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R&D Engineering Engagement in EM Operations

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EM Robotics Team Visit

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Background

- SRNL R&D Engineering
  - *Specialize in design of remote equipment and systems*
  - *Typically equipment, tools and robotics used in nuclear environments*
  - *Usually a collaboration between:*
    - Mechanical Systems & Custom Equipment Development
      - » *15-20 Mechanical Engineers*
    - Instrumentation & Electrical Systems Development
      - » *15-20 Electrical and Software Engineers*
- Variety of On Site and Off Site Customers
  - *Canyons*
  - *Spent Fuel Storage*
  - *SRS High Level Liquid Waste facilities*
  - *TRU Waste Processing*
  - *Pu Processing & Canning Facility*
  - *Defense Threat Reduction Agency (DTRA)*
  - *Waste Isolation Pilot Plant*

Background

- SRNL R&D Engineering has developed extensive experience in the design and development of remote systems for use in radioactive and inaccessible environments.

- Common Themes:
  - *Developing Engineering designs and solutions to mitigate risk to workers in nuclear/hazardous environments*
  - *Integrating commercially available components with in-house designs, i.e. 'not reinventing the wheel' to give best value to the customer*

- Completed those designs with a highly experienced work group of mechanical, electrical and software engineers (typically 15-25 yrs of experience)

Initial Engagement

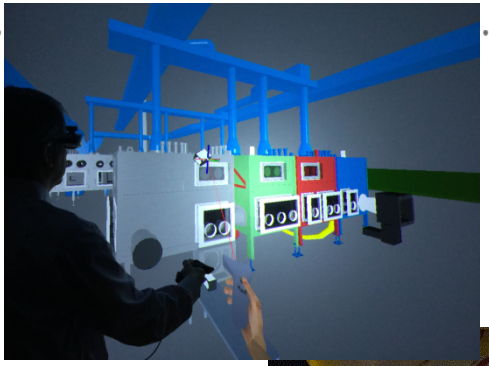
- **How does R&D Engineering engage with EM Customers for robotics work?**
  - Starts with a Documented Work Requests
    - *Technical Assistance Request*
    - *Technical Task Request*
    - *Formal Project Scoping Documents*
  - Then, Facility Interface Assignments
    - *Robotics expertise assigned to work with Facility Ops and Engineering Leads*
      - H-Canyon Crawler
    - *Formal Projects – Robotics expertise integrated into and are a member of Project Team*
      - Pit Disassembly and Conversion Project
    - *Many of our robotics engineers have plant operating experience*

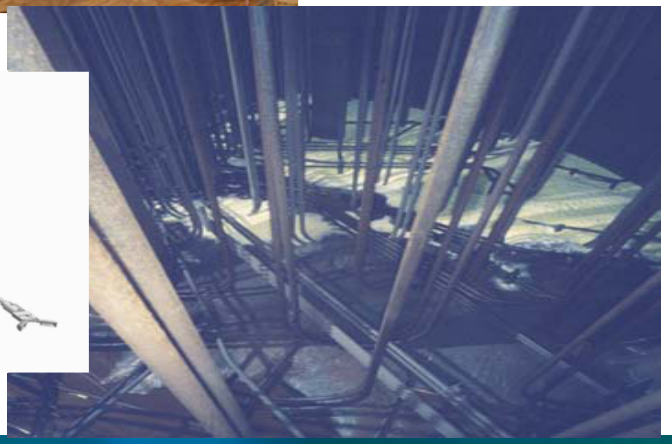
Determining Technical Approach

- **How do we determine technical approach?**
  - Begins with strong facility and project team interface
  - Factors considered:
    - *Cost – what is the customer's budget?*
    - *Timing – how quickly does the facility need it?*
    - *Facility Outages – typically a window of opportunity to deploy*
    - *Contamination/Dose – Is 100% remote required?; chemical, radiological compatibility*
    - *Facility Configuration – Access/space constraints*
    - *Power – Tethered or Battery*
    - *Video Quality – Tethered or Wireless*
    - *Retrievability – Tethered*
    - *Make vs. Buy*
    - *Mockup & Testing*

