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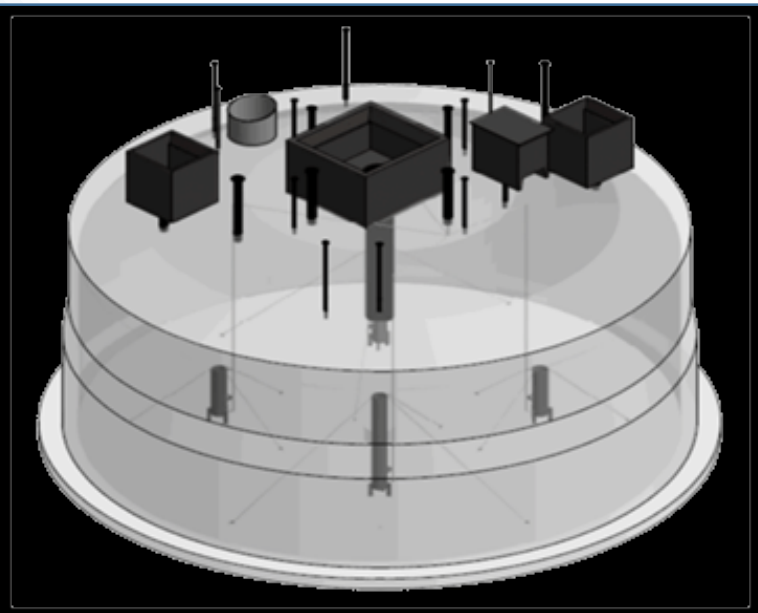

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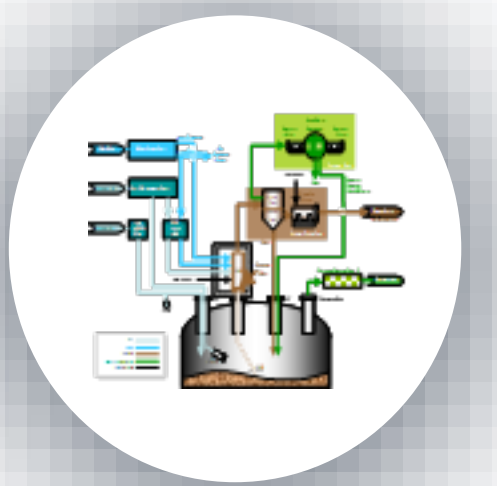
Tank Retrieval Development

October 2018

The purpose of this program: Support completing tank farms retrieval goals

Mission Need*: A technology is needed for retrieving solids from Hanford tanks that contain primarily solids (sludge, salt cake, and hard pan).*

- Initial focus is retrieving from single shell tanks in A and AX Farm
- Ultimate goal of developing a tool box of viable retrieval techniques for various waste forms, chemistry, and physical properties



CURRENT TECHNOLOGY NEEDS UNDER ASSESSMENT

Standard Sluicer

Equipment Type
- Articulating/Limited

Tank Application
- Sound Integrity (below level of waste)

Deployable Technologies
- Sluicing, Dissolution

Waste Types
- Sludge, salt cake, and hard heel wastes

Installation / Operation
- Limited Reach
- Pairs Deployed (typically)
- Requires 12-inch Risers

Use
- 8 of 18 retrievals
- S-112 and C-Farm

MAR-S Sluicer

Equipment Type
- Articulating long reach

Tank Application
- Sound Integrity (below level of waste)

Deployable Technologies
- Sluicing, High Pressure Water, Dissolution

Waste Types
- Sludge, salt cake, and hard heel wastes

Installation / Operation
- 55-inch center dome cut
- Complexity limits use

Use
- 1 of 18 retrievals (C-107)

CURRENT TECHNOLOGY NEEDS UNDER ASSESSMENT

MAR-V Vacuum

Equipment Type
- Articulating long reach with in-tank vacuum system

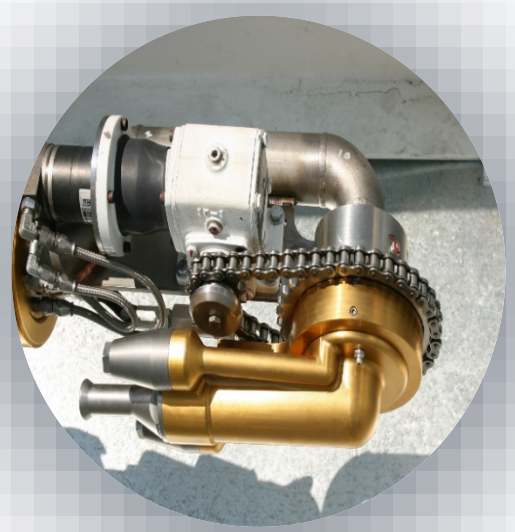
Tank Application
- Leaking/potential leaking tanks

Deployable Technologies
- Vacuum Sluicing, High Pressure Water, Dissolution

Waste Types
- Sludge, salt cake, and hard heel wastes

Installation / Operation
- 55-inch center dome cut
- Complexity limits use

Use
- 1 of 18 retrievals (C-105)



Extended Reach Sluicer

Equipment Type
- Articulating, long-reach

Tank Application
- Sound Integrity (below level of waste)

Deployable Technologies
- Sluicing, High Pressure Water, Dissolution

Waste Types
- Sludge, salt cake, and hard heel wastes

Installation / Operation
- Pairs Deployed (typically)
- Requires 12-inch Risers

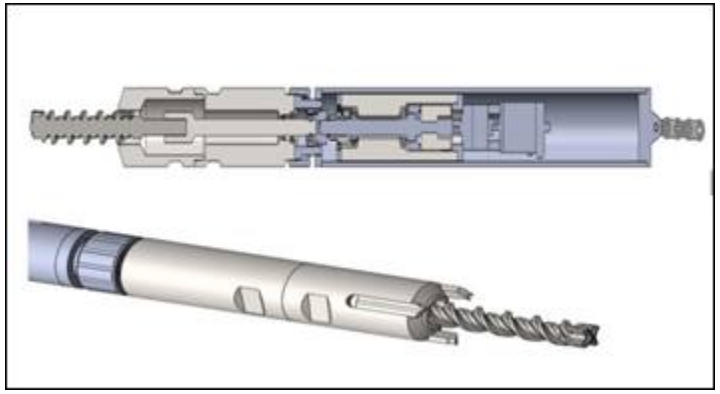
Use
- 6 of 18 retrievals
- C-Farm and AY-102
- Selected for A/AX Farm

