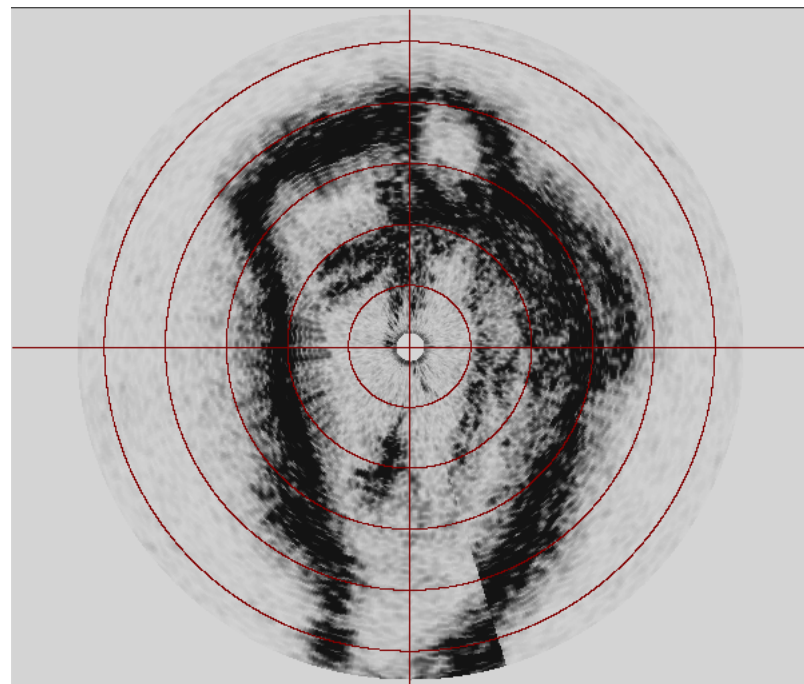
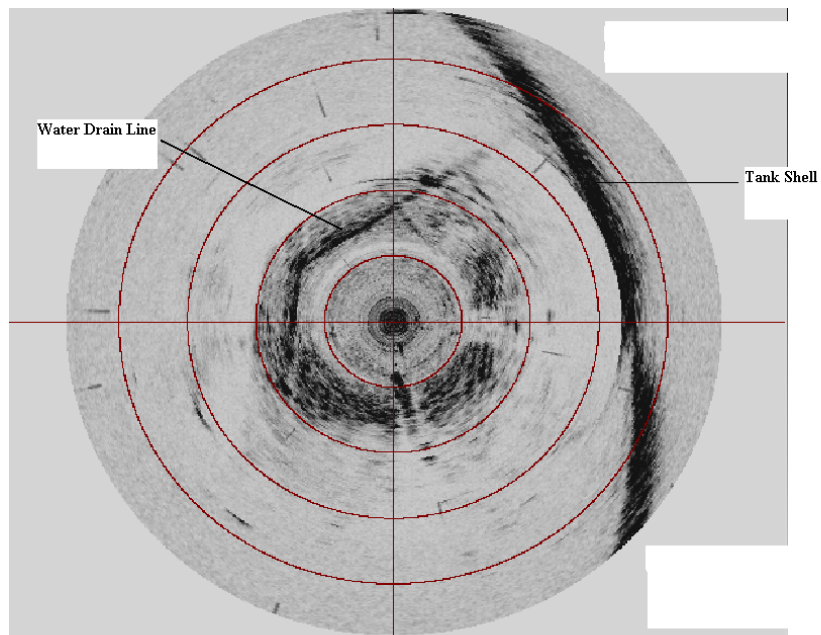
# Sonar

- The sonar system, like the navigation and ultrasound system, uses acoustics to image the interior of the tank
- Sonar systems are crucial aids to the operator
- Sonar systems have limitations:
  - Its high frequency limits its ability to operate in very thick products.
  - The unit is effected by temperatures over 120 degrees F.



