FIU-DOE Fellow Research Experience

Dayron Chigin, DOE Fellow, Class of 2012
Electrical Engineering Undergraduate Senior

ARC Mentors: Dwayne McDaniel, Ph.D., P.E. & David Roelant, Ph.D.

Hanford Mentors: Ruben E. Mendoza; Manager, Waste Transfer and Storage Engineering, Base Operations Engineering & Rick E. Nelson; Electrical Engineer, Base Operations Engineering

washingtonriver protectionsolutions

INTERNSHIP

Hanford, Richland, Washington
Waste Transfer and Storage Engineering

Project: Leak Detection System Supporting the PC-5000 Process Condensate Transfer Line

Manager: Ruben E. Mendoza; Manager, Waste Transfer and Storage Engineering
Base Operations Engineering

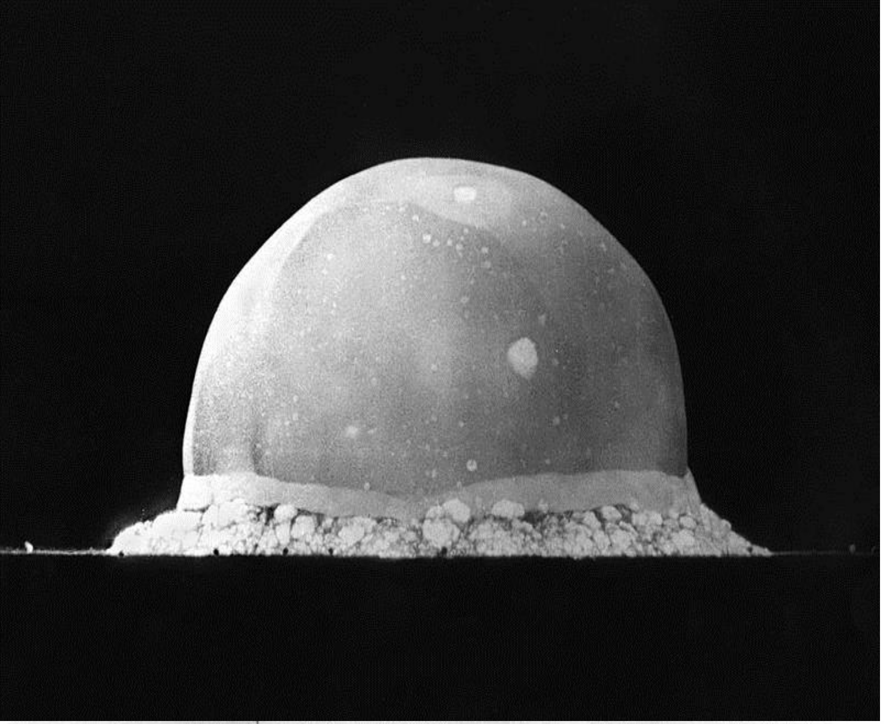
Mentor: Rick E. Nelson; Electrical Engineer, Base Operations Engineering

Intern: Dayron Chigin; FIU-DOE Fellow, Washington River Protection Solutions, Contractor to the United States Department of Energy, Electrical Engineering Intern

Hanford

Fully Operational B Reactor.

The United States Department of Energy (US DOE) acquired the Hanford Site, a 586-square-mile area of shrub-steppe desert, in the year 1943. DOE used the Hanford Site to produce plutonium during World War II and the Cold War. Unfortunately, the production process of plutonium from uranium left behind solid and liquid waste that posed a risk to the local environment, including the Columbia River. The image to the left shows the massive structure of the fully operational B Reactor.



THE TRINITY BOMB

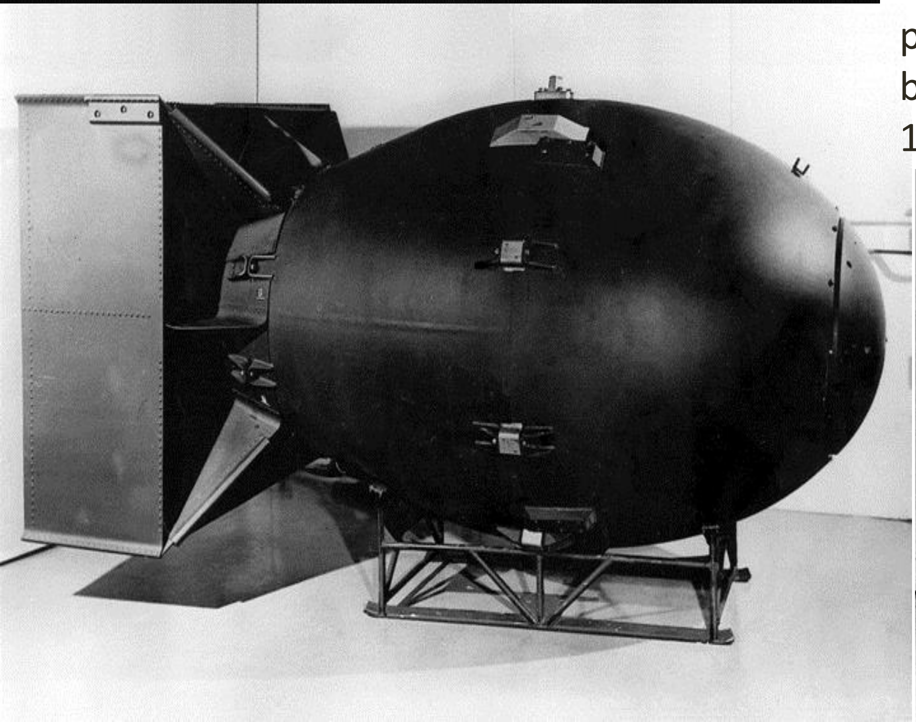
The plutonium produced at Hanford was used in the first nuclear bomb at the Trinity site, code name of the first detonation site. This Trinity site in located in Jornada del Muerto, southeast of Socorro, New Mexico. (Top Left, image of the explosion of the trinity device 16ms after detonation.)

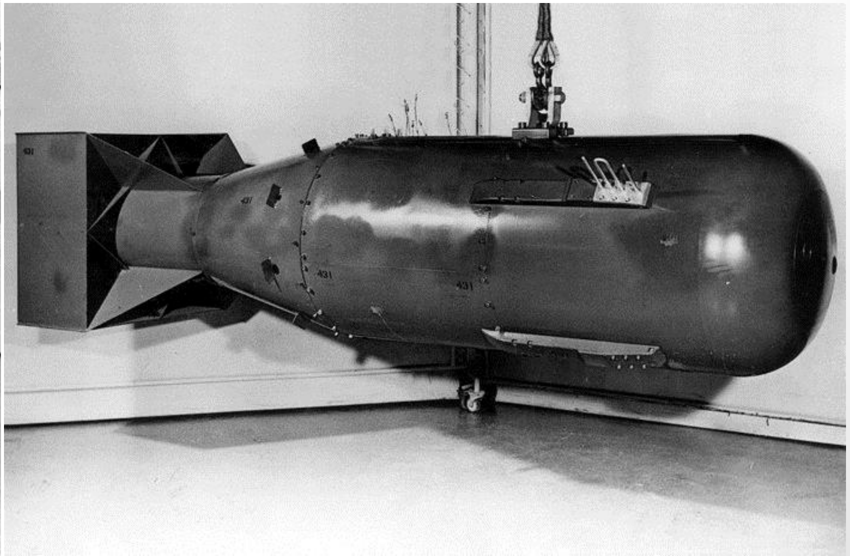
FAT MAN BOMB, NAGASAKI, JAPAN

Fat Man, was the codename for the type of atomic bomb that was detonated over Nagasaki, Japan on August 9, 1945. (Bottom Left)

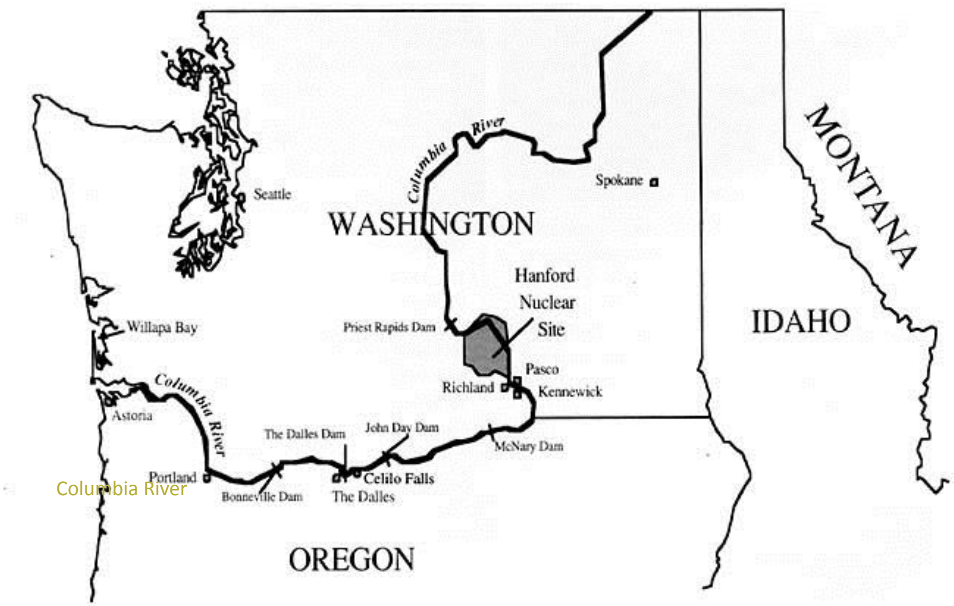
LITTLE BOY, HIROSHIMA, JAPAN

The material for the “Little Boy” bomb was produced in Los Alamos National Laboratory. This bomb was uses in Hiroshima, Japan on August 6, 1945 (Bottom Right)



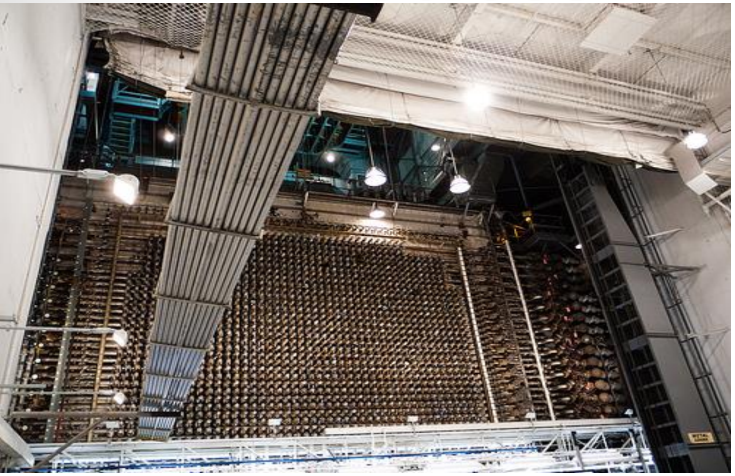


Why Hanford?

