Development of Inspection Tools for the AY-102 Double-Shell Tank at the Hanford DOE Site

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April 6, 2016

FLORIDA INTERNATIONAL UNIVERSITY

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Work supported by: U.S. Department of Energy Office of Environmental Management under Cooperative Agreement # DE-EM0000598

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4. Magnetic Miniature Rover
5. Testing and Evaluation
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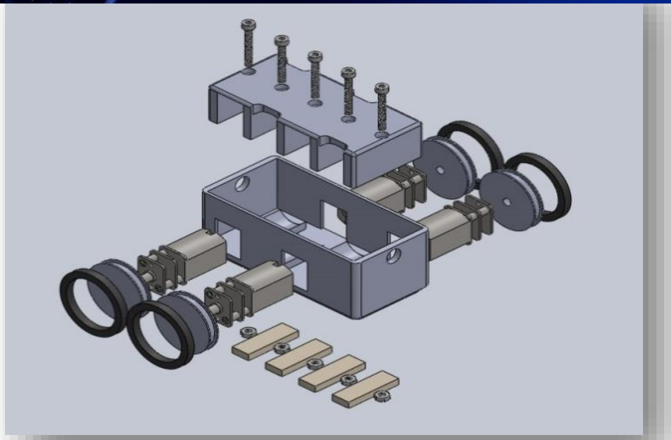
7. Testing and Evaluation
8. Path Forward



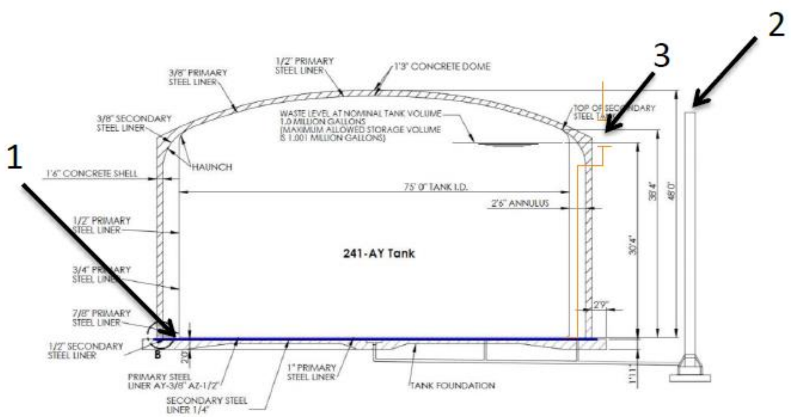
Task Description

Background:

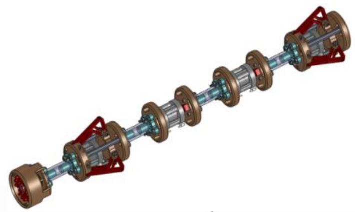
Tank waste was found in the annulus of tank AY-102.

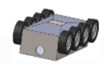
An inspection tool is required to isolate and pinpoint the source of the material entering Tank AY-102 annulus space