CURRENT TECHNOLOGY NEEDS UNDER ASSESSMENT

Current Waste Tank Retrieval activities under assessment:

- Rotary Core Dome Cutter
  - ❖ Allow up to six foot opening for equipment
- Enhanced Pumps and Sluicers
  - ❖ Working Extended reach sluicing system (ERSS) vendor to improve existing equipment
  - ❖ Conducting market survey for other vendors
- Laser system to better assess initial and post-retrieval volumes
- Auger Sampler characterization and closure samples
- Considering development of a tool arm aid in-tank operations
- Alternate Retrieval
  - ❖ Mechanical Waste Gathering System (MWGS)
  - ❖ Hanford Waste End Effector (HWEE)

Rotary Core Dome Cutter



Auger Sampler Concept

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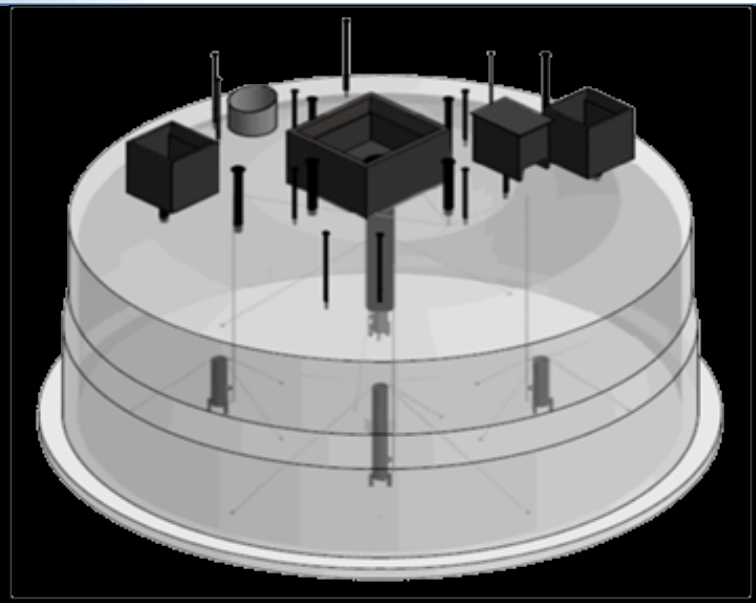

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ALTERNATE RETRIEVAL TECHNOLOGY DEVELOPMENT, MECHANICAL WASTE GATHERING SYSTEM (MWGS)

October 2018

MWGS PHASE I: BACKGROUND

- Down selection process determined end effector and deployment configuration that met the criteria.
- Selected equipment that was successfully used in the mining and fishing industries.

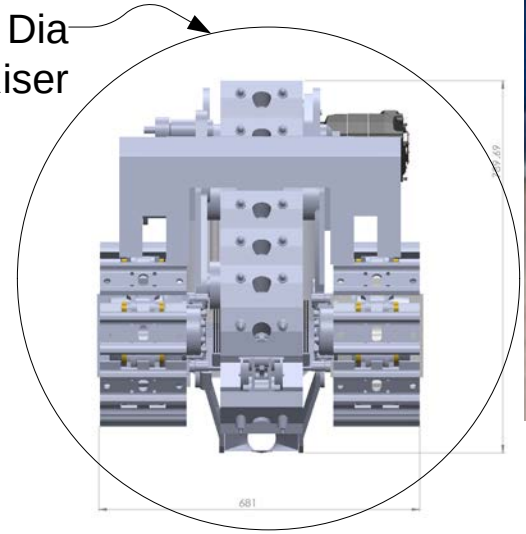
Technologies		Does system avoid water introduction?		Can system withstand large reaction forces?		Is system robust?		Is system compact (fits through a 42-in. riser)?	
End Effector Type	Deployment Configuration	Yes	No	Yes	No	Yes	No	Yes	No
Mechanical Cutting		✓		✓		✓		✓	
Tool Kit (Brokk®)		✓		✓		✓			✓
Slucing			✓	✓		✓		✓	
	Compact ROV	n/a	n/a	✓		✓		✓	
	Large ROV	n/a	n/a	✓		✓			✓
	Mast System	n/a	n/a		✓	?	?	✓	
	Folding ROV	n/a	n/a	✓			✓	✓	

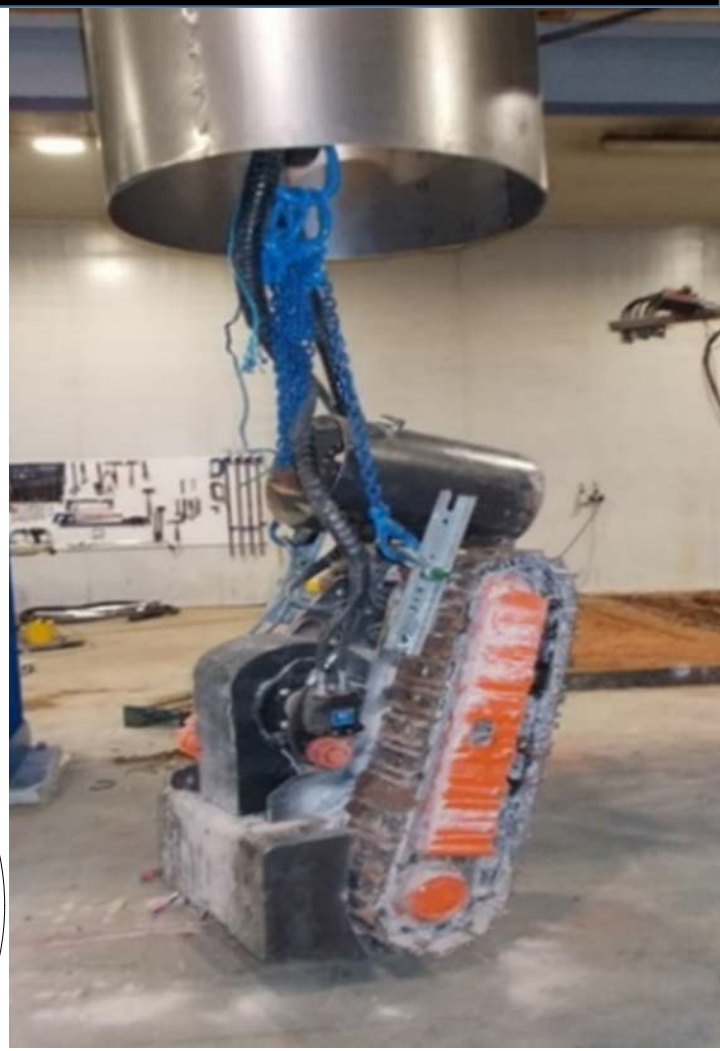
ROV= remotely operated vehicle.