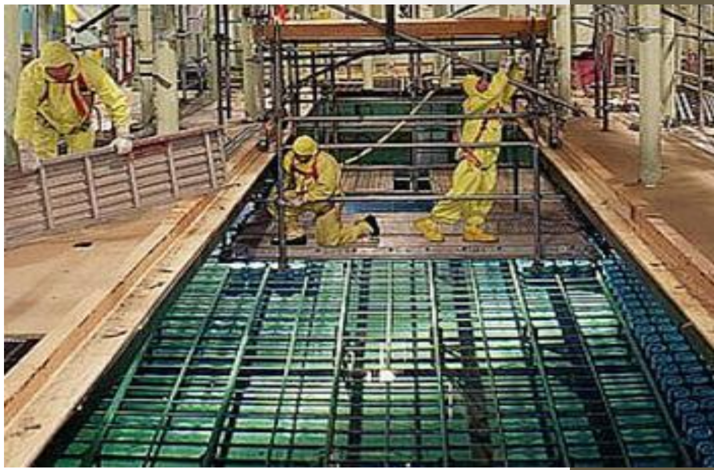


- Hanford was named after the small town of Hanford that was in place when the US took control of the area.
  - Paid each citizens a modest price for their land. They had approximately 30 days to evacuate the land, whether they accepted the price offer or not.
- Why this area?
  - It's isolated location
  - The Columbia River
    - It is the largest river in the Pacific Northwest.
    - It's water flows south from Canada and provides very cold water for reactor purposes.

B-Reactor


B Reactor Core.

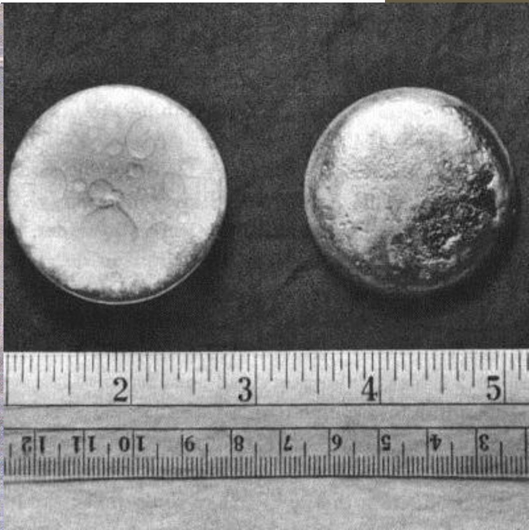
The B-Reactor core along with its 2004 aluminum tubes for the injection of uranium bars are shown in the image of the left. Approximately 750,000 million gallons of water per minute was pumped in order to cool down reactor

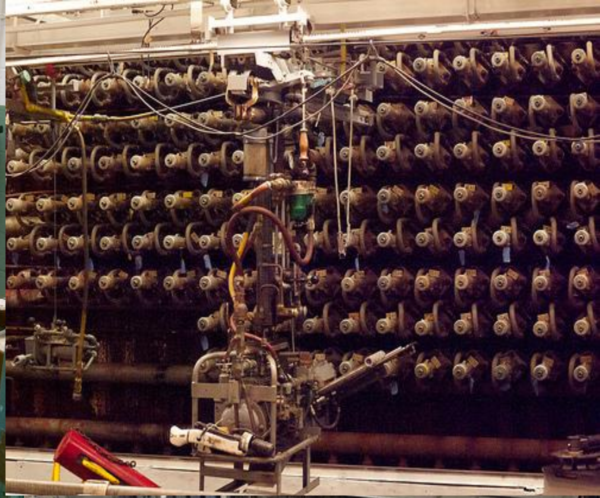

Depository Pool at B-Reactor

$$^{238}_{92}\mathrm{U} + ^{1}_{0}\mathrm{n} \longrightarrow ^{239}_{92}\mathrm{U} \xrightarrow[23.5\ \mathrm{min}]{\beta^-} ^{239}_{93}\mathrm{Np} \xrightarrow[2.3565\ \mathrm{d}]{\beta^-} ^{239}_{94}\mathrm{Pu}$$

Uranium238 ➡ Neptunium239 ➡ Plutonium 239

The elements were pushed out the back side of the reactor into a pool of water where they cooled and some of the radioactivity decayed away. The fuel elements were eventually taken by train from the B Reactor to the separations processing facilities in the 200 Area where the plutonium was removed from them. It took approximately 13 months to have the reactor up and running.

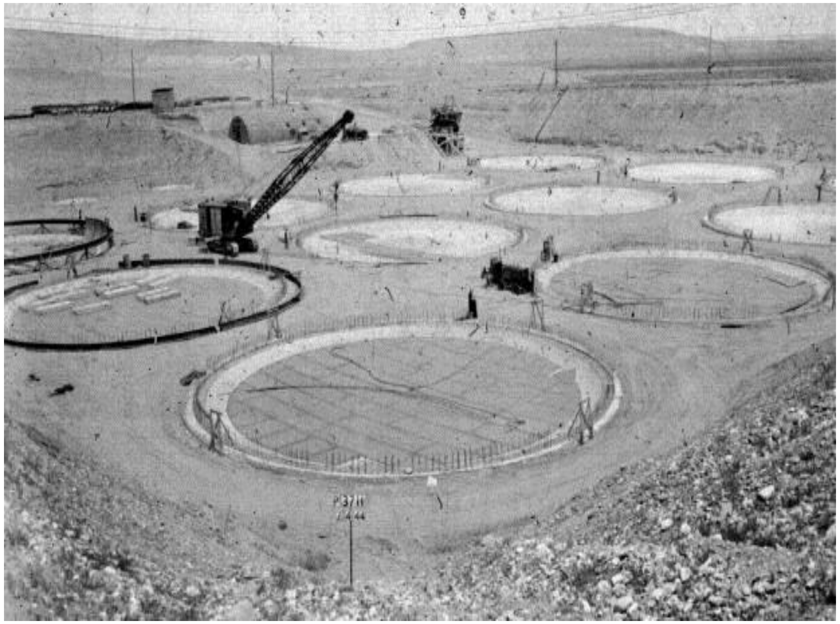




B-Reactor Images

DEPARTMENT OF ENERGY
UNITED STATES OF AMERICA

Waste Treatment



Initial Construction of a Tank Farm

Today, there is a reported 56 million gallons of radioactive waste stored in underground waste depository tanks. Throughout the years, certain tanks have been discovered to be leaking some of this stored waste.

Radioactive Symbol

Tri-party agreement

Hanford Federal Facility Agreement and Consent Order

Tri-Party Agreement

In 1989, the United States Department of Energy, Environmental Protection Agency, and Washington State Department of Ecology entered into a legally binding agreement to clean up 99.9% of the waste found in the 177 underground waste depository tanks. This agreement was called the Tri-Party Agreement.

Waste Treatment Plant (WTP)

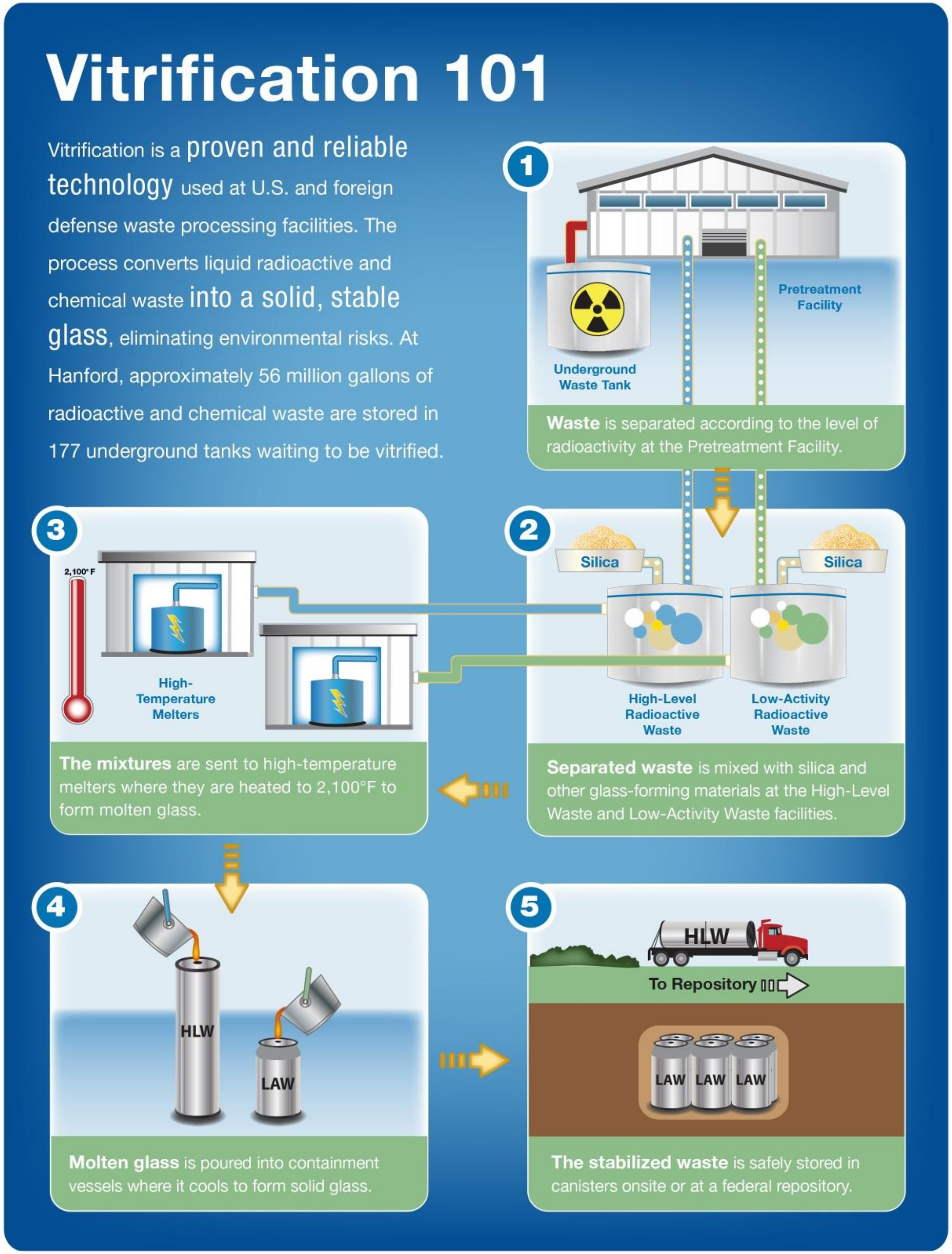
Waste Treatment Plant (WTP) or VIT Plant