Areas of EM Engagement

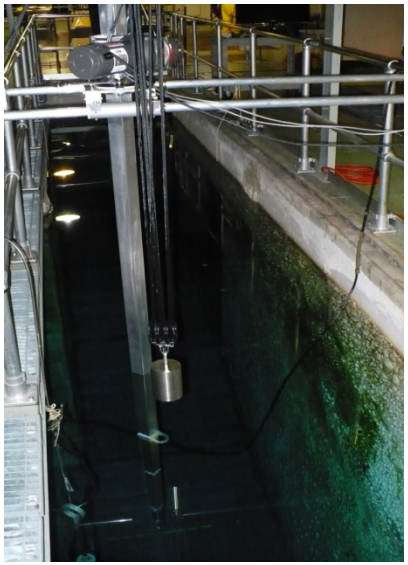
- **Nuclear Materials Processing**
  - **Surveillance/Life Extension**
  - H-Canyon
  - HB-Line
  - Spent Fuel Storage
  - Pu Processing & Canning Facility
- **D&D**
  - **Physical and Radiological Characterization**
  - 105-C Reactor
  - 235-F Pu Processing
- **Waste Processing**
  - **Radiological/Chemical Characterization**
  - High Level WasteTank Farms
  - Defense Waste Processing Facility
  - Saltstone
  - Waste Isolation Pilot Plant



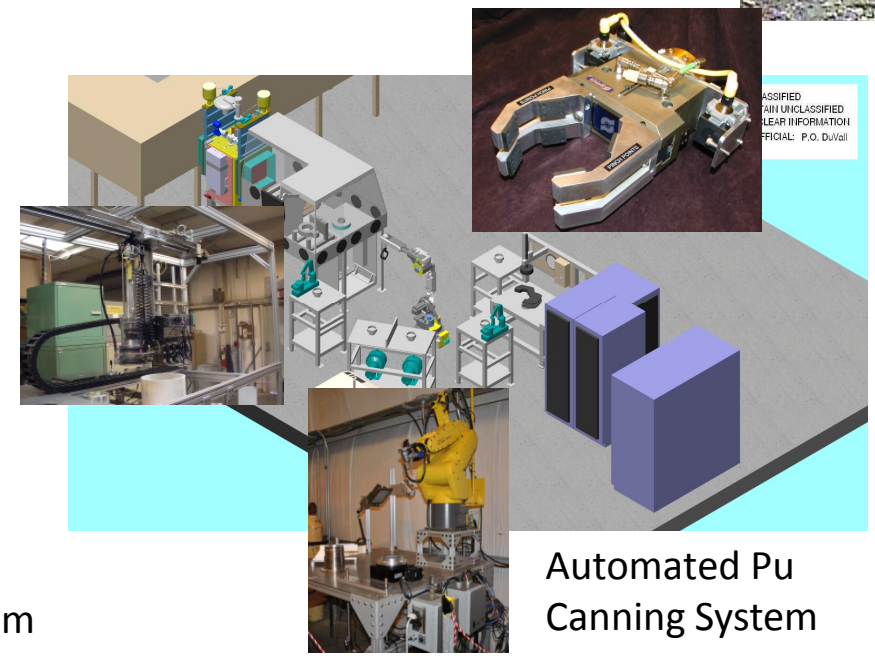


Nuclear Materials Processing

- **Nuclear Materials Processing**
  - **Surveillance/Life Extension**
  - **Operations**
  - H-Canyon
  - HB-Line
  - Spent Fuel Storage
  - Plutonium Processing & Canning Facility



Fuel Basin Remote System



Automated Pu Canning System

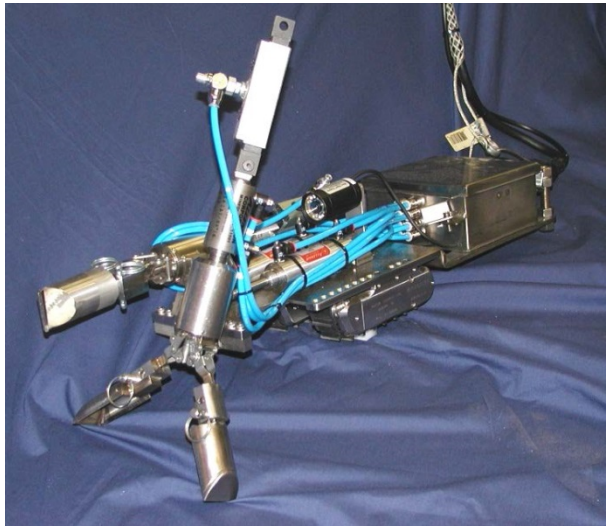
H-Canyon Crawler

Waste Processing

- **Waste Processing**
  - **Characterization**
  - High Level Waste Tank Farms
  - Defense Waste Processing Facility
  - Saltstone
  - Waste Isolation Pilot Plant