MWGS PHASE I: PROOF-OF-PRINCIPLE DEMONSTRATION

Phase I - Proof-of-Principle Demonstration (FY17 and FY18)

- Working prototype system demonstrated a Remote Operated Vehicle (ROV) to:
  - Break up tough asphalt and unreinforced concrete
  - Vacuum gathered the resulting material into a nearby vessel to be sluiced out of the tank.
  - Sandstone (60MPa compressive strength) was also successfully mobilized.
- This testing did not address tank deployment
- Additional development activities identified:
  - Rotocutter speed optimization
  - Tank bottom sensor integration
  - Vacuum and sluicing system enhancements
  - Human machine interface (HMI) modifications



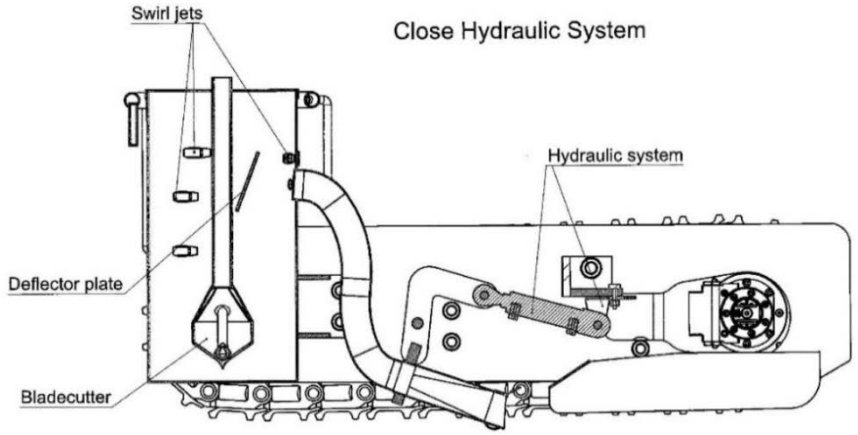


MWGS PHASE II: PROTOTYPE SYSTEM TESTING

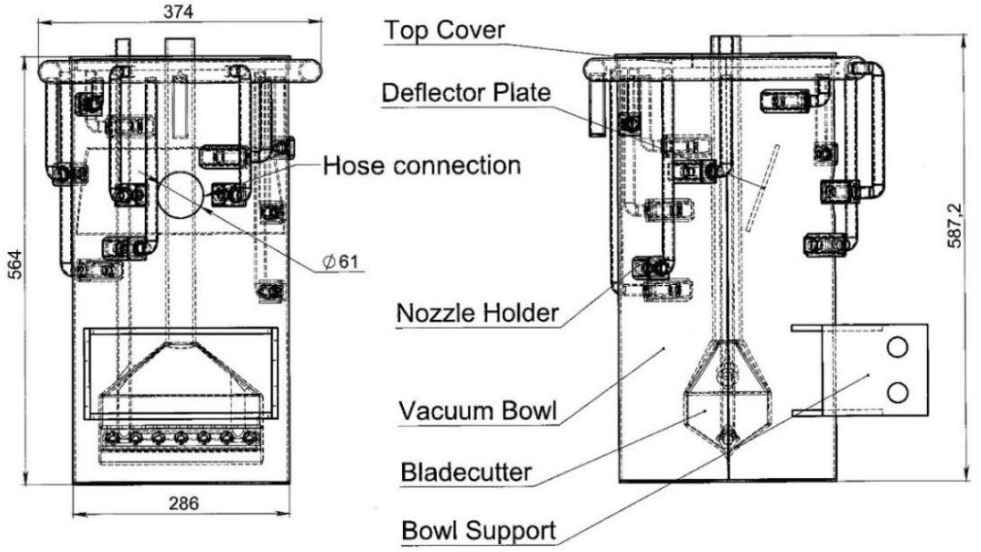
- Mechanical Cutting
  - ❖ Rotocutter and vacuum system were tested in separate ROVs to improve technology elements.
  - ❖ Evaluated capability of MWGS to break up representative substrate simulants.
  - ❖ Performed endurance testing to evaluate tooth wear.
  - ❖ Two metal detecting sensors were tested to ensure that the tank floor is not compromised during operation (see figure).
- Control System Development
  - ❖ Demonstrated ability to remotely operate MWGS via a range of closed circuit television (CCTV) cameras and remote controls.
  - ❖ The Human Machine Interface (HMI) was modified to display when either sensor detected metal.

Figure shows Rotocutter at the start of testing, showing both metal detectors with protective nylon cuffs.