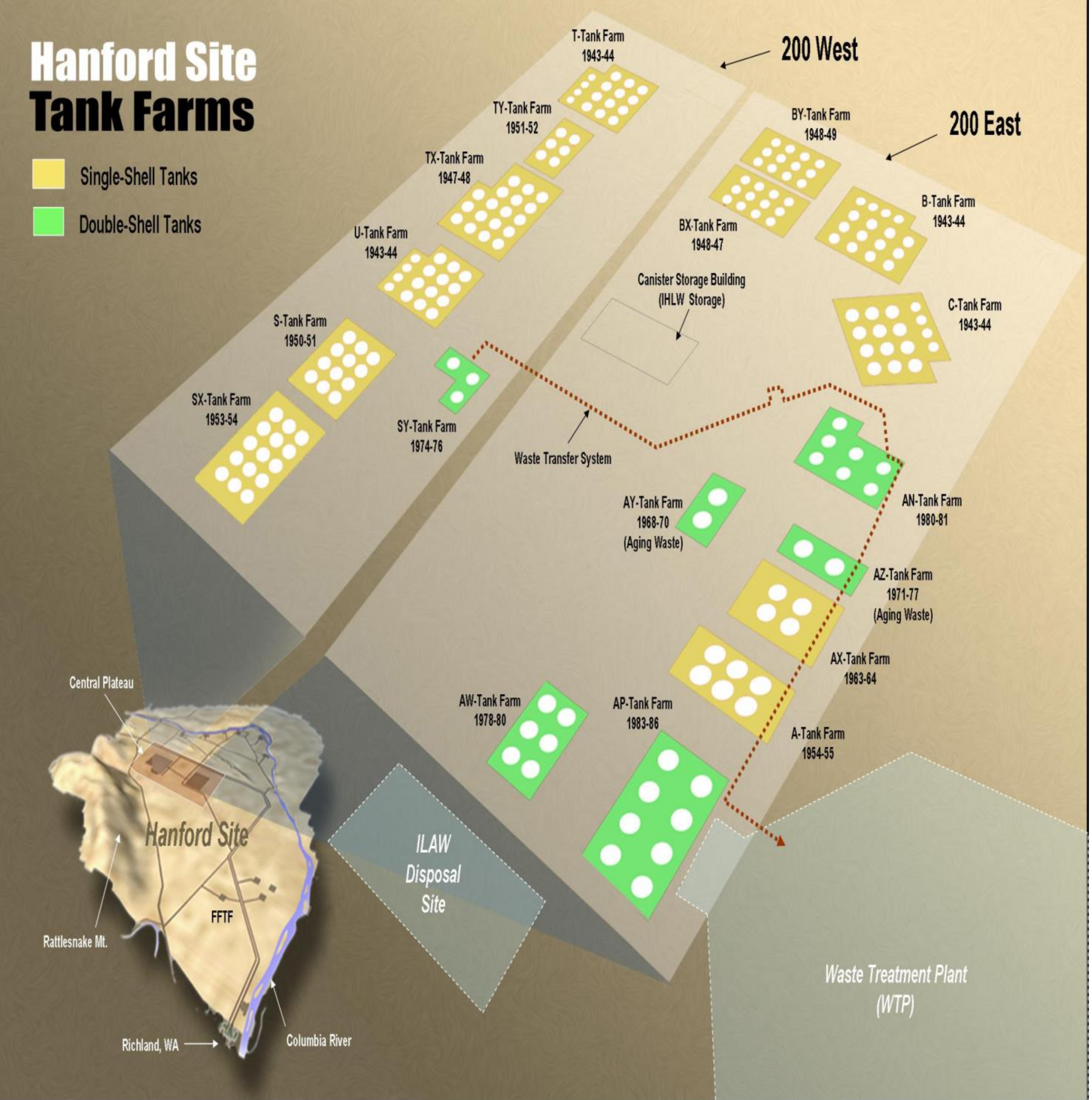
The United States Department of Energy Environmental Management Division has been charged with this task. In order to do so, a one of a kind Waste Treatment Plant (WTP) is currently under construction. Along with the primary contractor, Bechtel National Inc., the US DOE is designing and currently building the WTP. The WTP is capable of separating radioactive liquid waste into different categories of high level waste (HLW) and low level waste (LLW) for treatment and processing into stable glass forms suitable for permanent, safe disposal.

Vitrification

The process of treating this waste into a safe glass state is known as Vitrification. Even though Vitrification processes have been conducted at other DOE sites such as Savannah River Site, the WTP in Hanford will be a project on a larger scale covering approximately 65 acres of the Hanford Nuclear Reservation. The WTP will be fully operational by 2019. It is said that the WTP will be running upwards of 2050 in order to successfully treat all the waste at Hanford.

It's expected the Lab will analyze about 10,000 waste samples each year. When waste initially arrives at the WTP, the Lab will be used to determine the correct proportions of waste and glass forming materials that need to be mixed together. Determining the right "recipe" will produce a consistent vitrified waste product. For LAW, the mixture is anticipated to be about 20% waste and 80% additives; HLW's expected "recipe" for producing consistent, vitrified high-level waste is 30% waste and 70% additives.





Emptied Tanks

- What will be done with these tanks when emptied?
- Do you have any ideas?
- Neither do they.

Emptied Tanks

- Some Ideas Presented:
  - Fill with sand
  - Fill with special gravel
  - Demolish
  - Leave completely isolated

- The final decision must abide with the Tri-Party Agreement and have the approval of all three of its supporters.

- What did my internship have to do with all of this?

My Department

Waste Transfer and Storage Engineering

What I Learned about the Job and about Myself

- I enjoy working with others in a team like environment
- I realized an engineering career is right for me
- There are standards for everything, for a reason (goes with the saying "rules are meant to be followed")

What I Accomplished

- Generated ECN's
- Generated Preventative Maintenance Procedures
- Generated Preventative Maintenance Identifications (PMID's)
- Edited AutoCAD Files

What Advice I would Offer Future Interns

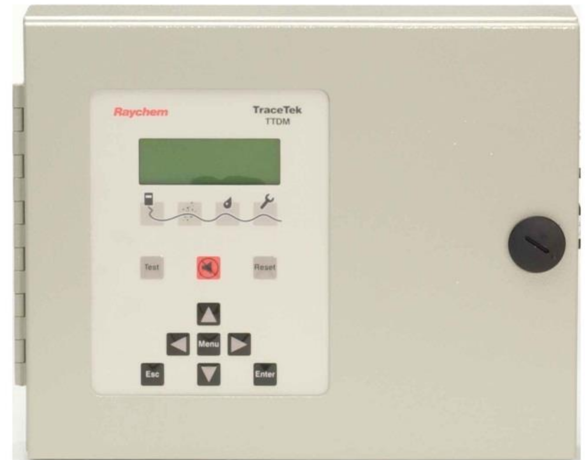
- Try to become involved in all available tasks
- This is a learning experience so try to learn as much as you can
- Communication is key to understanding others and making the most of this internship

On-Going Project

- Preventative Maintenance (PM) Procedure
  - Leak detection system supporting the PC-5000 process condensate transfer line between the 242A-Evaporator and the Liquid Effluent Retention Facility (LERF).

History on the Project

- Back in 2010 ECN-726604 was performed.
  - Sole purpose was to upgrade the system to prevent false alarms during Evaporator campaigns.
  - Changed 6 leak detectors along the PC-5000 with corresponding junction boxes now placed above grade in order to avoid dirt, sand, and water corrosion problems.
    - Leak Detectors called : TTMINI-Probes (bottom right image)
  - Replaced the leak detector master control module in the LERF building.
    - Module called: TTDM-128 (top right image)



Why is it important?

- The 242-A Evaporator is critical to Hanford's cleanup mission since there are no current plans to build more underground waste storage tanks at the Site, and the space within the existing double shell tanks at Hanford is limited. By boiling off the liquids, the Evaporator process creates space in the existing tanks which will be used to store waste being retrieved from the aging single-shell tanks.

Why is it important (cont.)

- The Evaporator sends its liquid to LERF (right image) which is capable of holding 23,000,000 gallons of material. LERF accepts and stores waster waters from a number of Hanford sources. From here the waste water is then routed to the Effluent Treatment Facility (ETF) for treatment (image below).

What My Task is

- In response to Problem Evaluation Request (PER) WRPS-PER-2013-0663
- Preparation for upcoming Evaporator Campaigns
- Work along side William White (Procedures) and Rick E. Nelson (Base Ops Engineering) to develop suitable procedures
  - This procedure must abide to DOE-WRPS standards.
  - Must clearly state the purpose and the steps the individuals conducting the procedures should follow.
  - Should consist of information from user manual supplied by manufacturer.
  - Must be conducted on an yearly basis, continuously.

What I had to do to accomplish my task

- Closely analyze ECN-726604 R-2
- Dissect the user manual for TraceTek TTDM-128 leak detection module.
- Master DMCS in order to locate necessary drawings
- Learn to reference drawings from other drawings in order to find required components of different systems
- Communicate well with individuals such as Darrel T. Heimberger in order to understand the purpose of the system and the changes made via ECN-726604 R-2
- Understand WRPS Administrative Procedures in order to successfully complete the task.

Current progress of task

- We have successfully produced a draft of the procedures.
  - During our Job Hazard Analysis (JHA) meeting certain concerns and inquiries about the locations of certain valves and their purposes arose by the craft. This led us to some editing requirements.
- Before I left Hanford, we were currently awaiting our next JHA meeting to finalize the procedures.
- After JHA meeting is finalized, procedures seem adequate for all parties
- Training for the craft begin
- Job will be completed at earliest convenience.

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Task 18.1 Evaluation of FIU's Solid-Liquid Interface Monitor for Rapid Measurement of HLW Solids on Tank Bottoms (New)

Mentor: Dwayne McDaniel, Ph.D., P.E.
& David Roelant, Ph.D.

DOE Fellow: Dayron Chigin; B.S. Electrical Engineering (12/2014)

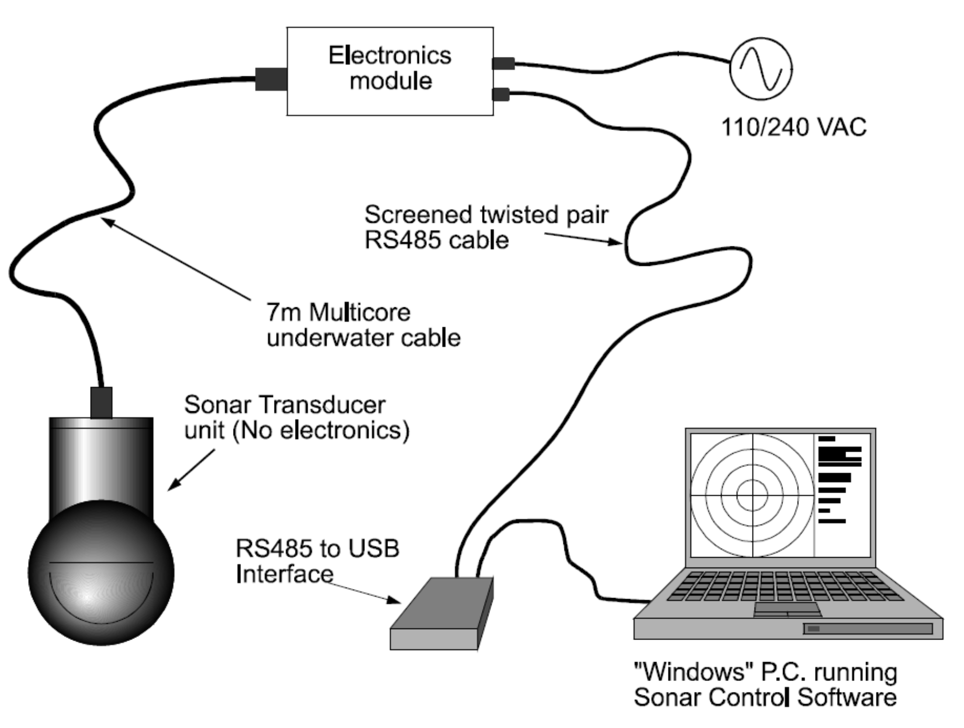
The DOE-FIU Science and Technology Workforce Development Program Director: Leonel Lagos, PhD, PMP