Tank 18F sampler

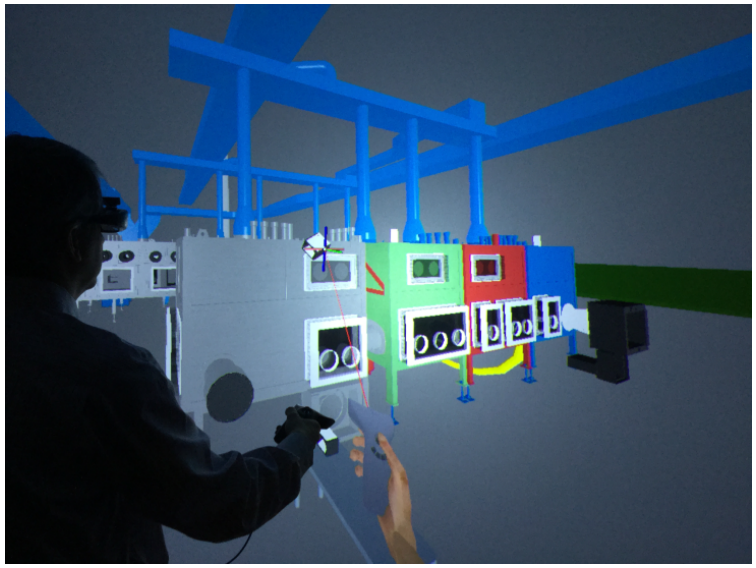
WIPP Camera System



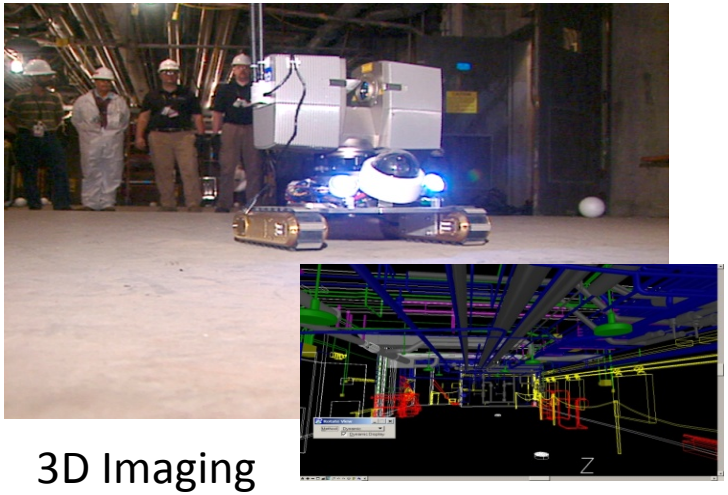
D&D

- **D&D**
  - **Physical and Radiological Characterization**
  - **Remote Specialty Tooling**
  - 105-C Reactor
  - 235-F Pu Processing

Virtual Reality



235-F Remote Tooling



3D Imaging

Example of EM Engagement Approach

2015 H-Canyon Recovery Vehicle

Approach for 2015 Recovery Vehicle

Mission, Cost, Timing, Assignments

- **Mission: Recover 2014 Inspection Vehicle in H-Canyon Air Tunnel for:**
  - use in future inspections OR
  - move from pathway and then inspect air tunnel as feasible
- **Cost: Vehicle budget <$75k**
- **Timing: 12 months to develop and test prior to June 2015 facility outage**
- **Assignments:**
  - R&D Engineering assigned overall Lead Robotics Engineer
  - H-Canyon Facility assigned Ops specialist and Engineer