PHASE II: NEW VACUUM ROV SYSTEM TESTING

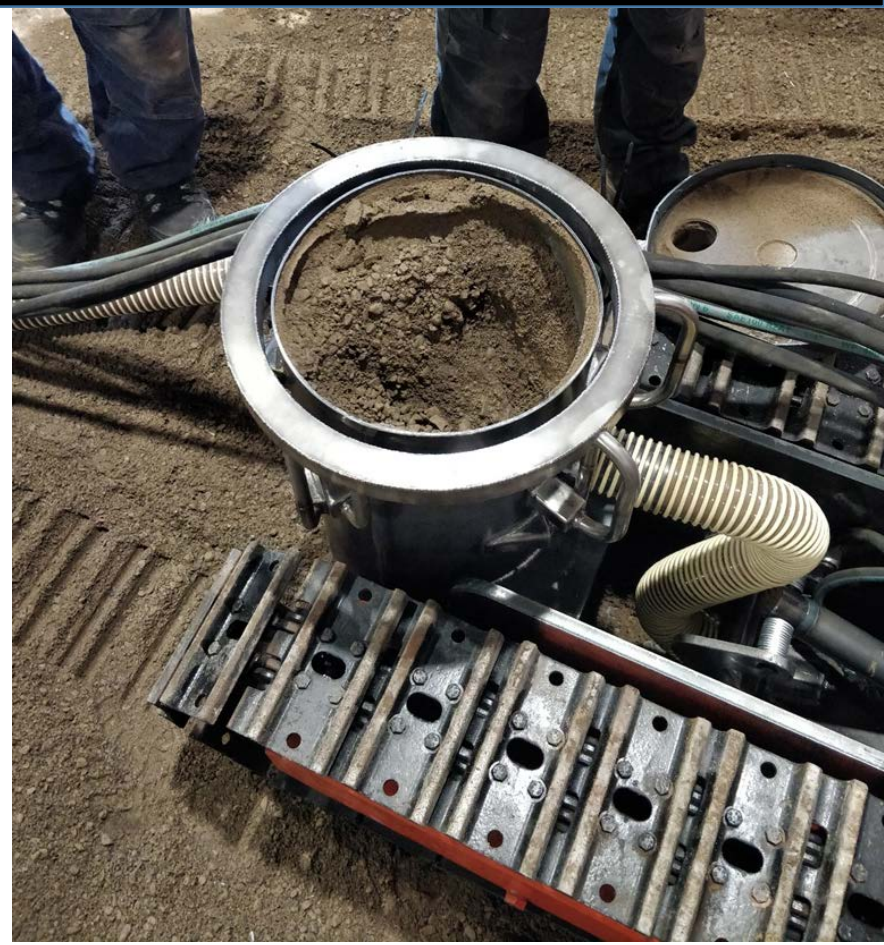


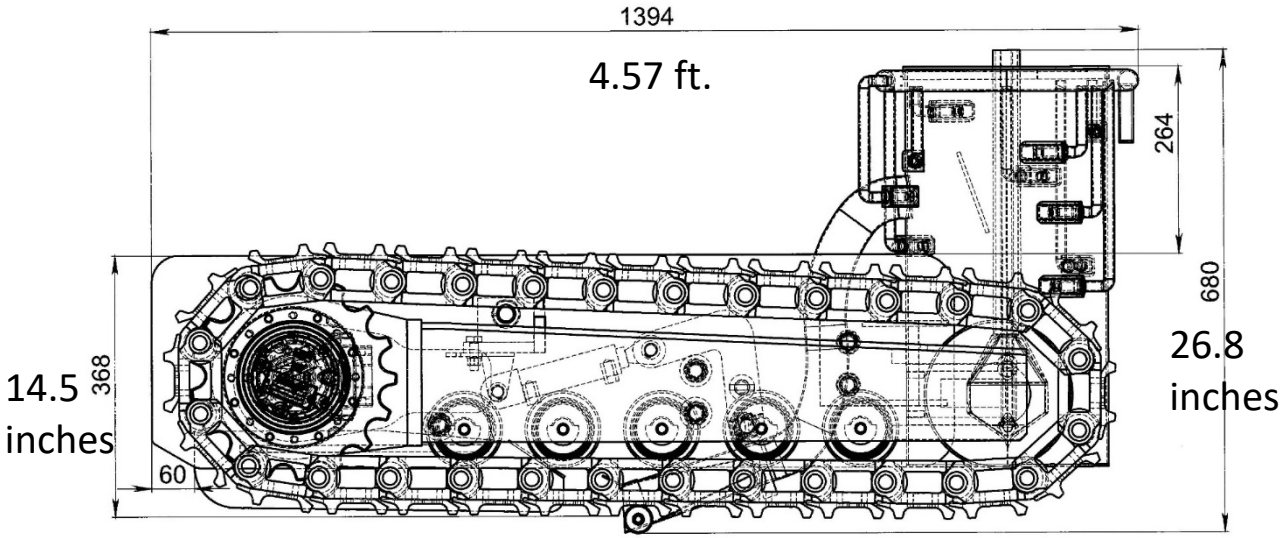
- Vacuum and Sluicing System Improvements
  - ❖ Enhanced vacuum and sluicing systems for greater efficiency.
  - ❖ Tested vacuum and sluicing systems in separate ROVs for long runs with minimal human intervention.
  - ❖ Vacuum material recovery improved from 50% to 80% by weight on a single pass.
  - ❖ Improved sluicing conveyance of recovered material was successful with particle sizes up to 20mm (0.78 inches).



PHASE III: FUTURE ENHANCEMENTS AND TESTING FOR TANK DEPLOYMENT READINESS

- Recombine rotocutter and vacuum/sluice ROVs in to single ROV.
- Optimize rotocutter effectiveness.
- Vacuum collection system improvements (avoid/remove vacuum blockages in the nozzle and pipe).
- Improve conveyance sluicing system and develop hydraulic forward pumping system to pump slurry up to 60 feet vertically out of the largest Single-Shell Tanks.
- Improve process control (HMI).
- Optimize in-tank umbilical management.
- Enhance tank bottom sensor system.





TECHNOLOGY READINESS LEVELS

The Table shows the Technology Readiness Level (TRL) at the end of Phase II.

At the end of Phase III all systems will be at least TRL 6.

MWGS Individual System Components	TRL 1	TRL 2	TRL 3	TRL 4	TRL 5	TRL 6
	Have the basic process technology process principles been observed and reported?	Has an equipment and process concept been formulated?	Has equipment and process analysis and proof of concept been demonstrated in a simulated environment?	Has laboratory-scale testing of similar equipment systems been completed in a simulated environment?	Has bench-scale equipment/process testing been demonstrated in a relevant environment?	Has prototypical engineering scale equipment /process testing been demonstrated in a relevant environment; to include testing of the safety function?
ROV						
Rotocutter						
Vacuum collection system						
Conveyance (blade cutter, aux pump, settling tanks)						
Process controls (HMI)						
Umbilical (i.e. hydraulics feed)						
Tank bottom sensor						