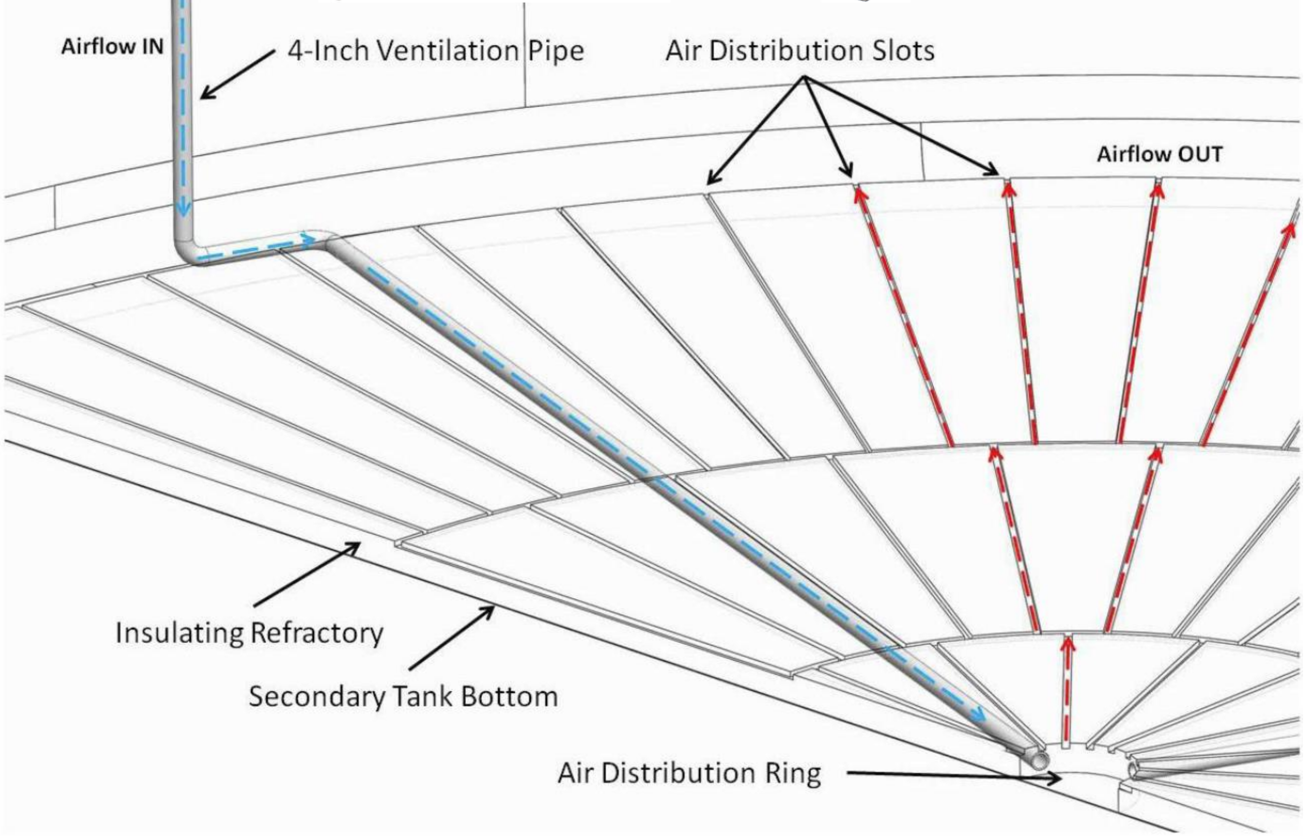
There are three possible entry points: (1) refractory air slots through the annulus, (2) 6" leak detection piping, (3) 4" air supply piping

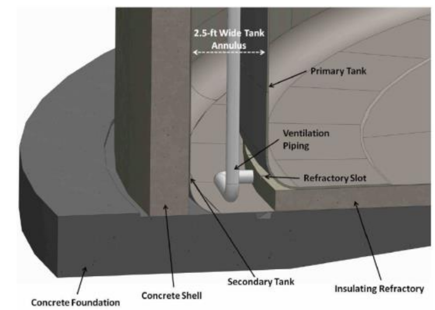


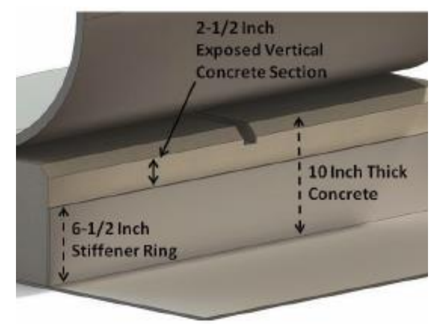
Proposed Inspection











Refractory Slot Inspection Tool

Objective: To develop an inspection tool that navigates through the refractory pad air channels under the primary liners of the DST's at Hanford while providing live video feedback

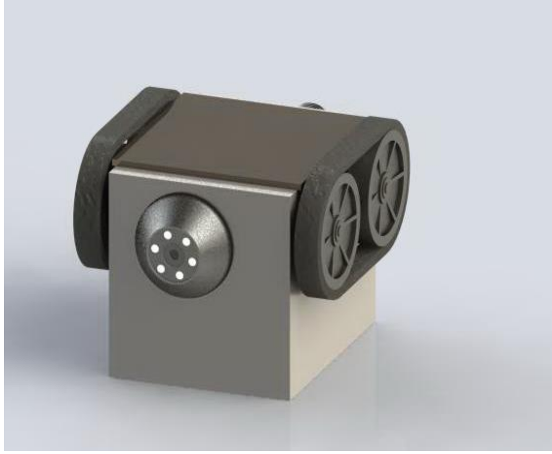
Design parameters:

- Travel through small cooling channels with dimensions as small as 1.5" x 1.5"
- Device will be remote controlled
- Device will be inserted through a riser to the annulus floor
- Provide live video feedback
- Device will need to be rad hardened (~ 80 rad/hr)
- Device will withstand relatively high temperatures (~ 170 °F)
- Device must not subject the channel walls to pressures greater than 200 psi, the compression strength of the refractory material.
- Navigate ~ 50 feet to the tank center, while maneuvering through four 90° turns (First phase – 17 feet, no turns)