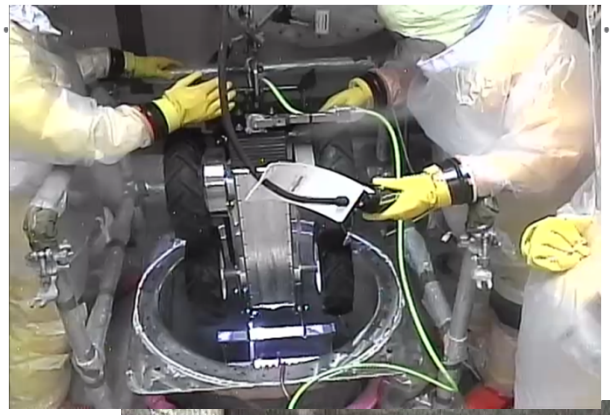
2014 Air Tunnel Inspection Vehicle

Fallen 2014 Inspection Vehicle

Approach for 2015 Recovery Vehicle

Facility Conditions

- 30 inch manway to enter tunnel
- 30 mph (50 km/hr) air flow
- Acid vapors
- Alpha Contamination: millions dpm/100 cm2
- Dose Rate: 10 to 1,000 mRem/hr (0.1 mSv to 10 mSv/hr) beta and gamma
- Small ponds of standing water
- Uneven floor surfaces with debris and obstacles
- Degraded concrete is mud like on tunnel floor
- 1 meter and 0.5 meter air duct (inspection obstacles)



Approach for 2015 Recovery Vehicle

- **Vehicle Design**
  - Tele-operated for simplistic low cost approach
  - Tethered to allow reliable power, video and a mechanism to manually retrieve
  - Left and right drive motors for skid steering
  - Two actuators, arms and forks
  - Counter weights to keep rear wheels down when lifting 2014 vehicle
  - One pan-tilt-zoom camera and one light source

- **Recovery Vehicle features from 2014 Inspection Vehicle Lessons Learned**
  - Added pitch and roll indicator
  - Added Beta and Gamma electronic dosimeters

- **Recovery Vehicle built by vendor for $63K**
  - Cost Effective to buy and modify instead of make