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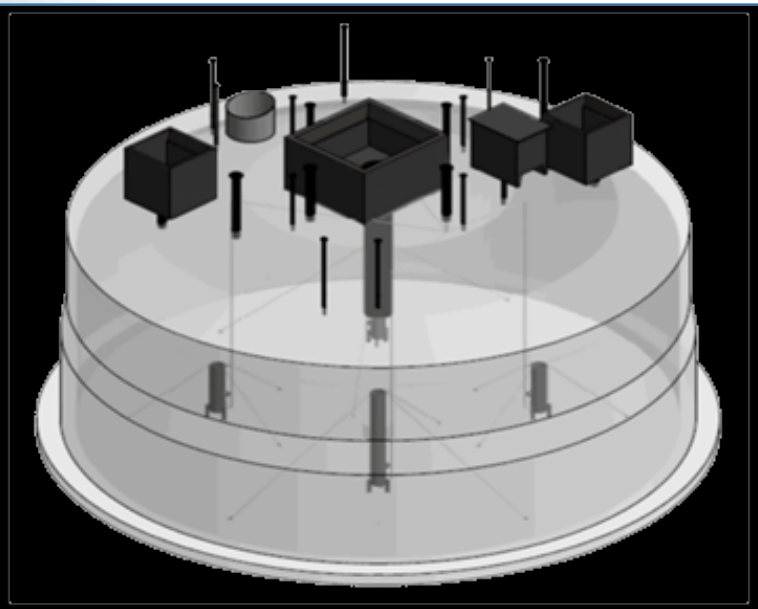

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ALTERNATE RETRIEVAL TECHNOLOGY DEVELOPMENT, HANFORD WASTE END EFFECTOR (HWEE)

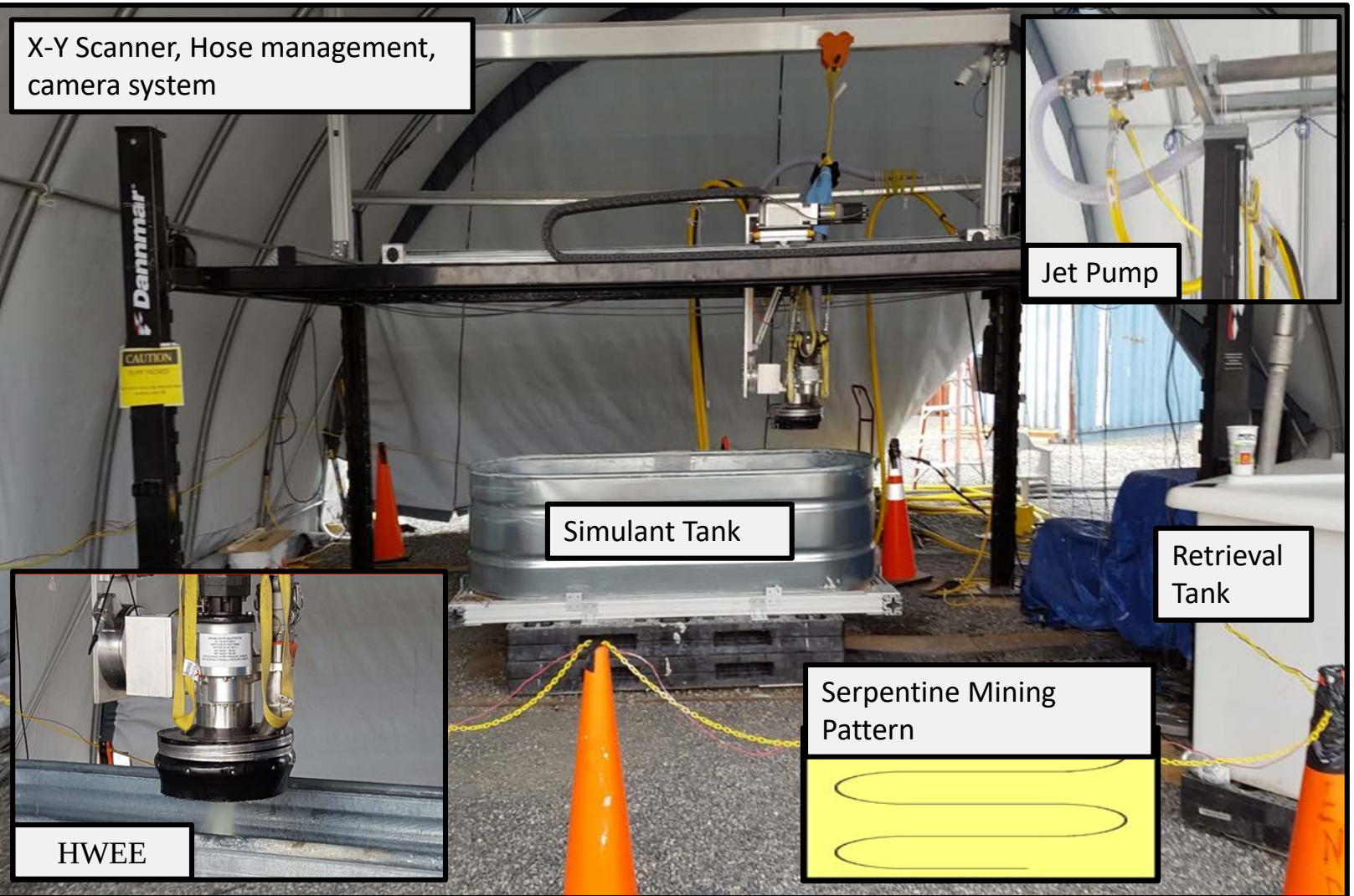
October 2018

HWEE DEVELOPMENT BACKGROUND

Previous Application

- Hanford Waste End Effector (HWEE) is a confined slucing apparatus;
  - ❖ Previous design developed by Pacific Northwest National Laboratory at Hanford in the late 1990's early 2000's
  - ❖ Deployed at DOE's Oakridge Tennessee site to successfully remediate 8 small gunite tanks
  - ❖ Was not deployed at Hanford because of the success of competing retrieval technologies
- HWEE is being reconsidered due to the need to reduce water usage during retrieval activities
- Confined Slucing uses high pressure low volume water to dislodge sludge and hardpan;
  - ❖ Uses 3 rotating cutter jets positioned parallel just above the solids surface (~ ½ inch offset)
  - ❖ Uses confinement skirt around cutter head to backstop mobilized solids and reduce aerosol generation
  - ❖ Uses a co-located eductor system to maximize conveyance of mobilized waste