Initial Designs

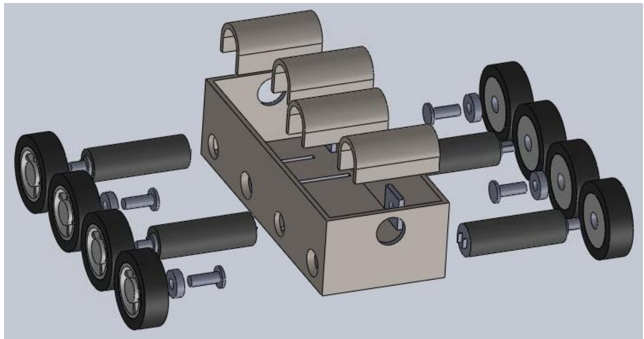
General approach

- Use of tank-treads for improved maneuverability
- Upside down travel to avoid refractory debris (via magnets)



Early prototypes

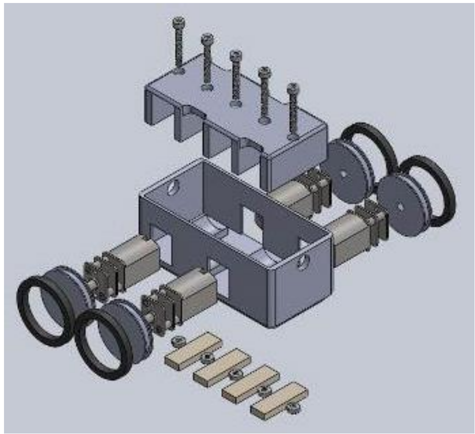
- Insufficient pulling force
- Inadequate clearance with tank surface
- Cumbersome reassembly
- Difficulty overcoming obstacles (small wheels)

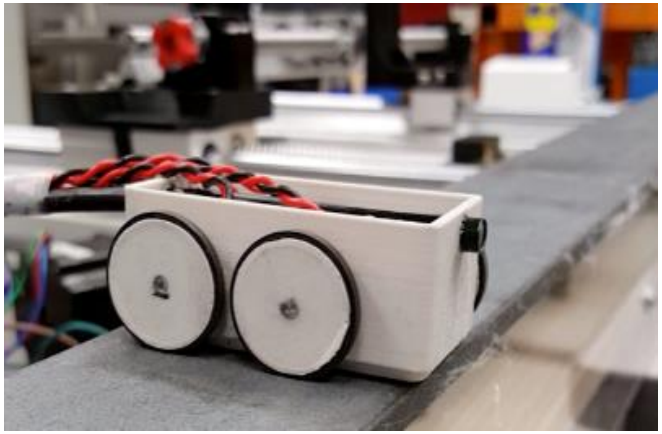


Current Prototype

The general design of the inspection tool has been completed and a prototype was assembled. Modifications that led to significant improvement in the performance include:

- Wheels being 3D printed and the diameter was increased by 6 mm to improve obstacle avoidance ability
- With the larger wheels, stronger motors, capable of 10x the amount of torque were used
- Brackets that fix the motors in place, allowing for motor replacement in the event of a motor failure
- Motors that utilize metal gears versus plastic gears

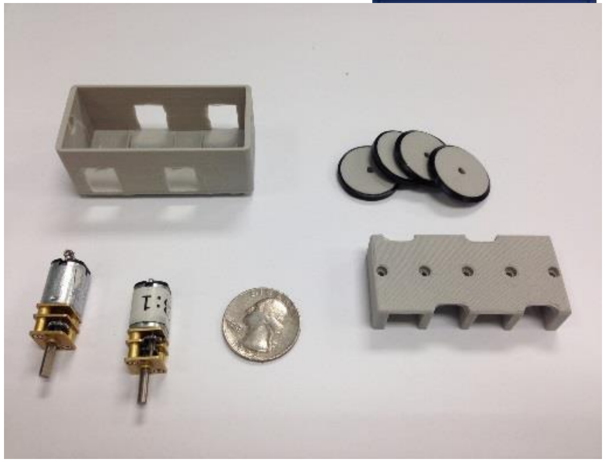




System Components

The components that make up the current design include:

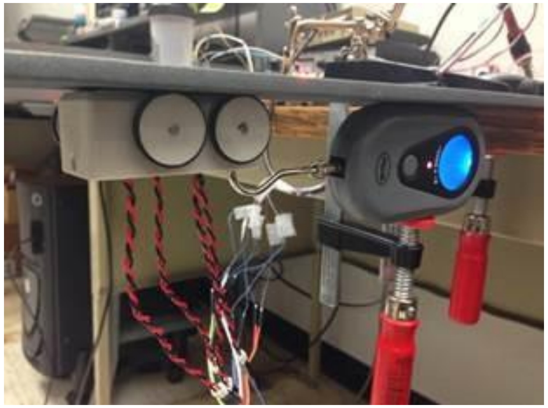
- Arduino Uno board with ATMega328 microcontroller
- Eggsnow USB Borescope Endoscope 5.5mm inspection camera
- 298:1 Micro Metal Gearmotor (4)
- 3D printed 20mm x 3 mm wheels (4)
- Square-Profile O-Ring for wheels
- 3D-printed body and bracket
- Neodymium magnet - 3/4” x 1/8” x 1/10” –3 lb pull force (4)
- Tether: 10M in length, 6mm wide and expandable to 11 mm wide, braided sleeving



Bench Scale Testing

Maximum pull force:

- Device weight: 0.18 lb
- Average pull force: 4.75 lb
- Tests performed at: 5V
- Power/Weight ratio: 26
- Motor rated for 3-9 V
- Pull force average obtained from 15 measurements



Bench Scale Testing

A mock-up of the outside channels with a 1.5” x 1.5“ cross section was manufactured.

- Successful navigation of the first 17 feet while pulling the tether and providing video feedback
- Effective maneuvering and path correction

Air Supply Line Inspection Tool

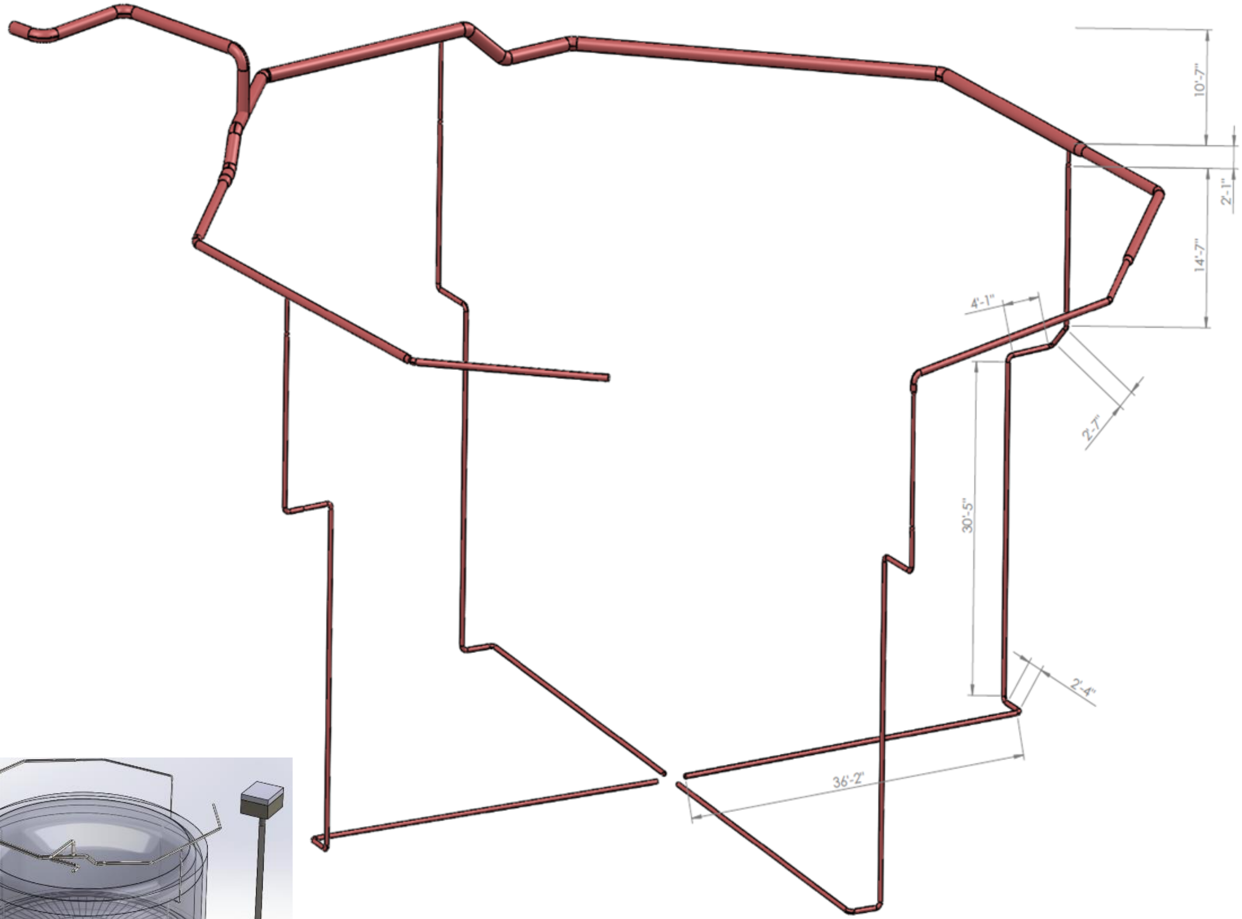
Objective:

To develop an inspection tool that crawls through the air supply pipe that leads to the central plenum of the primary tank of the DSTs at Hanford and provides video feedback

Design parameters:

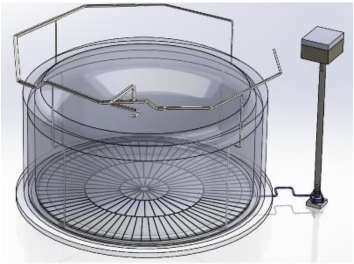
- Device will be remote controlled
- Video feedback will be recorded for future analysis
- Device will need to be radiation hardened (~ 80 rad/hr)
- Device will withstand high temperatures (~ 170 F)
- Device will be used in pipes and fittings with 3” and 4” diameter
- Device will turn through elbows, bends, and transitions
- Device will crawls through vertical runs

Inspection Path (AY-102)



The proposed inspection distance will be approximately 100 feet with a significant portion being gravity fed.

The path is made up of schedule 40 pipes which are 3 and 4 inches in diameter, with reducers and several elbows.



Conceptual Design

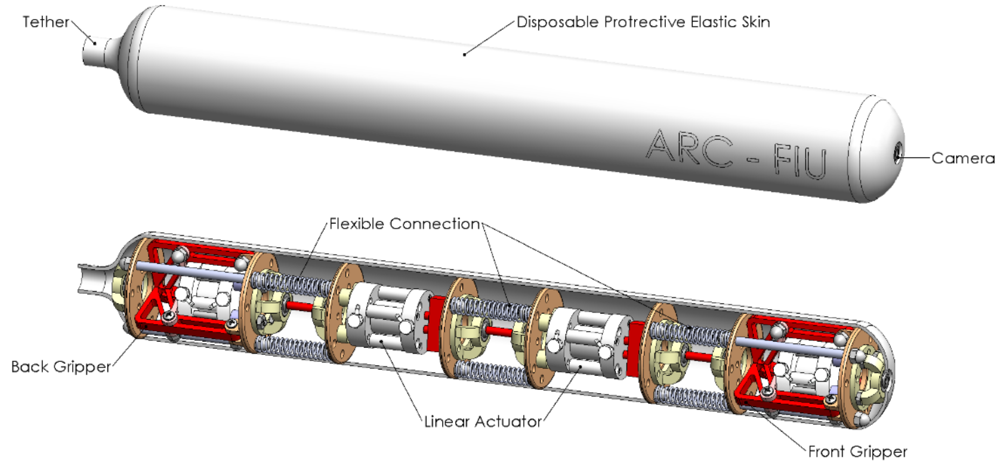
The inspection tool has a modular design.

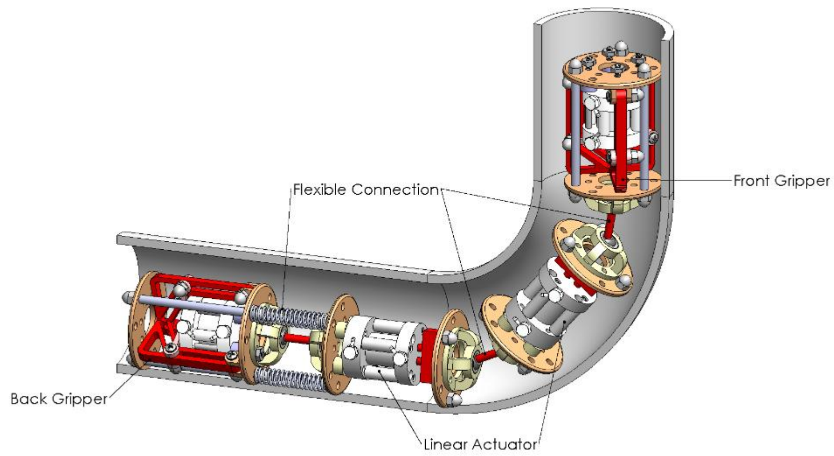
The device is composed of interchangeable modules connected with flexible links.