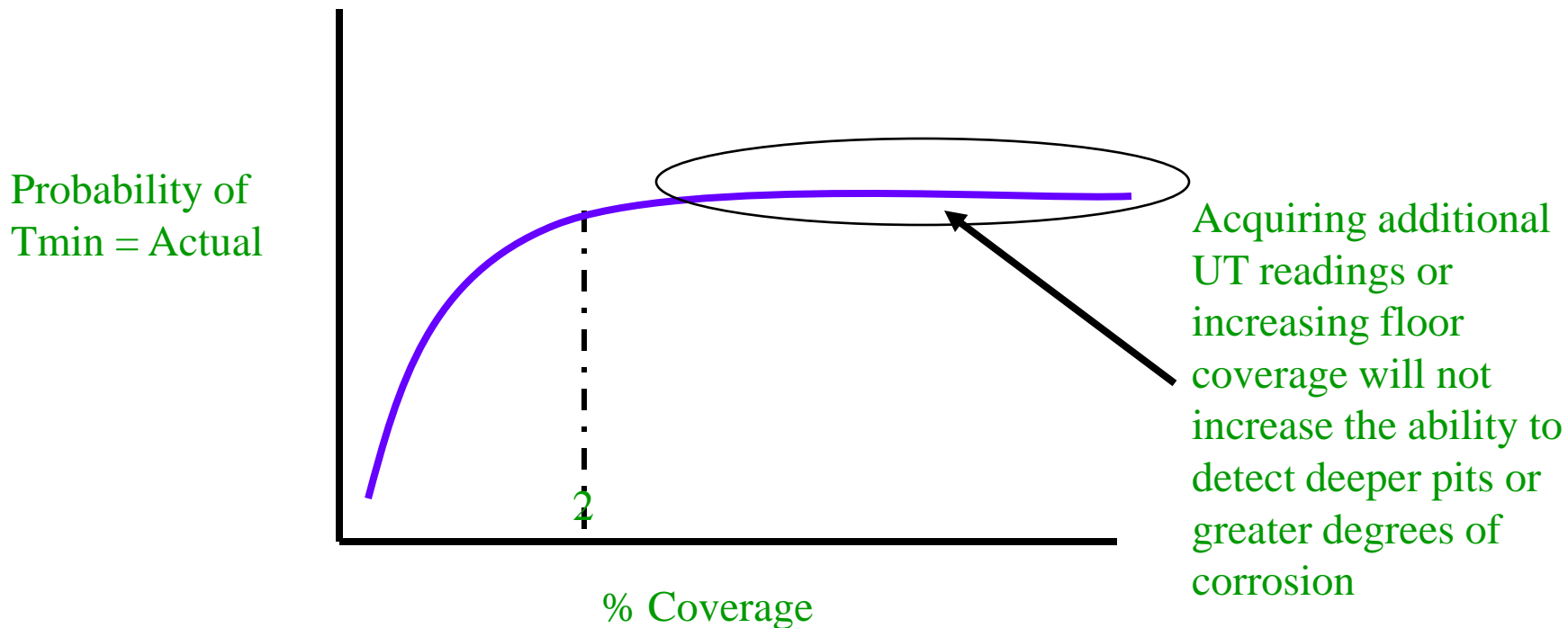


## Sonar (continued)





# The Probability of Detecting a Deeper Pit as a Function of % AST Floor Coverage<sup>1</sup>



<sup>1</sup> Probability profile created from actual field validation data collected for ExxonMobil (1998)

## Potential Robot Application Barriers

- Tanks with multiple internal obstructions on or near the floor.
- Tanks with internal floating roofs and fixed upper roof.
- Tanks with excessive sludge.