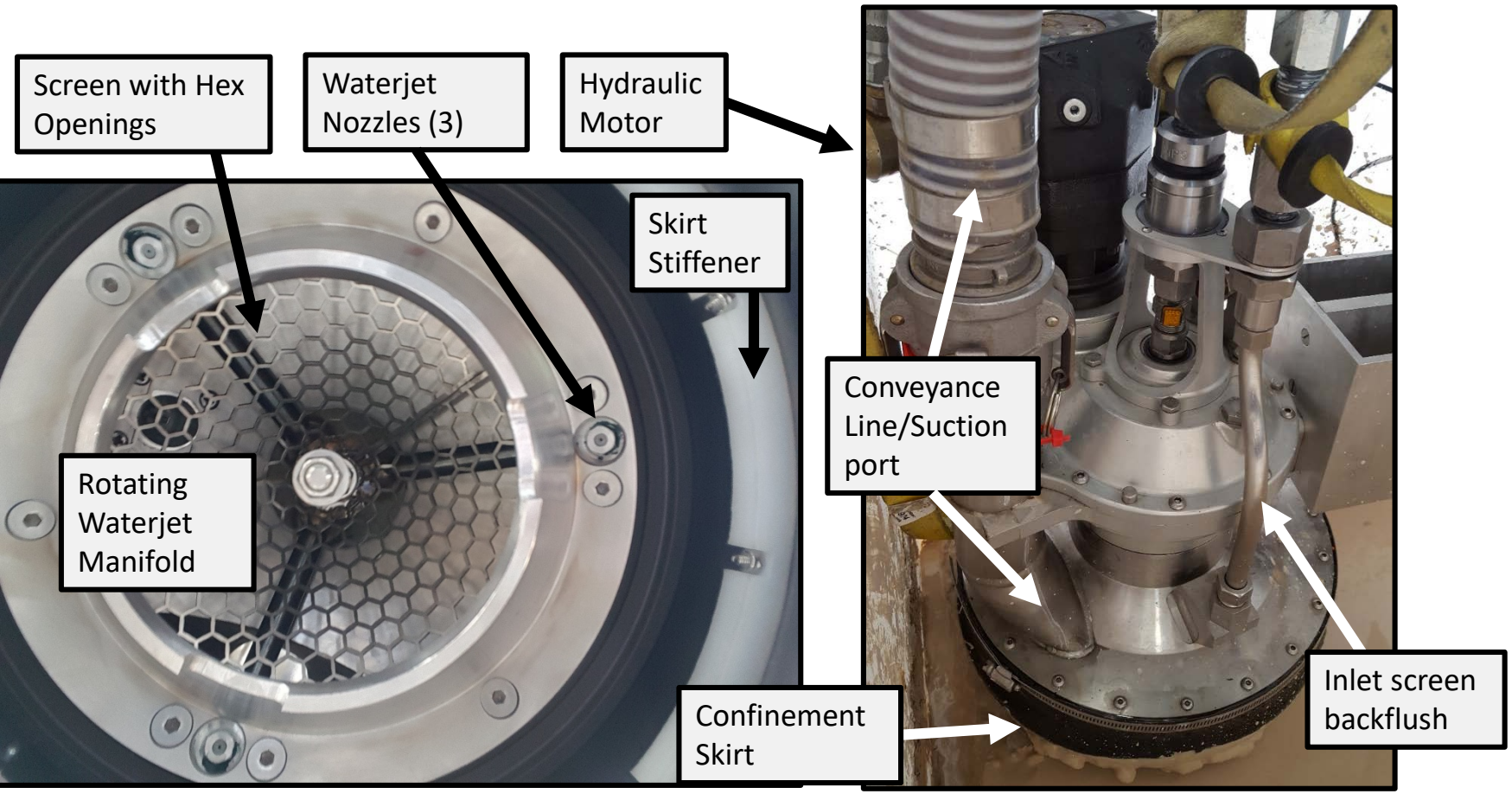
Phase I Testing program August 2016 – September 2017



Goal: Determine retrieval effectiveness of HWEE for retrieval of simulants with varied hardnesses using simplified test bed.

- Three individual test runs:
  - ❖ Kaolin simulant (Sludge): kaolin/water, **3,500 Pa**
  - ❖ Kaolin-Plaster simulant (Hardpan): kaolin/plaster of paris/water, **150,000 Pa.**
  - ❖ Potassium Magnesium Sulfate (KMAG) simulant (Saltcake): **12,000,000 Pa**

HWEE PHASE I TEST BRIEFING CONTINUED



Test data and results included:

- Retrieval rate and dilution ratios
- Water usage
- Aerosol generation was tested for and qualitatively determined (visual observation only) See PNNL-26856 Rev 1
- Reaction forces
- Inlet screen flushing requirement

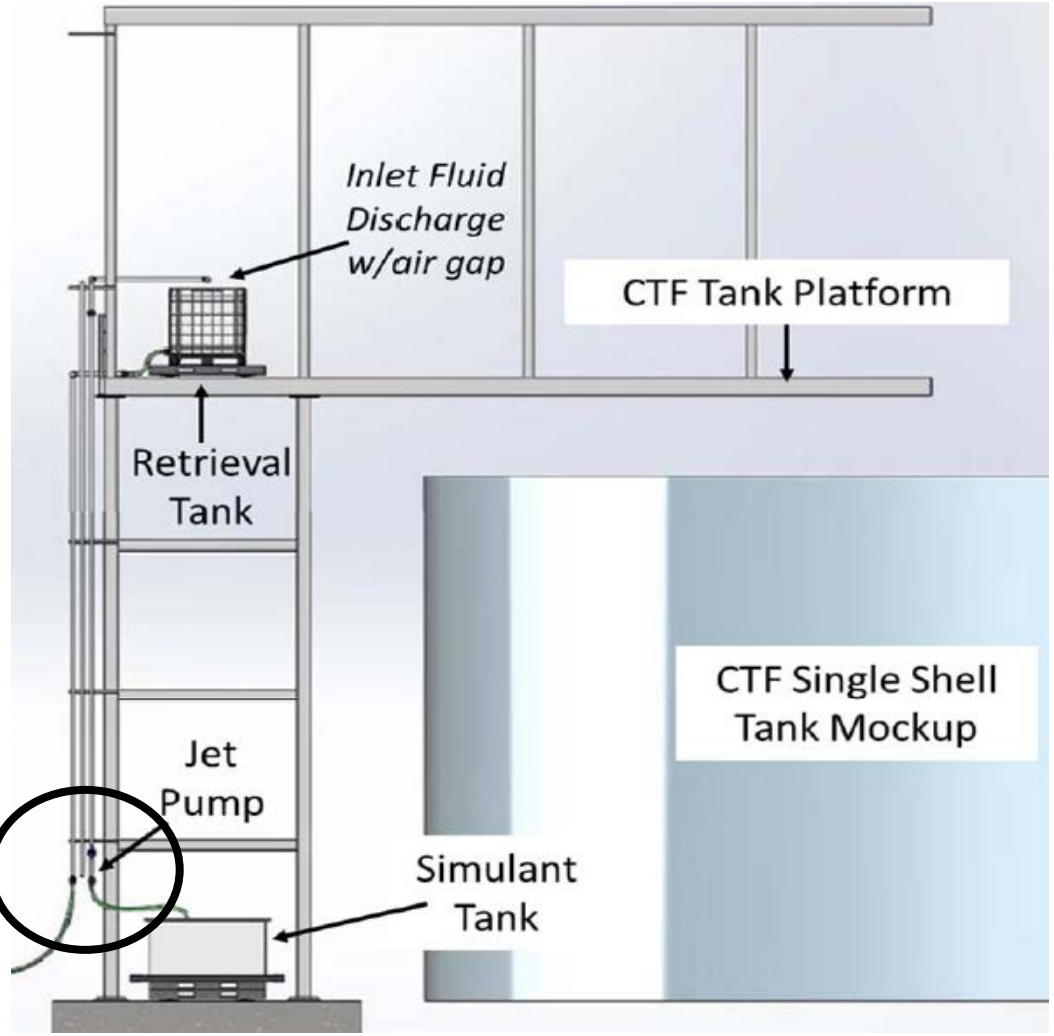
- Phase I Testing was successful for the softer material. Retrieval rates and dilutions ratios were improved from previous sluicer designs (See Slide #8)