The modular approach has the potential to be customized for specific tasks with the addition of extra modules.

For instance adding:

- instrumentation,
- material sampling, and
- pipe repair.





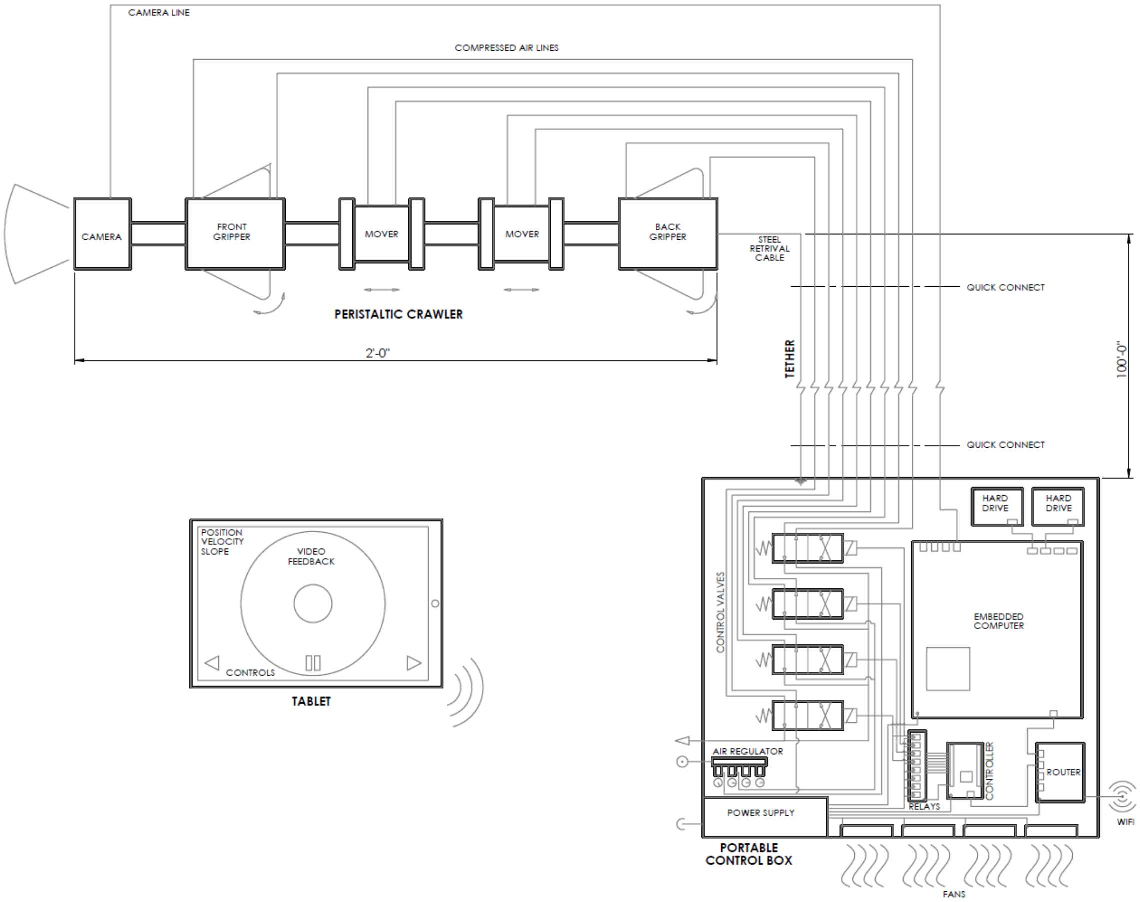
Overall Systems

The basic design is composed of five modules:

a front camera,
front and back grippers, and
two middle movers.

The movement is fully automated, which is remotely controlled by an handheld device.

The tool uses a programmable control interface and is customizable.