Approach for 2015 Recovery Vehicle

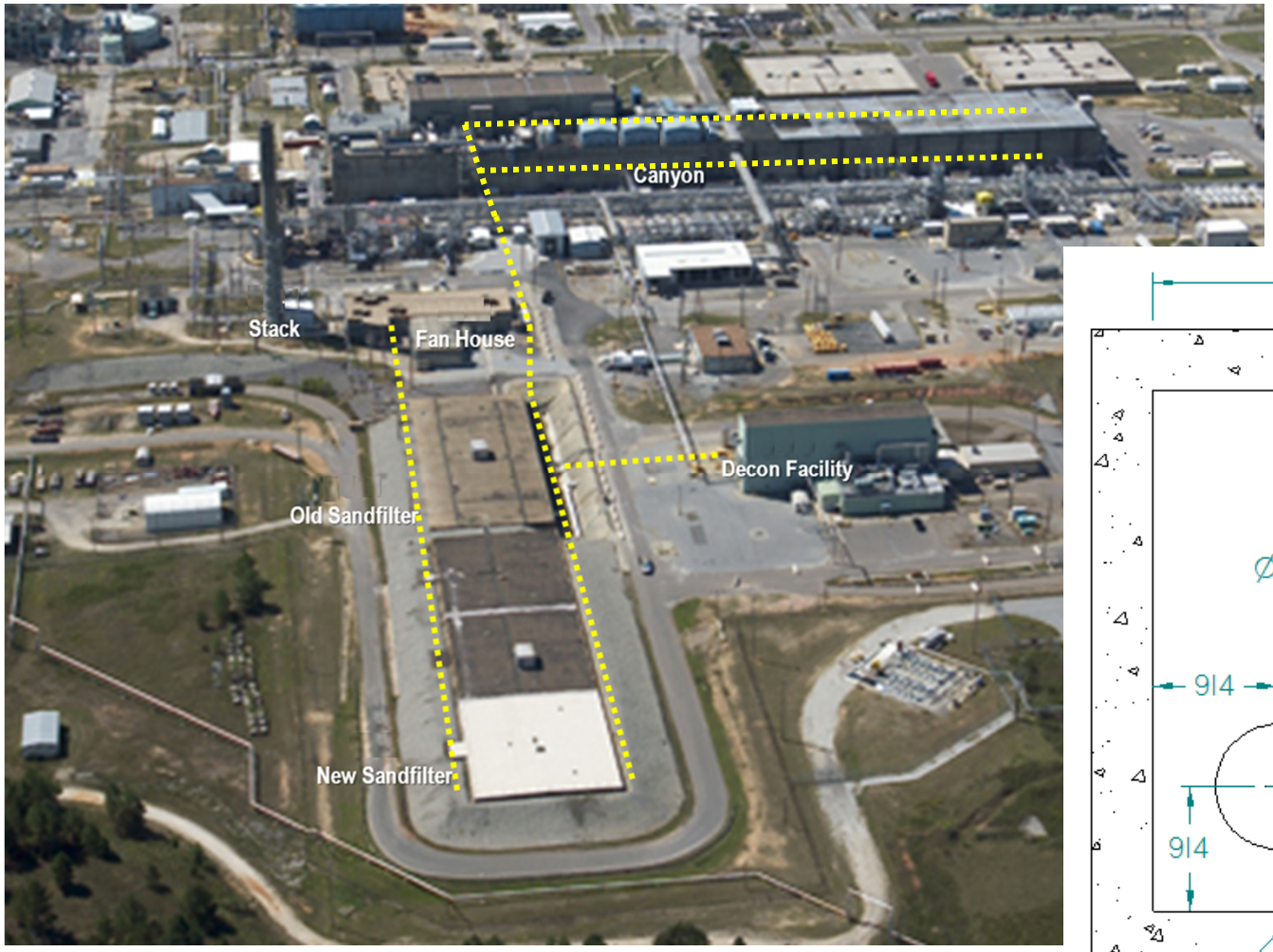
Mock-Up

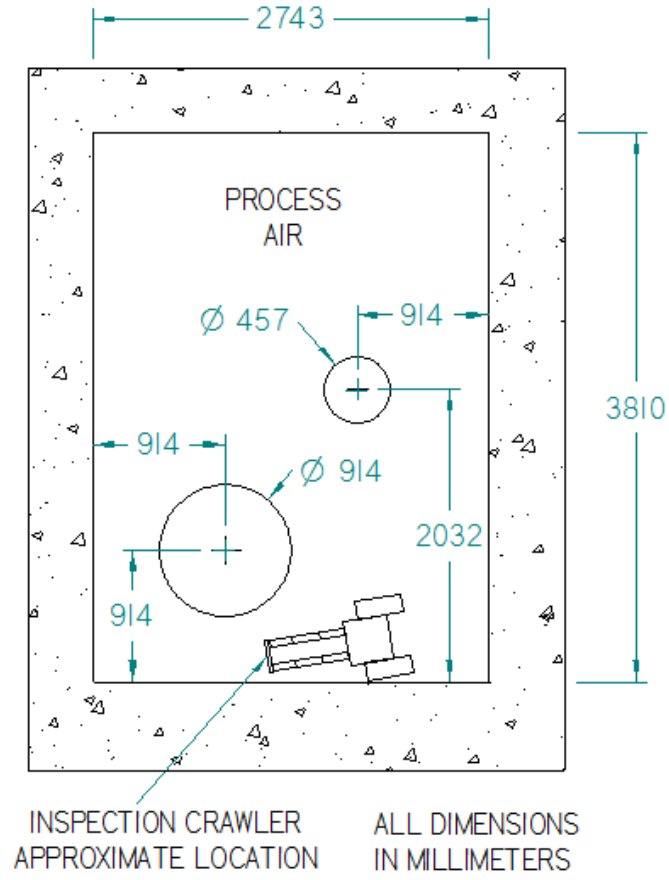
- **Mock-up and Testing are essential to success of any robotic deployment**
- **Maintain strong interface and feedback mechanisms with Operations and Engineering Staff during mock-up and testing**
- **Simulate conditions as realistic as possible**
  - Driving with camera view only
  - Rigging vehicle into air tunnel
  - Inclined and irregular terrain
  - Up-righting and pushing a simulated 2014 vehicle and obstacles with space constraints
- **Establish decision tree for potential upsets or barriers**

Deployment Results

- **Overall mission was successful**
- **Inspected areas of tunnel never seen before**
- **Up-righted and cleared 2014 vehicle from inspection path**
- **Recovered 2015 vehicle for future use**
- **Gained a better understanding of obstacles in the tunnel for future inspections**