Prior Development of SLIM

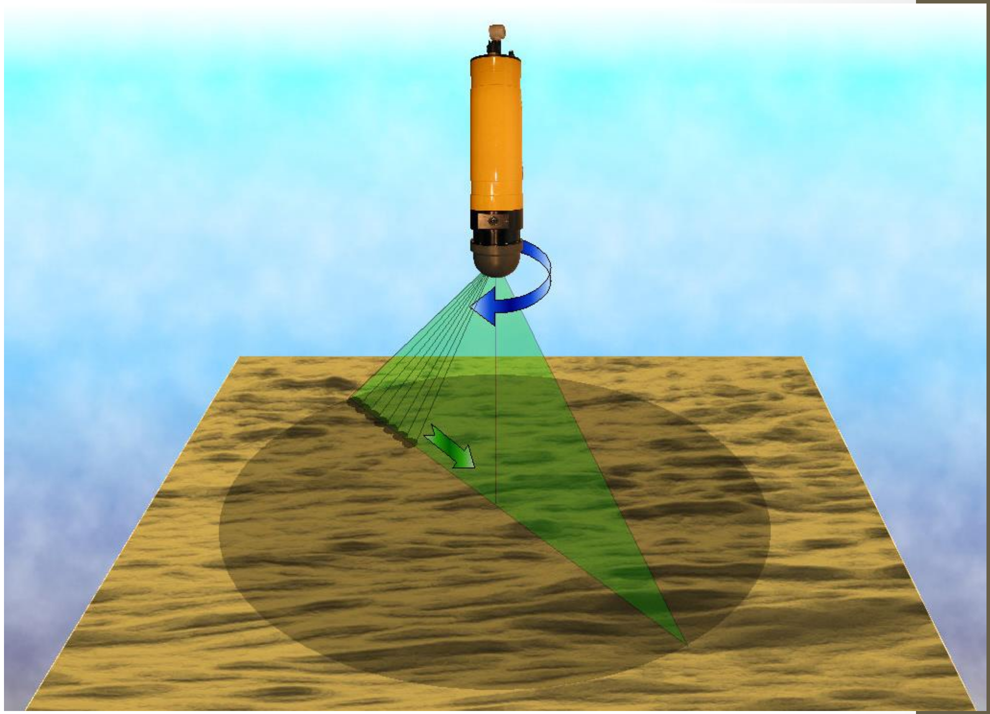
- SLIM was originally developed to map the sludge/supernate interface within the US-DOE Hanford Site's HLW tanks.
- It improved the methods for mapping solid layers, detecting slow settling solid depth and monitoring the tank filling process.
- 3D Surface map of SL interface
- Deployable 50+' into tank
- Chemical, rad resistant sonar design
- Down to 8 mm resolution (@ 1m)
- Remotely operated and monitored

Sonar Description

- The device consists of an acoustic transducer, rotation motor with gearbox, tilt motor, position reference sensor and pressure balancing mechanisms.



- Gathers a swath of data in the horizontal plane and then rotates the transducer through a pre-programmed angle around the vertical axis and repeats the process until a circular area underneath the sonar has been scanned in a sequence of radial spokes.



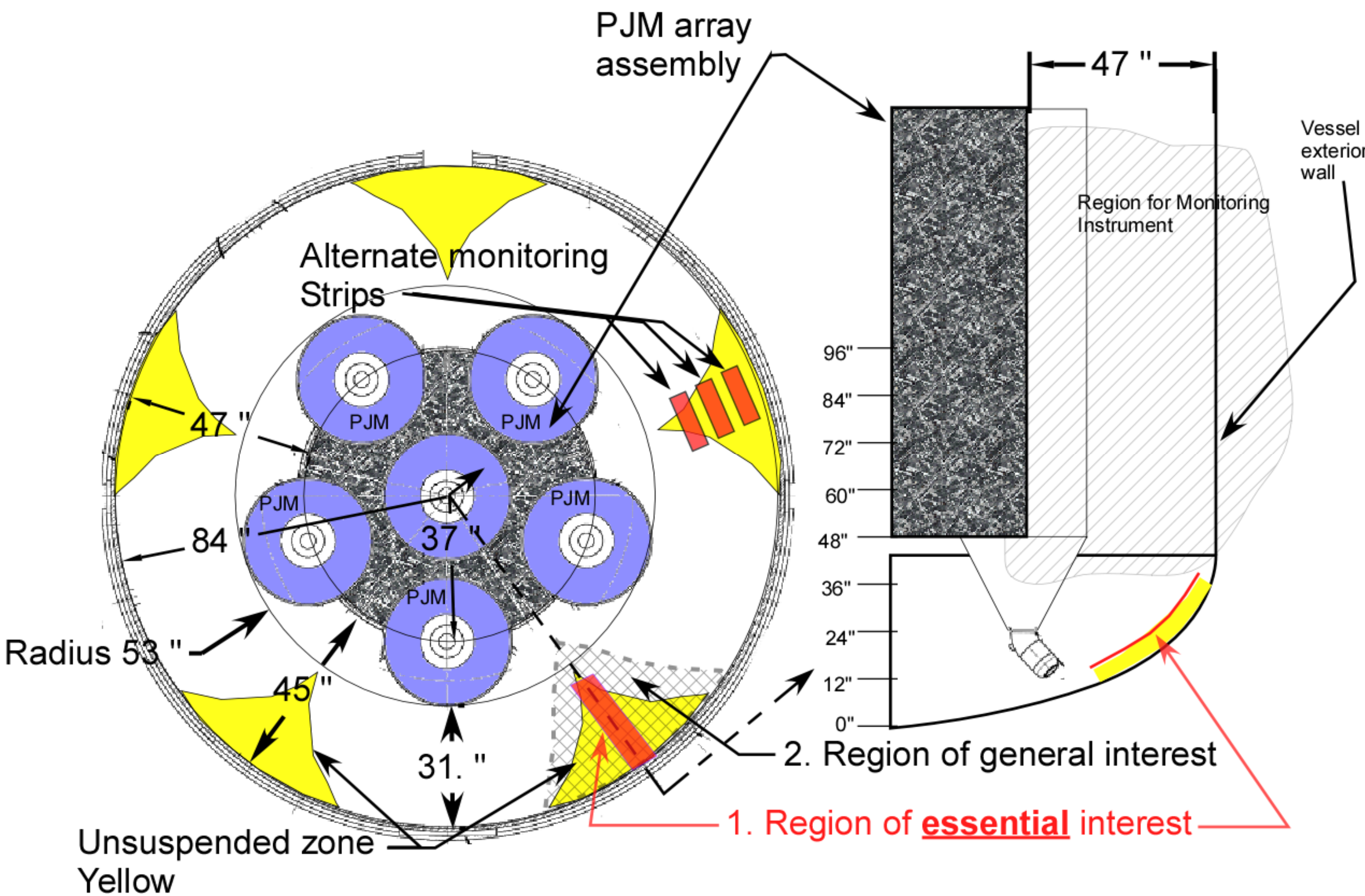
- # Sonar Description
  - It is an oil-filled device with no user serviceable parts within the unit.
  - Made of:
    - Hard Anodised Aluminium,
    - Polyurethane
    - Delrin

- Sonar Description
  - No semiconductors are incorporated into the device so that it may be deployed in areas of significant radioactivity.

- Sonar Description
  - Connected to an electronic processing unit by a 30m underwater umbilical cable.

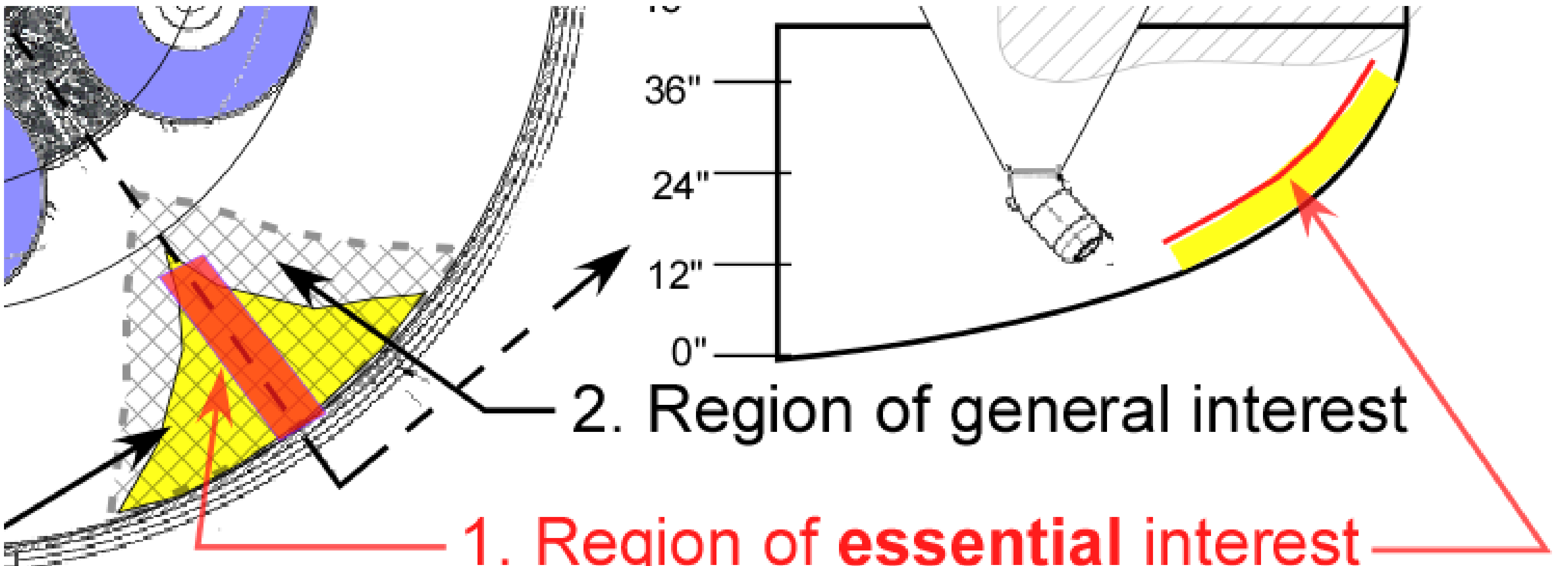
Test Plan

- Pulse jet mixing operations are conducted in Hanford's conditioning tanks. The PJM operations are used to prevent the slurry solidification at the bottom of these tanks.



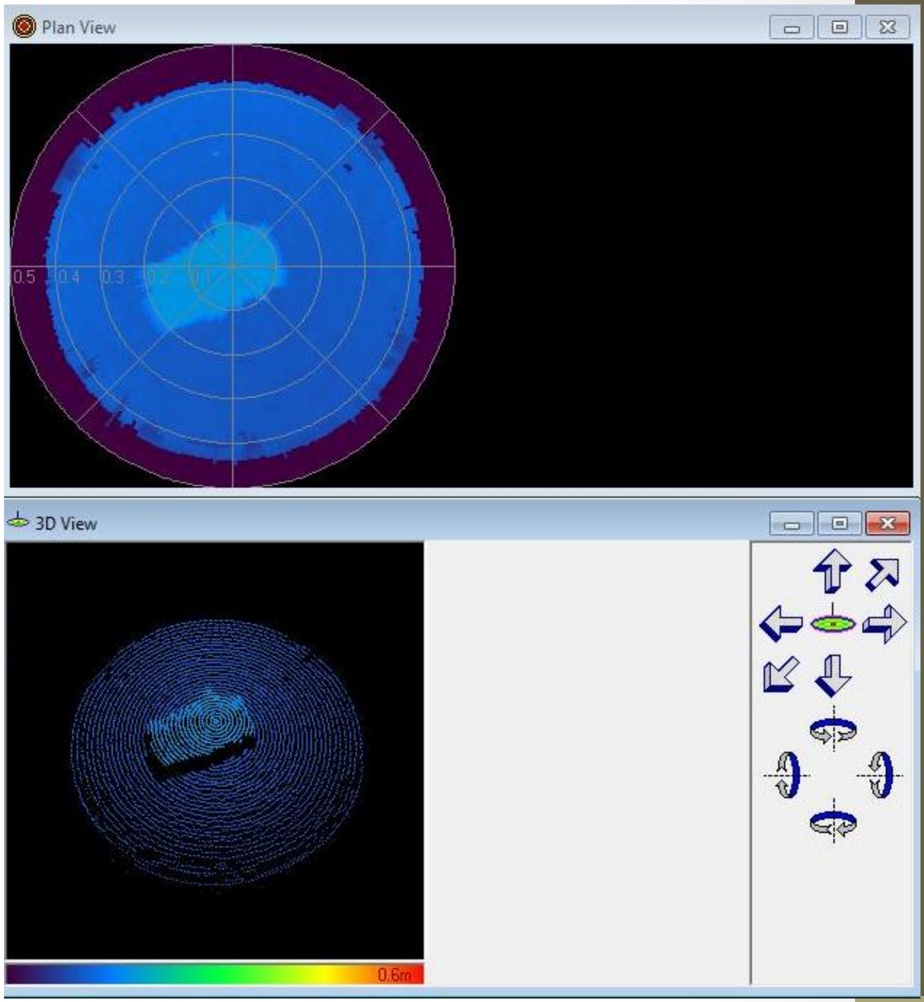
Test Plan

- Overlapping areas minimally affected by the PJM's are assumed to build up with waste over time along the designated areas of interest displayed in the figures on the right.