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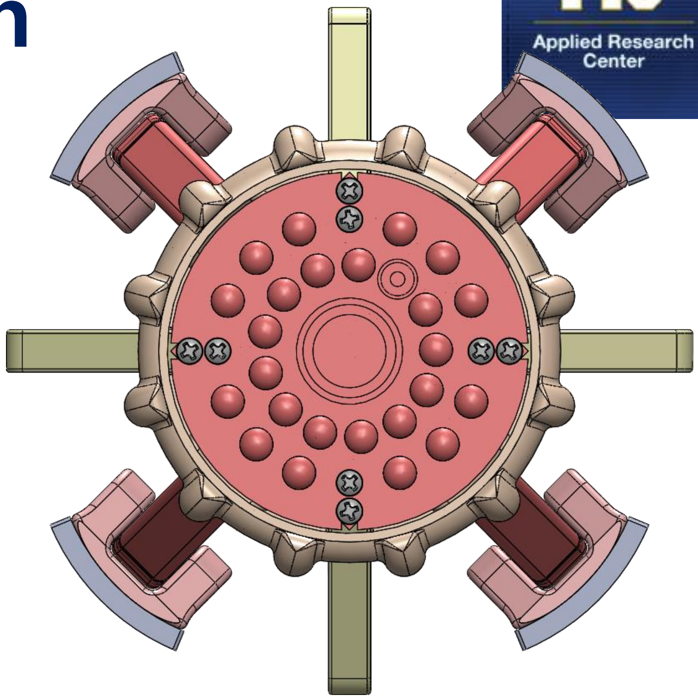
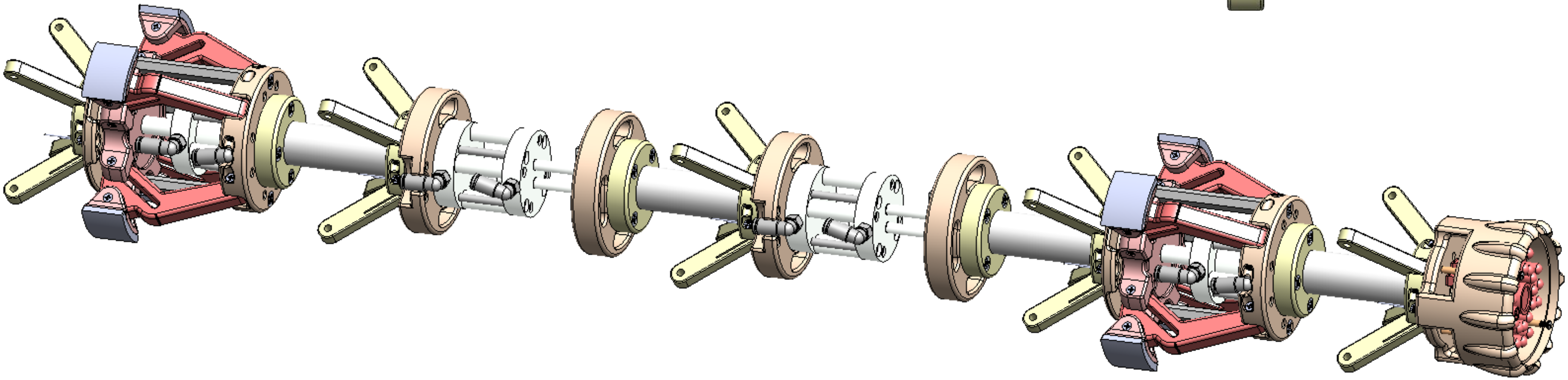
The Design



The crawler uses pneumatic actuators to emulate the contractions of the peristaltic movements.

The movement does not require embedded electronics and electric actuators.

The tool is suitable for highly radioactive environments with potential exposure to flammable gases.