Phase II Testing (FY18) October 2017 through August 2018

Goal: Assess HWEE capability in more complex and more realistic environment.

- Retrieving more challenging simulant;
  - Representing actual waste topography and waste layering (different hardness within the same simulant).
- Assessing waste conveyance challenges based on full size tanks
- Design for deployment through riser
  - Modify existing articulated mast for HWEE adaptation

Note: Jet pump is the same one used in the HWEE retrieval tests



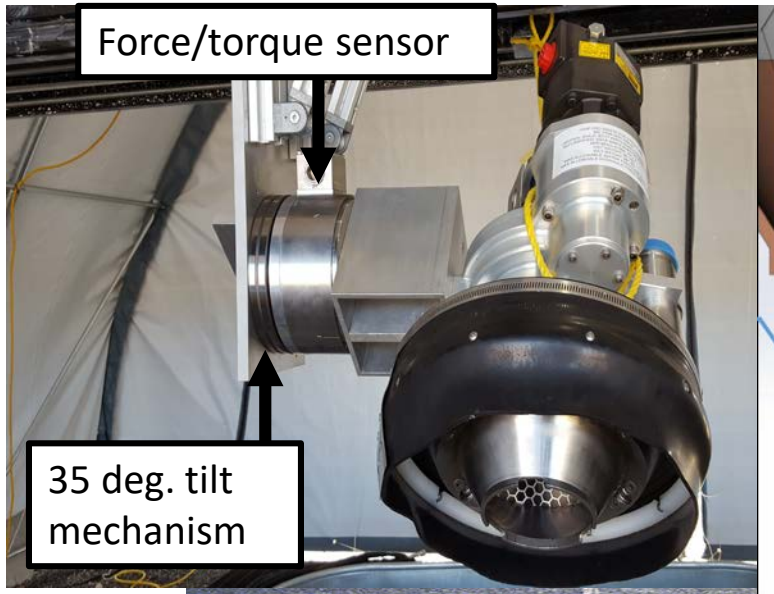
Cold Test Facility (CTF)

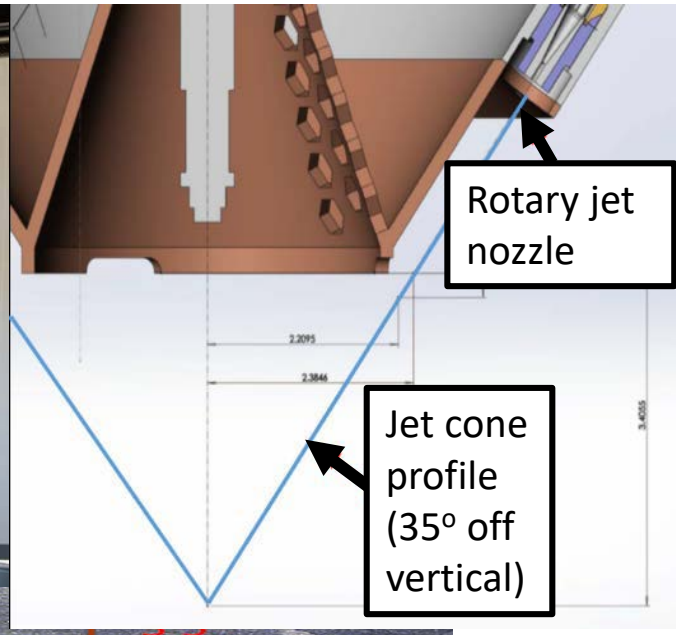
HWEE PHASE II TEST BRIEFING CONTINUED

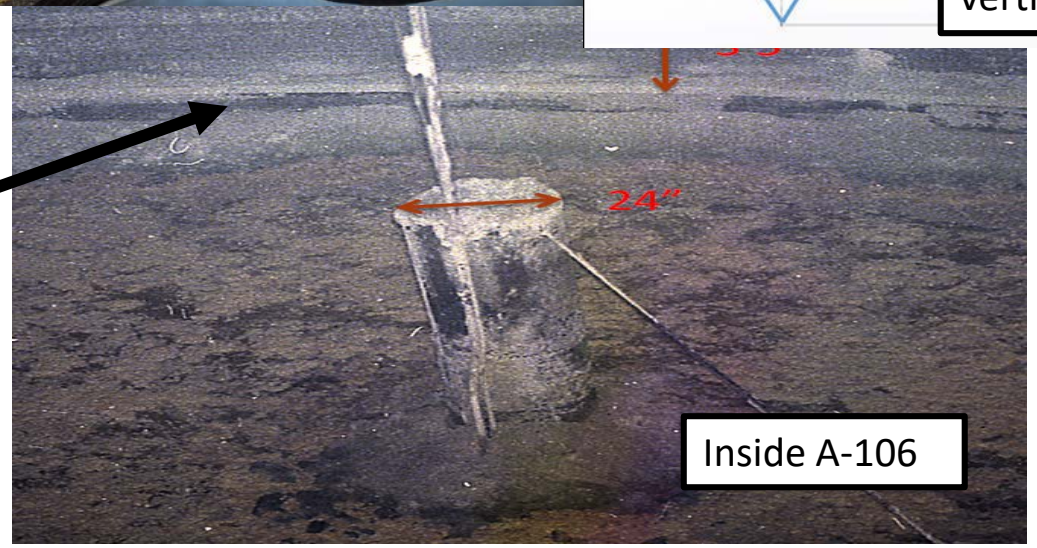
Changes to Phase I Test Platform included:

- Improved data collection processes
  - ❖ Water supply control valves changed from manual to automatic for cutter jets, flush jet and jet pump (i.e. improved retrieval and dilution ratio determination)
  - ❖ Instrumentation added to retrieval tank

- HWEE tilt added (automatic, one direction around Z-Axis—Max 35 deg. tilt)
  - ❖ Jets are already mounted at 35 degs so resulting jet spray at full tilt is pointed at the tank bottom corner
  - ❖ Addresses A-106 solids buildup (EXAMPLE bath tub ring) around tank bottom perimeter







PHASE I& II SUMMARY TEST RESULTS

Device	Retrieval Rate (gpm)	Dilution Ratio
Previous Hanford Sluicer	0.7- 4.3	0.01 to 0.05
HWEE Phase I	3.1 to 4.9	0.19 to 0.3
HWEE Phase II	3.1 to 7.6	0.11 to 0.24

Phase II conveyance jet pump test resulted in a very positive result to 38 feet. The station was not set up to assess pumping performance any higher because of time and funding constraints

PHASE III Test Goals (FY19)

End Effector

- Assess adaptability of the HWEE head to an articulated mast through functional testing

Retrieval Arm

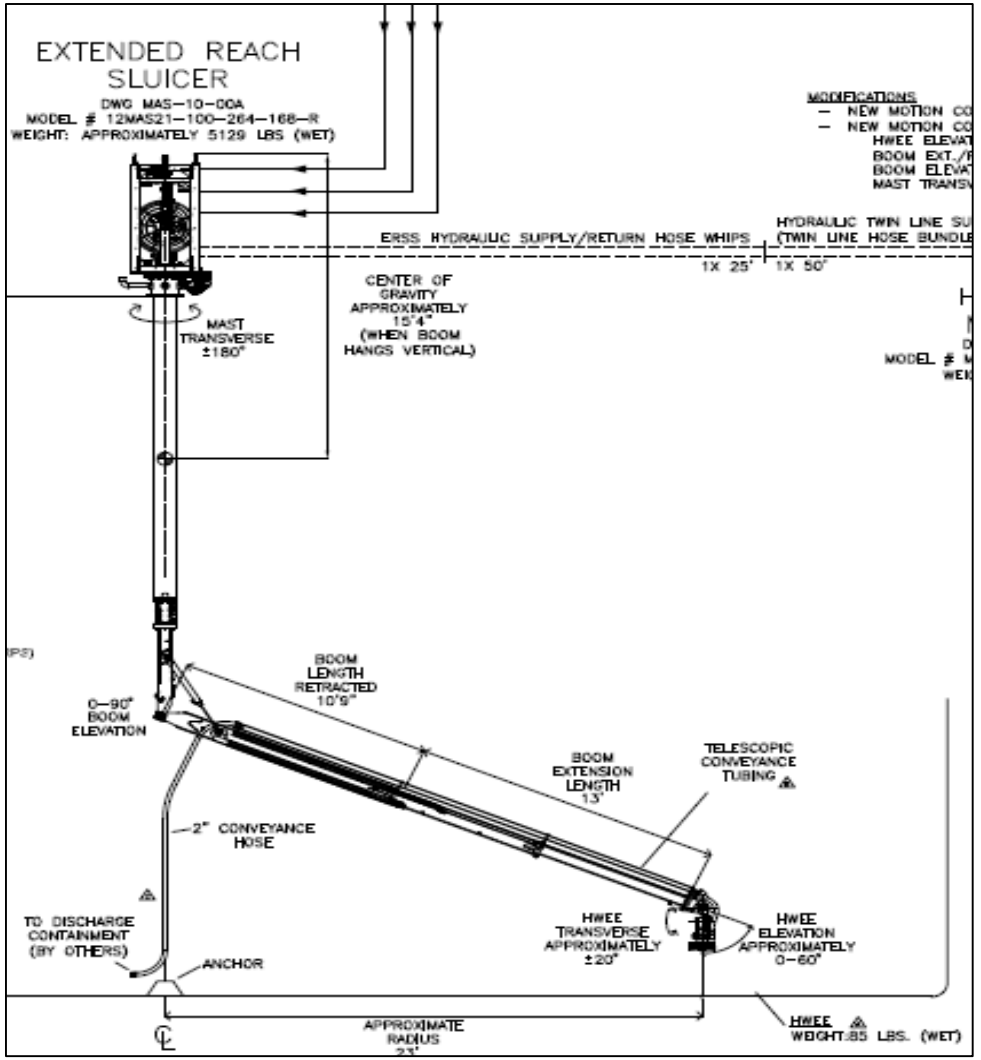
- Assess whether modifications made for HWEE adaption are viable
  - ❖ Hydraulic and water hose configuration and management
  - ❖ Load assessment due to HWEE head and conveyance system location

Conveyance System

- Demonstrate that waste retrieval from the tank and conveyance to the surface
- Use hosing system with equivalent length based on full size tank (million gallon)

Process Control (HMI)

- Develop mining strategy
- Show control of HWEE head with ½ in of the solids surface.



TECHNOLOGY READINESS LEVELS

The Table shows the Technology Readiness Level (TRL) for critical technology elements at the end of Phase II. At the end of Phase III all systems will be at least TRL 6.

HWEE Individual System Components	TRL 1	TRL 2	TRL 3	TRL 4	TRL 5	TRL 6
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End Effector						
Deployment Arm						
Conveyance System						
Process Control HMI						