H-Canyon Air Tunnel





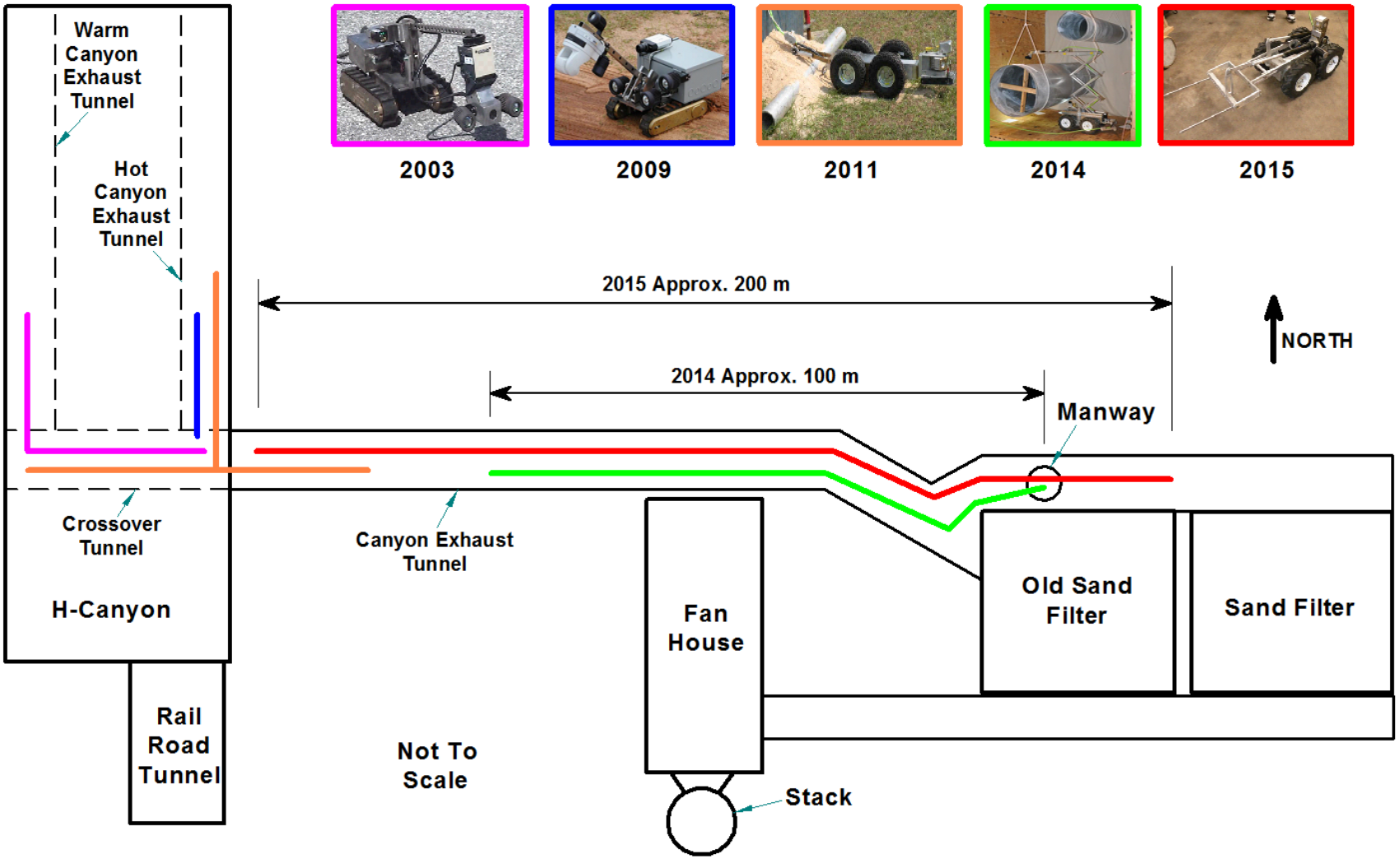
Video of 2015 Inspections

Needs for Improvement in Future EM Engagements

- **Ad Hoc Robotic Deployments**
  - Cheaper, quicker, modular, disposable components to reduce cost, schedule and mission risk
  - Smaller, miniature vehicles to deliver sensors to tight spaces
  - Low Cost 3D Scanning for physical characterization
  - UAV development for indoor surveillance and characterization