Benchmark Testing

- SLIM is expected to image the areas of interest within these conditioning tanks under an allotted time (< 20 seconds). SLIM can take anywhere from approximately 12 seconds to 12 minutes and 30 seconds to run a scan depending on desired data quality and 3D image resolution.



Primary system parameters:

1. Swath arc – 2-D field of view of sonar; for 30° swath arc; images +/- 15° from sonar axis; setting of 30°, 60°, 90°, 120°, 150°, or 180°
2. Swath motor step size – angle between sonar pings along the 2-D swath arc; setting varies from 0.9° to 9°
3. Rotate motor step size – the rotation angle between consecutive 2-D swaths, setting varies from 0.9° to 9°

Response variables:

- Total time to collect data to image settled solids floor area
- Accuracy of volume of settled solids

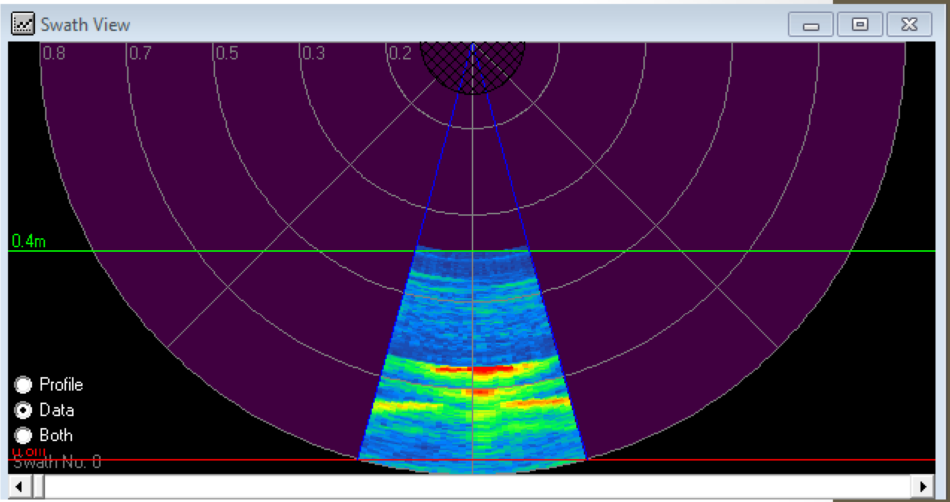
Factors on the sonar device that effect time:

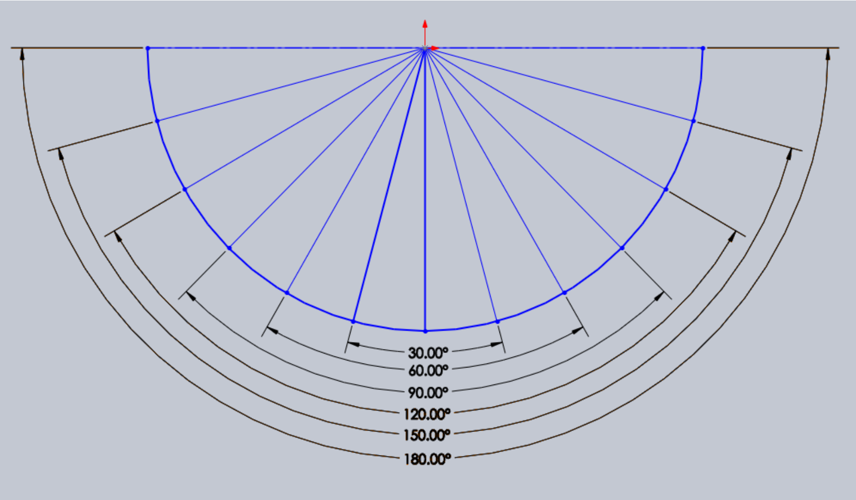
1.) Swath Arc Angles (30°, 60°, 90°, 120°, 150°, 180°)

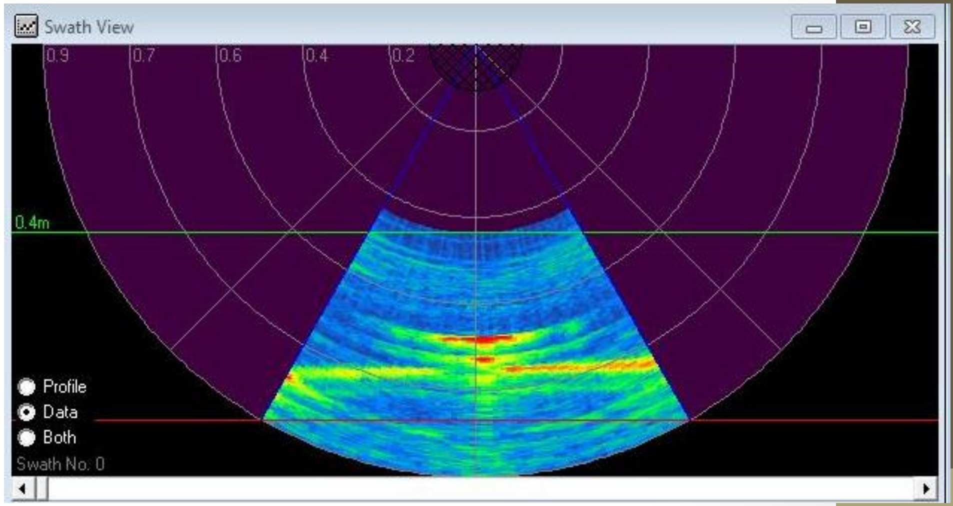
- Depending on the area beneath the device the user would like to image, one can set the require angle. Due to the increase in angle size, Swath Arc Angle effects time extensively. At the same settings, the time between a swath arc of 30° and 180° varies approximately by a factor of 6.

Time (minutes)	Rotate Step Setting	Swath Step Setting	Swath Arc	Tx	Detect Threshold	Freq.
~1:56 (116 Seconds)	1	1	30°	10	80	25
~12:26 (746 Seconds)	1	1	180°	10	80	25

Displayed Setting of Swath Arc is shown below.[30, 60, 90°, 120°, 150°, 180°. The Example on the right is for 30° Swath Arc and the one at the bottom right is for 60°.







Factors on the sonar device that effect time:

2.) Rotate Motor Step Size

- This setting specifies how many discrete .9° rotation motor steps are performed after each swath has been gathered by the sonar. For the finest detail, this setting should be set to one. By increasing this setting (max 10), the dataset capture speed will increase and the dataset size will be reduced.

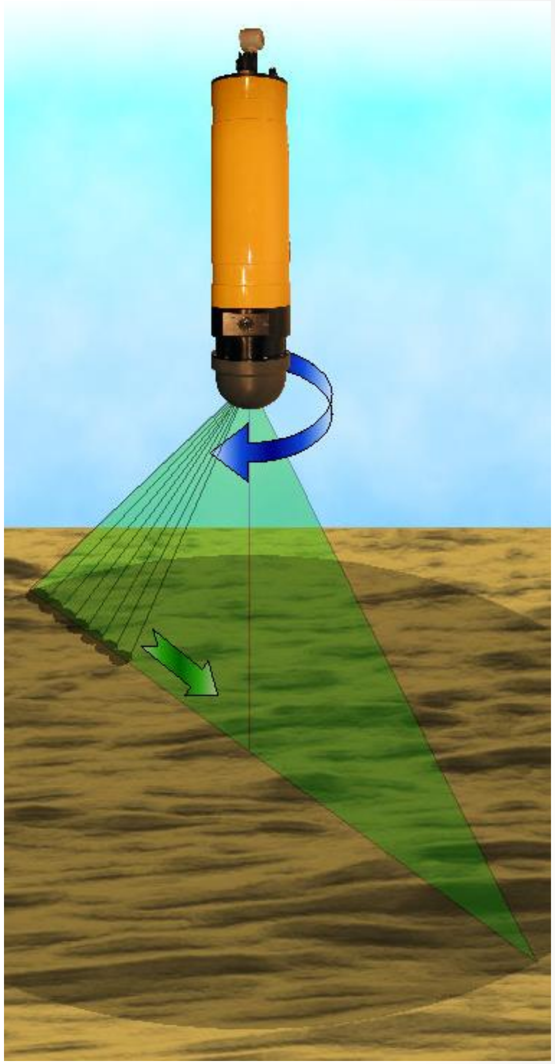
Number of Swaths at a 30° swath arc based on rotate motor step size setting	
# of 2D Swaths (at 30°)	Rotate Setting (Intervals of Image)
0-199(199) = 200 Swaths	1
0-199(198) = 100 Swaths	2
0-199(198) = 66 Swaths	3
0-199(196) = 50 Swaths	4
0-199(195) = 40 Swaths	5
0-199(198) = 33 Swaths	6
0-199(196) = 28 Swaths	7
0-199(192) = 25 Swaths	8
0-199(198) = 22 Swaths	9
0-199(190) = 20 swaths	10

$$\frac{200}{x} = y$$

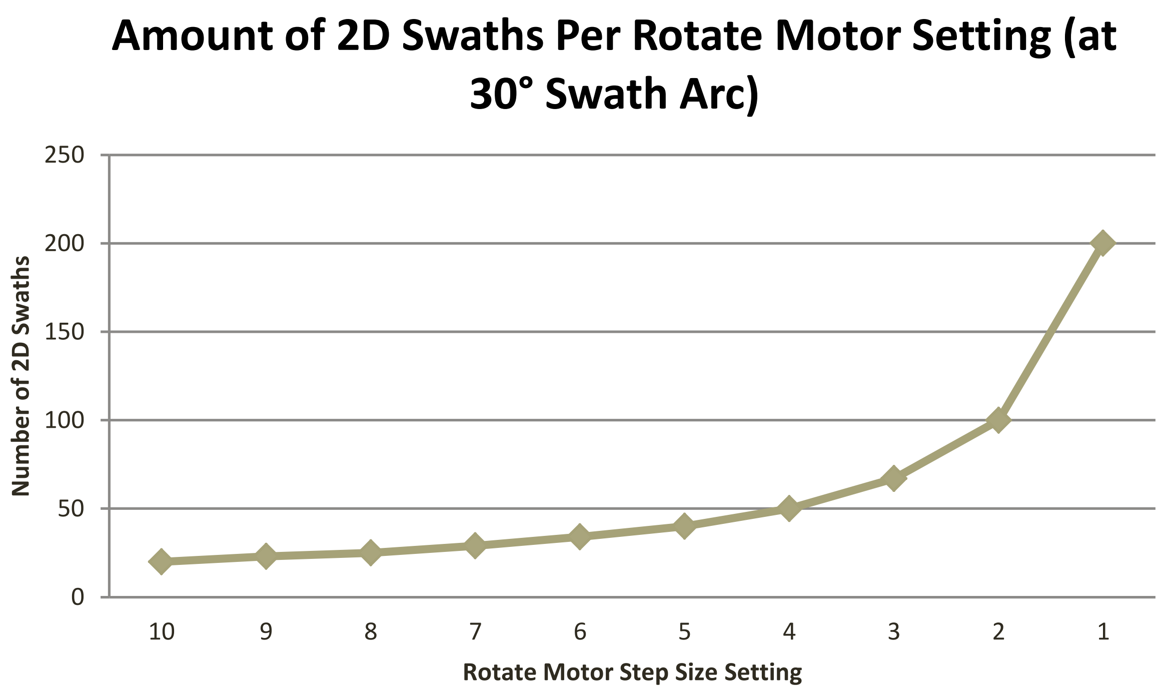
Where x = step setting, y = number of swaths, 200 is max number of swaths

Factors on the sonar device that effect time: 2.) Rotate Motor Step Size

- The rotate motor step rotates the device clockwise along a vertical axis. Depending on the specified setting for the particular scan, this defines the distance it will rotate to record its next horizontal swath.