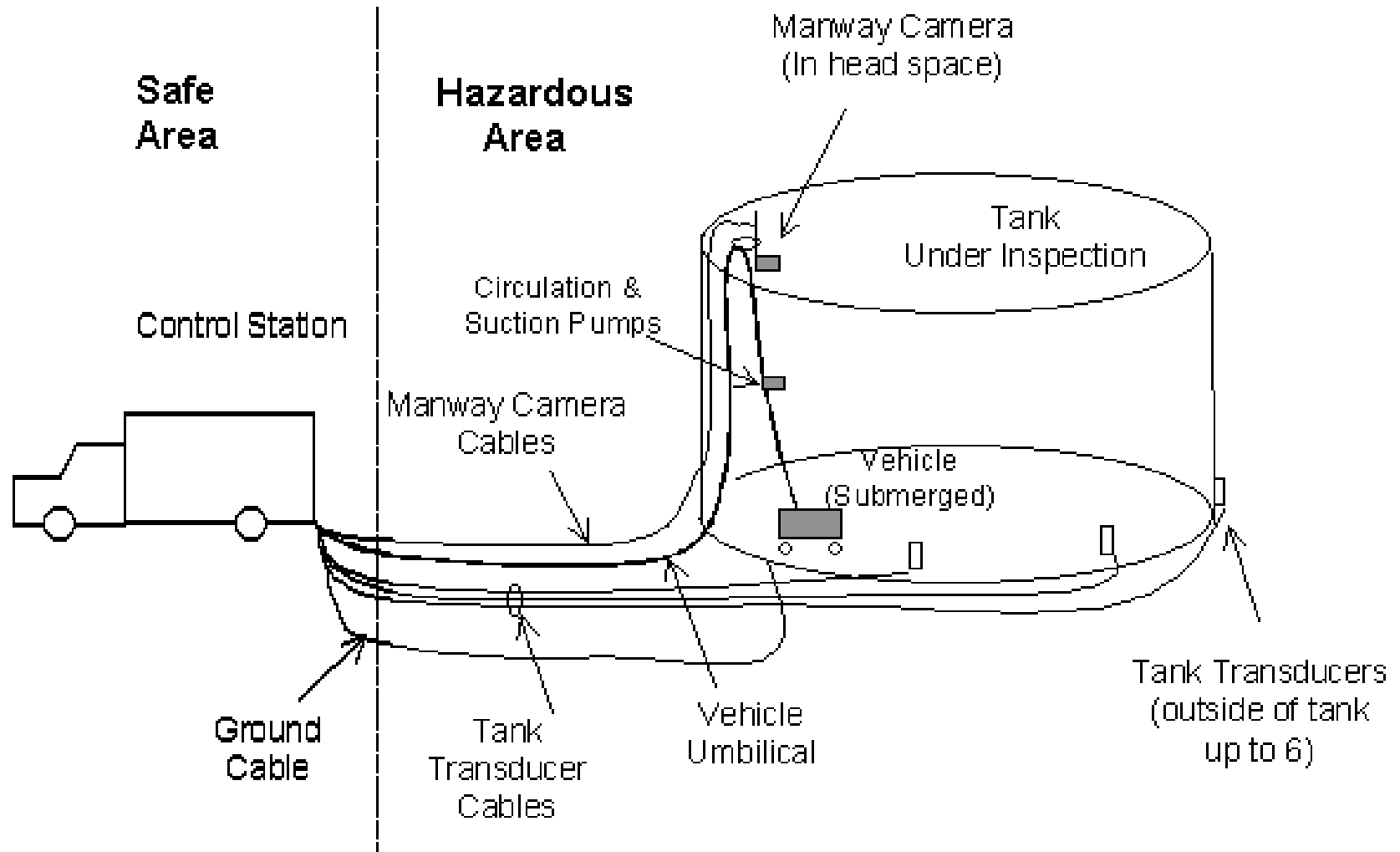




## Truck and Crane Access

- Crane Selection Will Be Based on the Distance from Tank
- Truck Must be Positioned Close Enough For Total Umbilical Length







**More Questions?**

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**THANK YOU**