- **New and Retrofit Facilities**
  - Robotics and Automation Mind Set during Facility planning vs. Humans in PPE
    - *i.e. when we build 21st century facilities, use 21st century technology to reduce risk to the worker*
  - Glovebox Robotics in place of human arms and hands
  - Flexible automation of equipment within the glovebox to minimize human hands

H-Canyon Inspection Vehicle Routes



2014 Inspection

Goals for 2014

- Develop low cost (<$75k) vehicle able to look over and behind 36” (1 meter) hanging air duct
- Navigate through difficult terrain and obstacles
- Capture and record video of tunnel wall inspection
- Retrieve vehicle for future inspections

Vehicle Features

- Larger tires, tele-operated vehicle
- Tethered for power, video reliability and manual retrieveability
- Scissor lift and extendable mechanical slide
- 2 pan tilt zoom cameras

Results

- 2014 Inspection Vehicle inspected 100 meters
- Captured and recorded video of tunnel never inspected to support structural analysis
- Vehicle fell over
- Fall due to:
  - Falling debris into extended arm causing it to become non-retractable
  - High and awkward center of gravity
  - Movement on uneven surfaces

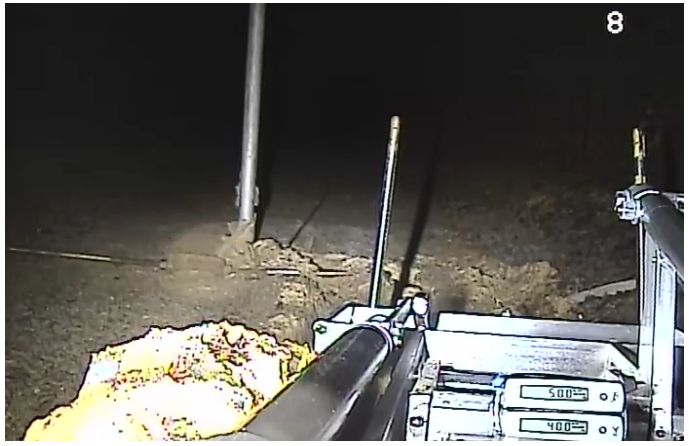
2014 Inspection Vehicle

Fallen 2014 Inspection Vehicle

Deployment Summary – Tunnel Obstacles

Approaching Water

Crossing Water, Approx. 13” (330 mm) Deep

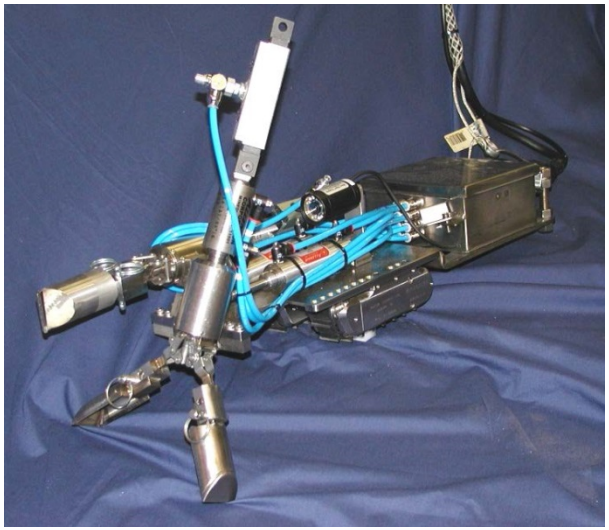


Conduit, Probes, & Supports

Expansion Joint Covers

Remote Sampling of High Level Waste Tank 18F

- SRS Tank Farm needed to sample contents on floor of Tank 18F
- Areas to be sampled not directly underneath riser
- Developed tethered Crawler to travel up to 40' through tank sludge to sample collection areas
- Obtained samples with detachable pneumatic 'snapper jaws'
- Avoided drilling through tank top to obtain samples not directly underneath riser



High Level Waste Tank 5 Sampler

Objective
Obtain samples from under access riser and from 'snow bank' to characterize contents in support of chemical cleaning.