Benchmark Testing



Factors on the sonar device that effect time:

3.) Swath Motor Step Size

- This setting specifies how many discrete 0.9° tilt motor steps are performed for each "ping" of the sonar. For the finest detail the Swath Step Size should be set to 1, but by increasing this setting the scan speed may be increased and the dataset size reduced.

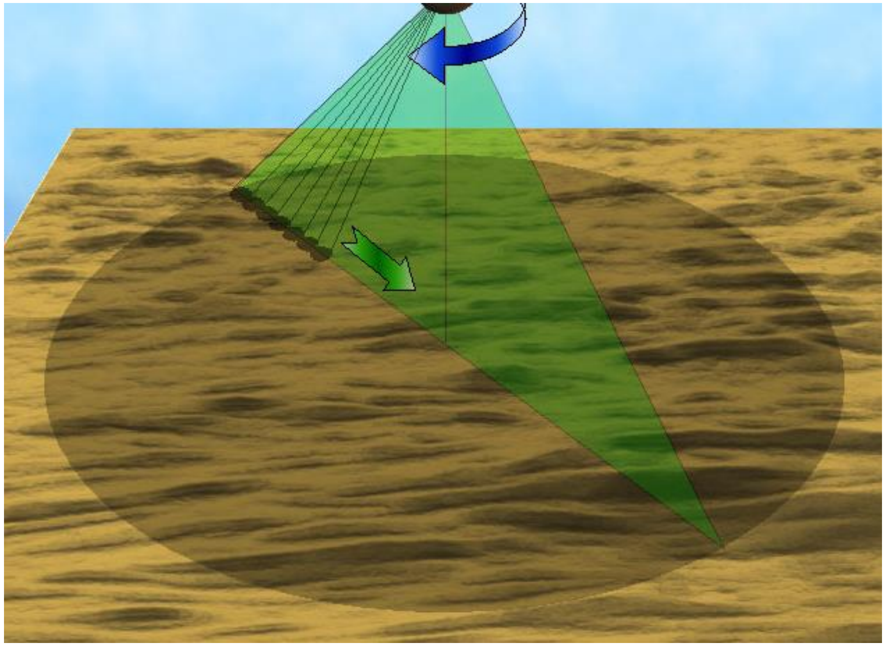
Number of ping at a 30° swatch arc based on swath motor step size setting	
# of pings (at 30°)	Swath Setting
33	1
17	2
11	3
8	4
6	5
5	6
4	7
4	8
3	9
3	10

$$\frac{\Phi}{(.9)\times(x)} = y$$

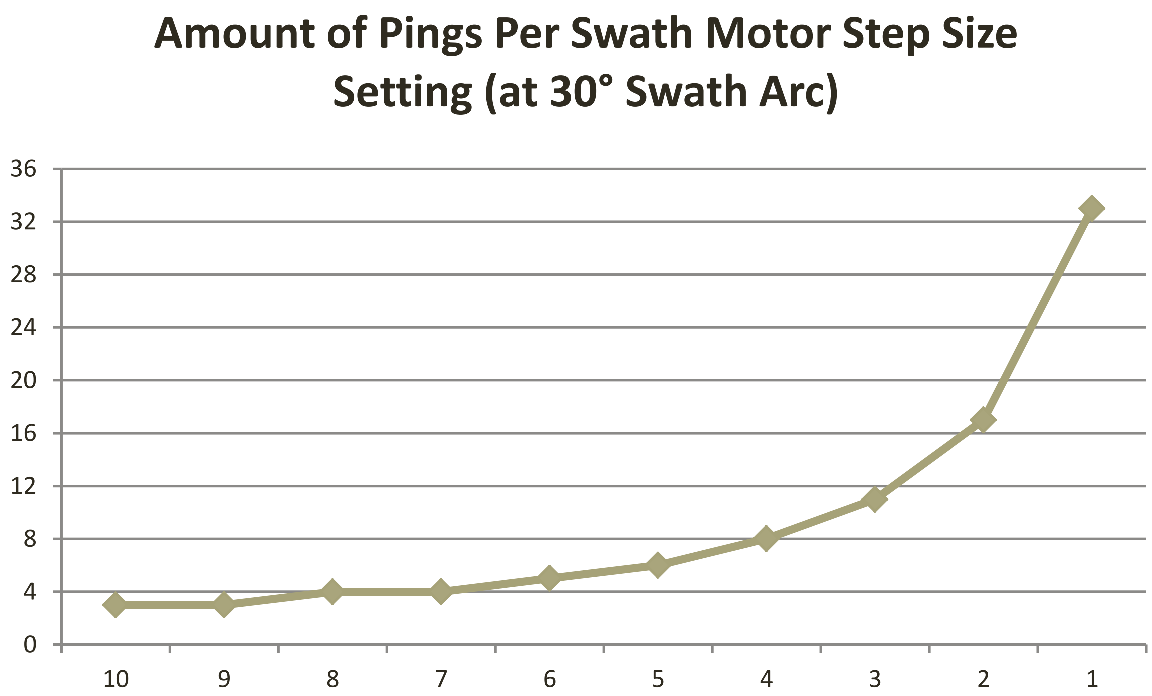
Where Φ = Swath Arc, x = Swath Motor Step Setting, y = Number of Pings at

Factors on the sonar device that effect time: 3.) Swath Motor Step Size

- This motor moves the device along a horizontal plan between each rotate motor step size. The higher the setting, the higher number of pings within each horizontal sweep.

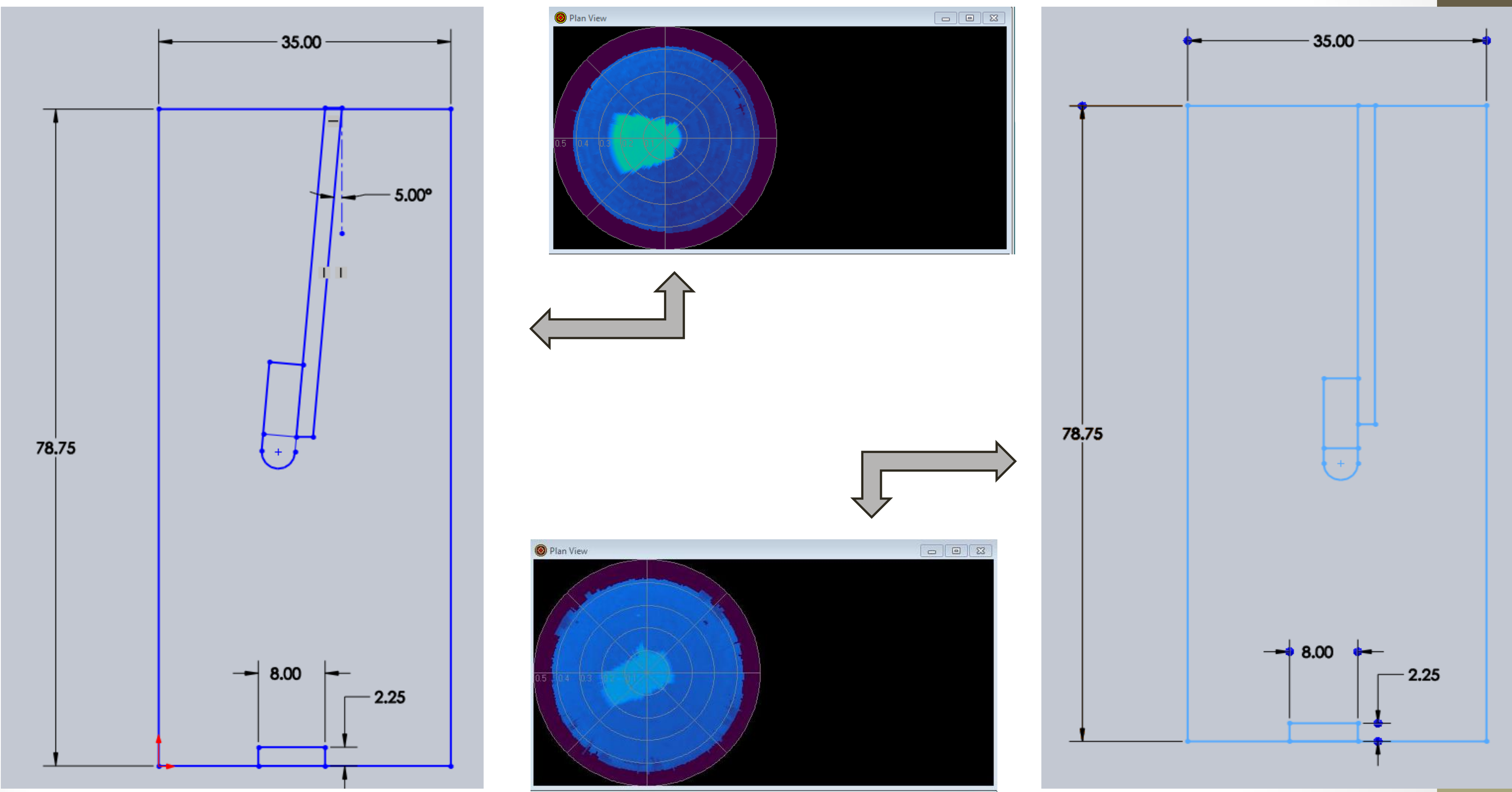


Benchmark Testing



Limitations:

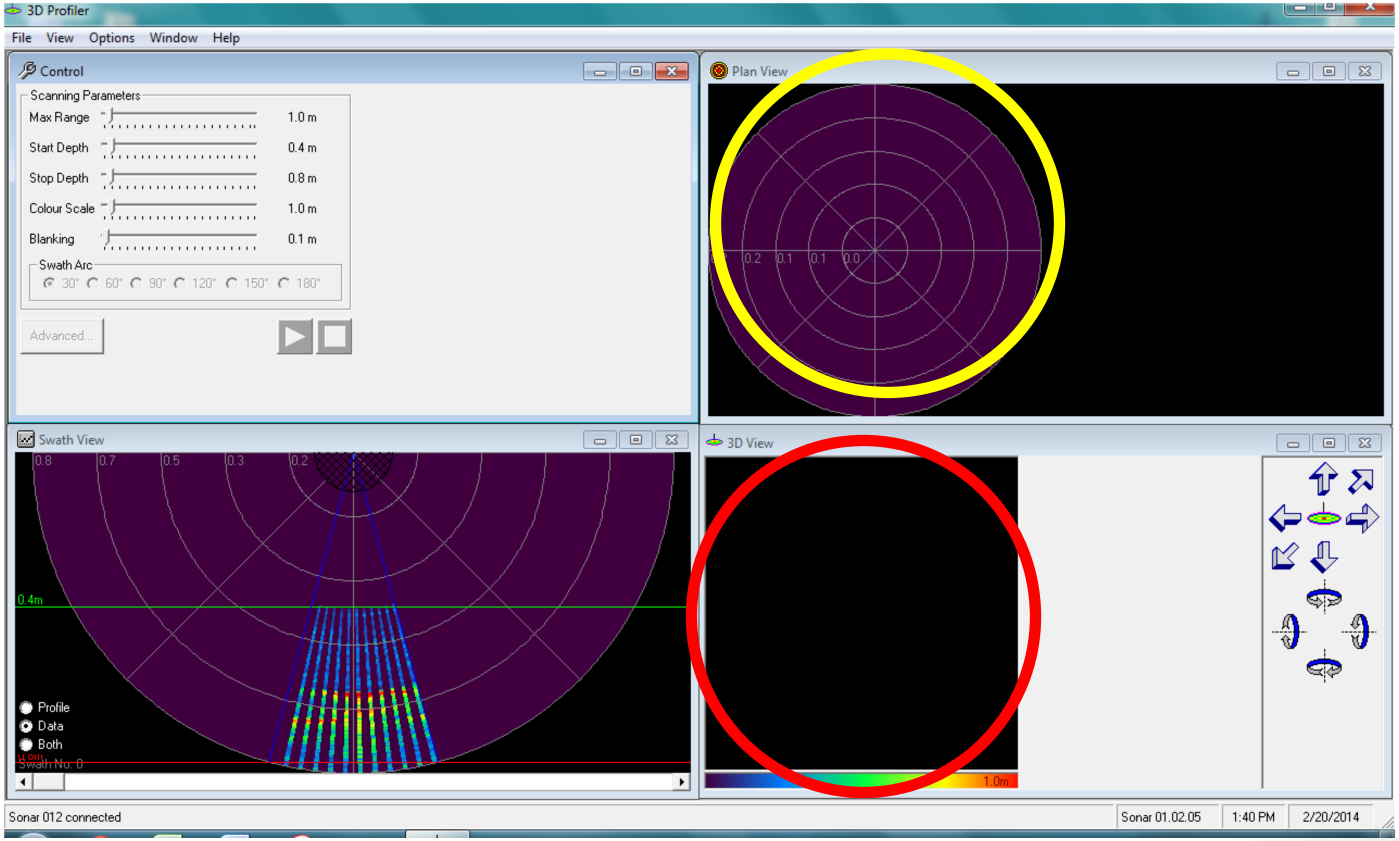
- Some limitations for the device include the angle of implementations into the tanks. As seen below, an offset of ~5° can produce a distorted images.



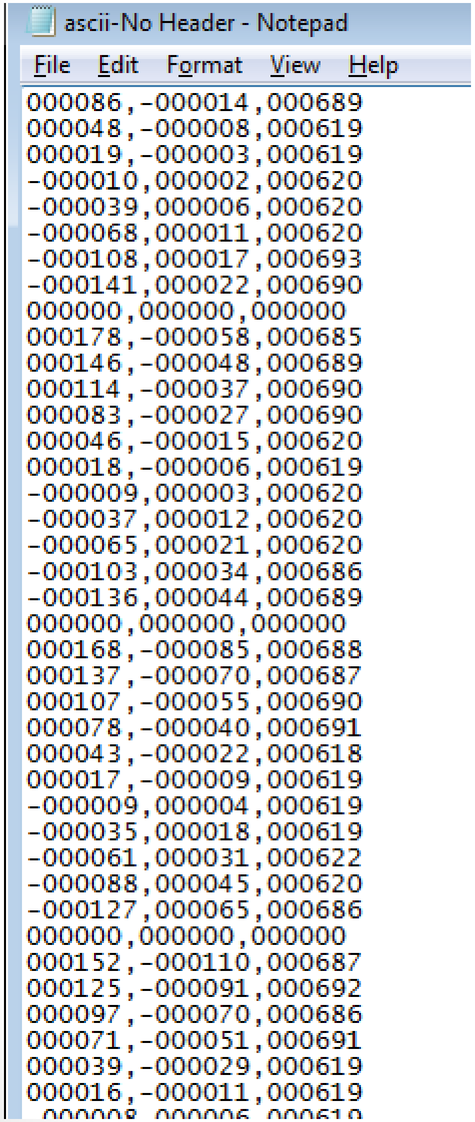
Limitations:

- A secondary limitation discovered with the technology is that under very low settings, the 3D profiler provided by the manufacturer does not provide any visual imaging.
- On the next slide we see an example from a matrix of trials (Trial 6, lowest quality settings of matrix) of the user interface of the technology along with a black screen in the “3D View” (In Red) section and a blank image of the “Plan View” (In Yellow).

Time of Scans While Varying Settings				
Trial	Time	Swath Motor Step	Rotate Motor Step	Swath Arc
1	~45 Seconds	1	3	30
2	~24 Seconds	1	7	30
3	~19 Seconds	1	10	30
4	~32 Seconds	3	3	30
5	~19 Seconds	3	7	30
6	**~15 Seconds**	**3**	**10**	**30**



Using the output ASCII code…



ascii-No Header - Notepad

File Edit Format View Help

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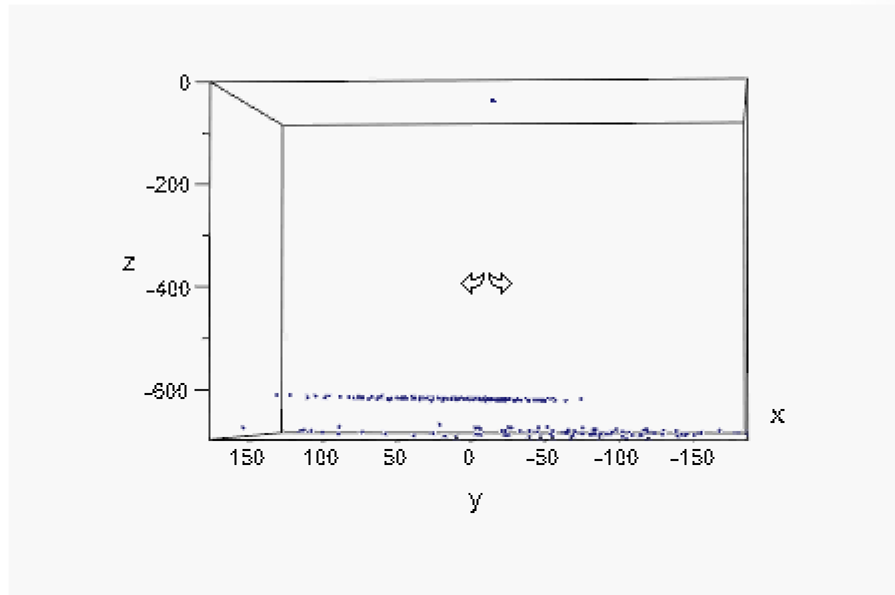
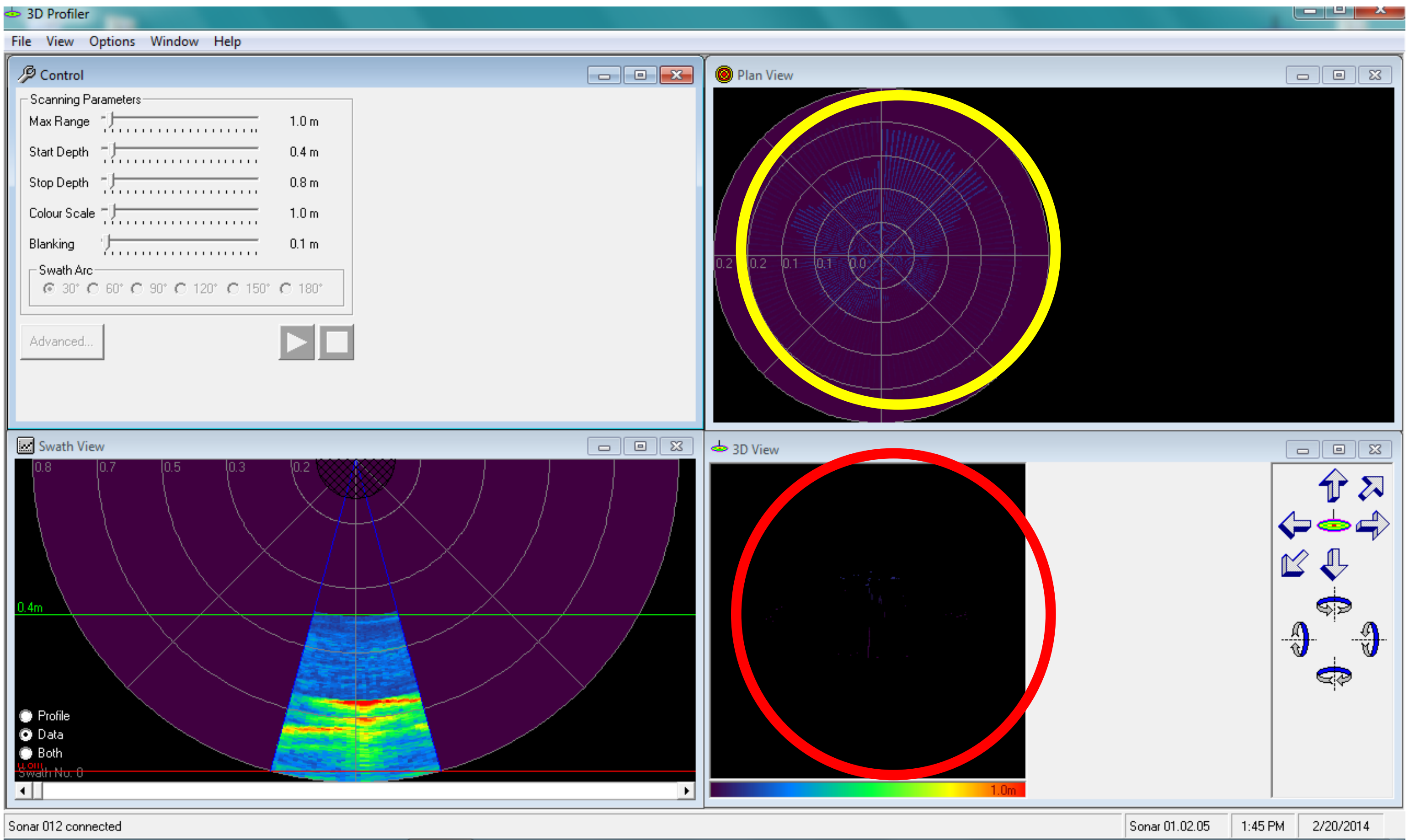
Using a MatLab 3D Plotting Command…



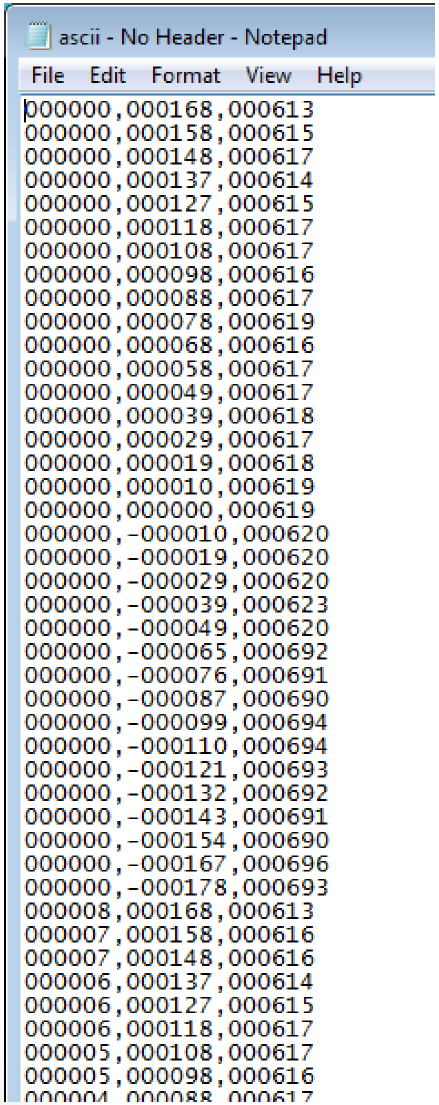
Limitations:

- Even on a relatively higher quality a similar output is still encountered.
    - On the next slide we see an example from a matrix of trials (Trial 1, relatively “high” quality) . The user interface still displays a black screen for the “3D View” (circled in red) due to the lack of data.
    - On the other hand, the plan view now shows some data in the “Plan View” (circled in yellow).

Trial	Time	Swath Motor Step	Rotate Motor Step	Swath Arc
1	**~45 Seconds**	**1**	**3**	**30**
2	~24 Seconds	1	7	30
3	~19 Seconds	1	10	30
4	~32 Seconds	3	3	30
5	~19 Seconds	3	7	30
6	~15 Seconds	3	10	30



Using the output ASCII code…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File Edit Format View Help

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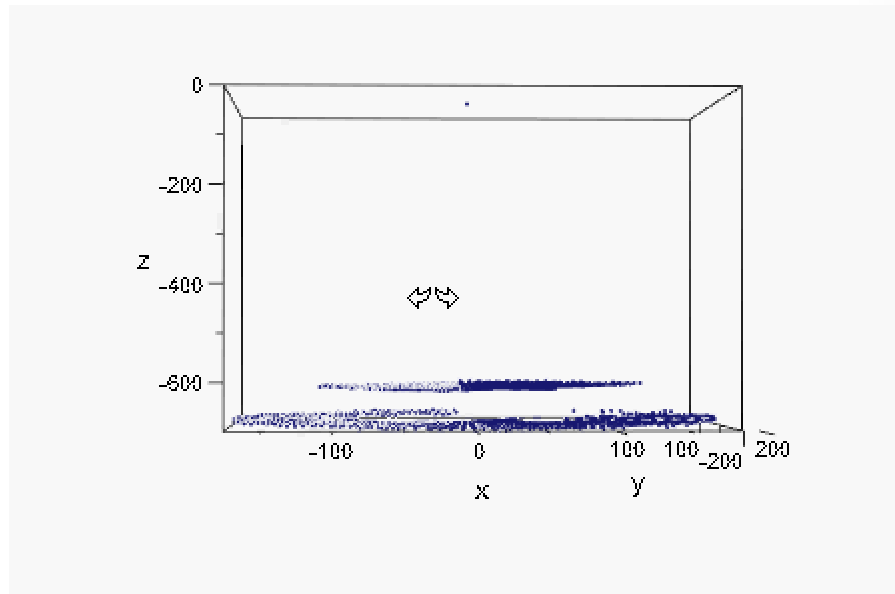
Using a MatLab 3D Plotting Command…



Path Forward

- The default 3D profiler provided by the manufacturer does not image low quantities of acquired data efficiently. For this reason, a secondary ASCII modeling program can be used along with the “raw” data provided by each scan in order provide higher resolution images.
- Future system calibration such as the calculation of the speed of sound in regards to fluid salinity and temperature will enable higher accuracy of acquired data and increased 3D image resolution enabling the estimate of volume of solids within each scan.

Pictures and Activities

Hanford Internship

Sitting in the control room of Hanford B-Reactor.

Taking a picture at the Office of River Protection in Richland, Washington with other Interns from URS.

2013 Poster Competition

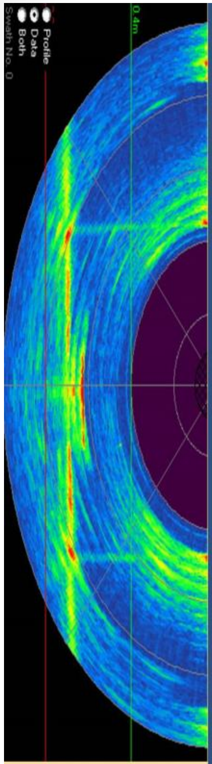
Presenting to Judge : Gloria Dingeldein

Presenting to Judge : Ines Triay

Presenti

nting to Judge : David Roelant

Waste Management Symposium 2014 Poster



Residual Waste Detection in HLW Tanks

by Dayron Chigin, DOE Fellow

David Roelant, Ph.D. and Dwayne McDaniel, Ph.D., P.E.

ABSTRACT

This research uses commercial sonar technology to monitor residual waste in the United States Department of Energy's (DOE) Hanford Site high-level-waste staging tanks, with primary focus on the detection and imaging of the settled solids at specified areas of interest along the tank surface within a limited amount of time.

BACKGROUND

High-level waste is generated at the US-DOE Hanford Site as a by-product from the processing of nuclear materials.

- Waste is currently stored in 177 underground carbon-steel waste tanks.
- Pulse jet mixers (PJM) are often used to break loose and suspend the solids that have settled at the bottom of the tanks. A typical tank can have six to eight pulse tubes.
- There is a need for instrumentation capable of detecting the clearing of or the failure to clear residual waste at the bottom of each tank where the impingement of the two adjacent wall jets converges, also known as "Region 1" (Figure 4).
- To meet this need, FIU's Solid Liquid Interface Monitor will be used.

Figure 1 (Right) : Solid Liquid Interface Monitor(SLIM)

PAST IMPLEMENTATION

- SLIM (Figure 1) was originally developed to map the sludge/supernate interface within the US-DOE Hanford Site's HLW tanks.
- It improved the methods for mapping solid layers, detecting slow settling solid depth and monitoring the tank filling process.

Figure 2 : SLIM's deploying mechanism for 75ft tanks

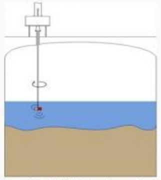


Figure 3 : SLIM"s deployment plan.

MOTIVATION

- SLIM must be capable of recording dynamic movements in Region 1 (red strip) zone between each PJM cycle.

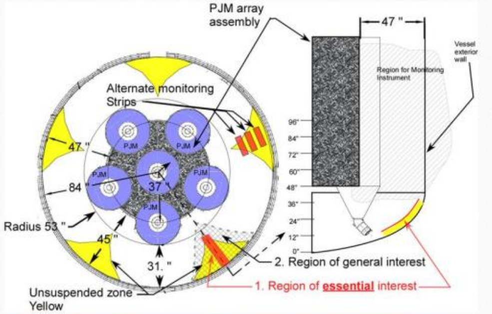
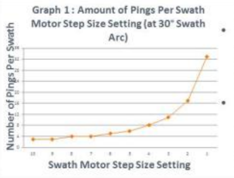
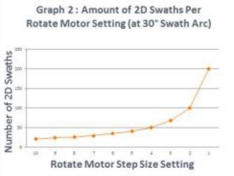


Figure 4 : Technical drawing of mock tank and predicted static areas unaffected by PJM

- The technology will have a limited amount of time (<30secs) to conduct its reading and produce as high resolution as possible.
- SLIM's initial design criteria was not intended to be time-limited.

BENCHMARK TESTING





- Initial benchmark testing was conducted.
- Multiple scans done in order to compile a matrix comprising of time duration and quality of difference scans while varying multiple settings on the device.
- Varied
  - Swath Arc (Set to 30° - 180° in intervals of 30°)
  - Swath Motor Step Size (1-10, 1=highest, 10=lowest, interval of 1)
  - Rotate Motor Step Size (1-10, 1=highest, 10=lowest, interval of 1)

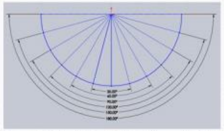


Figure 5 : Swath Arc Setting Range for SLIM

DEVICE OPERATIONS

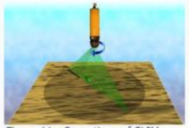


Figure 11 : Operations of SLIM

- SLIM is a dual-axis mechanically rotating sonar.
- Consists of:
  - Acoustic transducer
  - Rotation motor with gearbox
  - Tilt motor
  - Position reference sensor
  - Pressure balancing mechanisms
- Gathers a swath of data in the horizontal plane.
- Rotates transducer through programmed angle around vertical axis.
- Oil-filled device; no user serviceable parts; no semiconductors.
- Hard Anodized Aluminum and Polyurethane Delrin.
- May be deployed in areas of significant radioactivity.

RESULTS

At its highest settings for a 30° Swath Arc (seen in Table 1), SLIM takes approximately 2 minutes to provide an entire 360° scan as seen in the images below. For simplicity, we have placed a typical brick within the tank for initial testing. At the highest resolution setting (Trial 1), SLIM provides each swath with the quality seen in Figure 6. SLIM then rotates continuously, taking various swaths until it is able to compile a point cloud as seen in Figure 7. The 3D Profiler then applies a meshing algorithm to the point cloud as seen in Figure 8.

Table 1 : Time Duration for Varying Settings at 30° Swath Arc

Time	Trial	Rotation	Swath	Arc
~1:56	1	1	1	30
~1.55	2	1	1	30
~1.55	3	1	1	30
~1.57	4	1	1	30
~1.55	5	1	1	30
~32 s	6	3	3	30
~12 s	7	10	10	30
~ 13 s	8	9	9	30
~ 15 s	9	8	8	30
~ 15 s	10	7	7	30
~ 17 s	11	6	6	30
~ 19 s	12	5	5	30
~ 24 s	13	4	4	30
~ 48 s	14	2	2	30

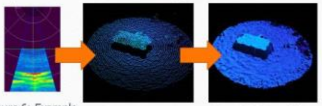


Figure 6: Example of High Quality Swath

Figure 7: Example of Swath

Figure 8: Example of Swath

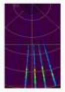


Figure 9 (Right): Example of Low Quality Swath

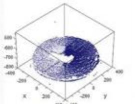


Figure 10 (Right): 3D point grid developed in MATLAB using output ASCII Code from low quality scan.

In order to reduce the amount of time, all settings were decreased to their minimal state. An example of quality for each individual swath at these settings is seen in Figure 9. The low settings provide insufficient data for the manufacturer's 3D profiler to compile a visible point cloud and much less to allow the meshing algorithm to work properly.

FUTURE WORK

- Production of an accurate 3D image using output ASCII data (Figure 10).
- Along with a third party mapping software a secondary mapping algorithm will be produced.
- Estimation of volumes for objects imaged.

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FIU | Applied Research Center
FLORIDA INTERNATIONAL UNIVERSITY

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