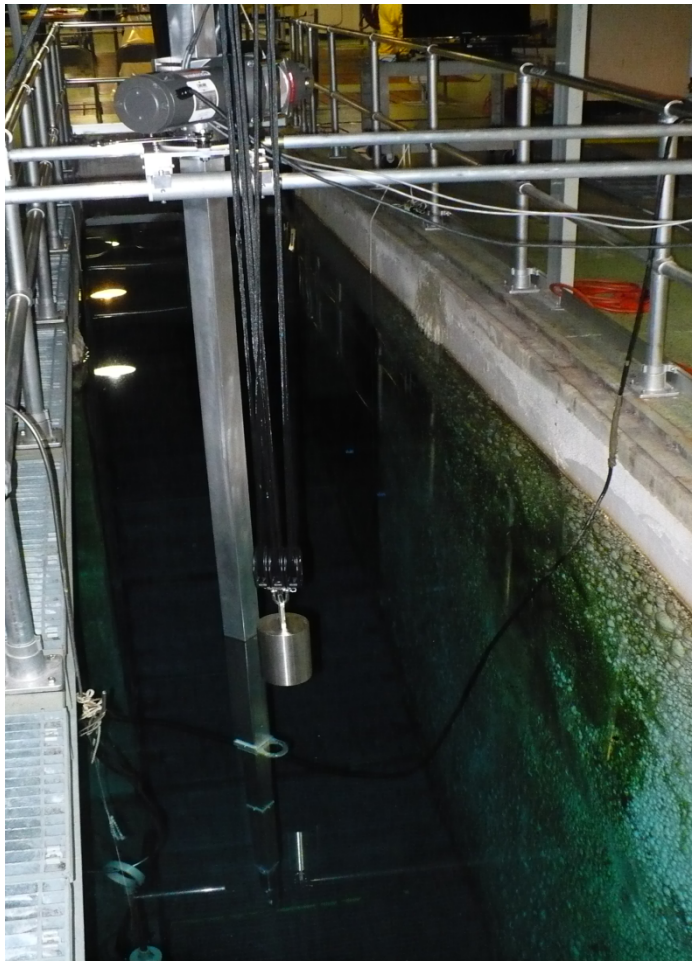
Inside Tank 5

Deployment Method

1. Deploy through riser in stowed position.
2. Rotate mast and raise elbow toward snow bank, open snapper jaws.
3. Extend piston to plunge snapper jaws into waste.
4. Close jaws and perform reverse of deployment for removal.

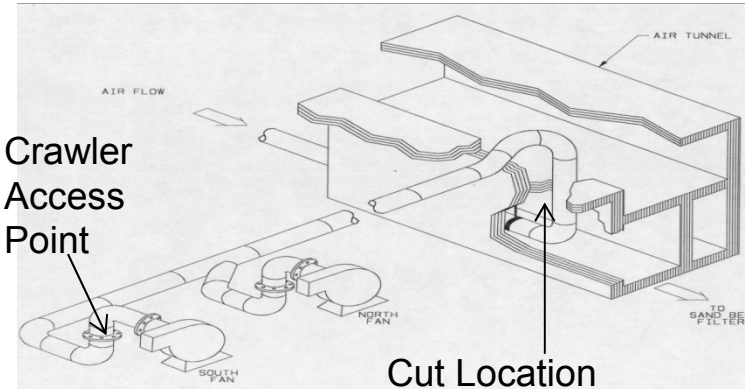
Ultrasonic Testing Delivery System

- Ultrasonic Testing of spent fuel 12 ft x 8” OD can in L-Area Basin
- 30 feet below level 0
- R&D Engineering designed mechanical delivery system
- Design included:
  - Telescoping mast controlled by cable wench
  - Block and tackle system for camera and UST cable management
- Successfully deployed by SRNL NDE group



Large Diameter Pipe Crawler

- Redirect F-Canyon air flow
- 36” diameter pipe
- Over 300 ft travel to cut area
- Route included a “Y” and gooseneck
- Plasma arc cutter and cameras on board crawler
- Successfully removed pipe section



WIPP Camera

Dome Camera

- 1080p HD-SDI video
- 18x Optical Zoom
- Pan/ Tilt/ Zoom
- Teradek wireless video transmitters
- Moxa wireless control transmitters
- 225 ft transmission range
- Long lasting lithium ion battery pack.

Drop down camera

- Inuktun SP-45 PTZ Camera
- 15 feet deployable cable reel
- Teradek wireless video transmitters
- Moxa wireless control transmitters
- 225 ft transmission range
- Laser locator to pinpoint drop-down location.
- Long lasting lithium ion battery pack

Results

- Captured video to support characterization of event scene
- Allowed Accident Investigation Board to reach final conclusions