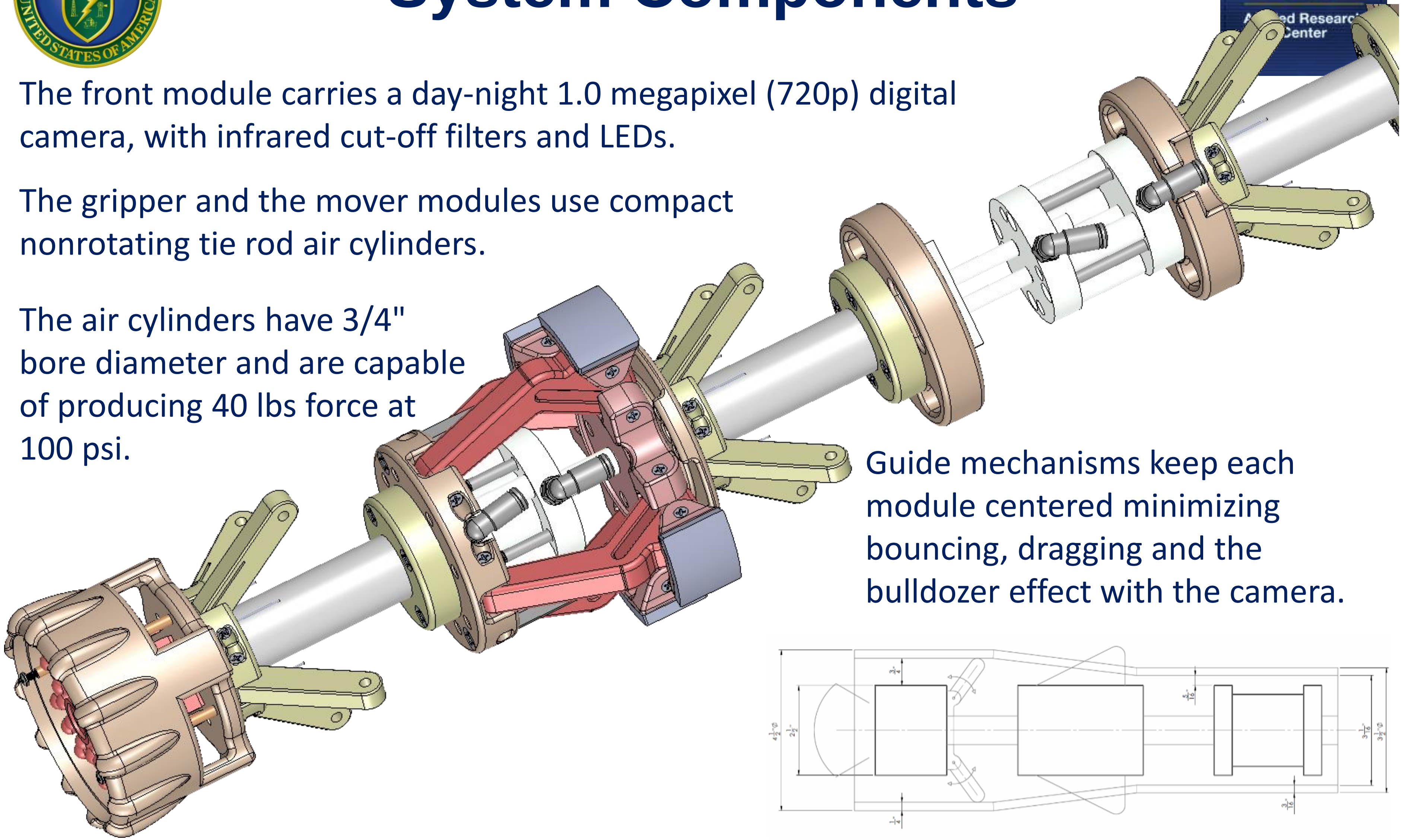


System Components

The front module carries a day-night 1.0 megapixel (720p) digital camera, with infrared cut-off filters and LEDs.

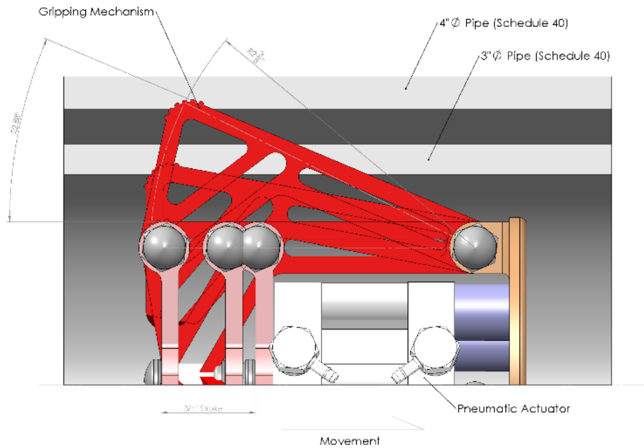
The gripper and the mover modules use compact nonrotating tie rod air cylinders.

The air cylinders have 3/4" bore diameter and are capable of producing 40 lbs force at 100 psi.



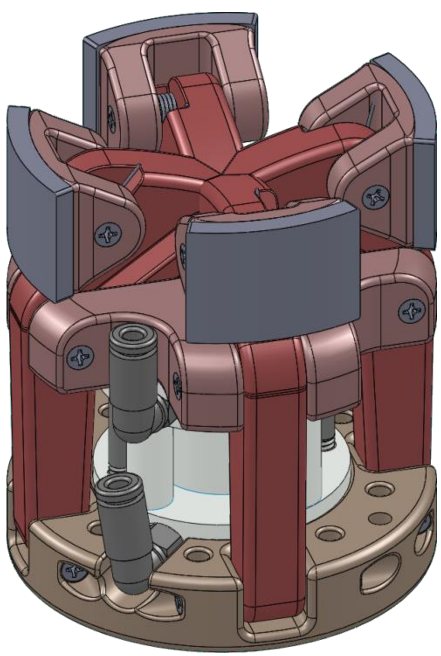
Guide mechanisms keep each module centered minimizing bouncing, dragging and the bulldozer effect with the camera.

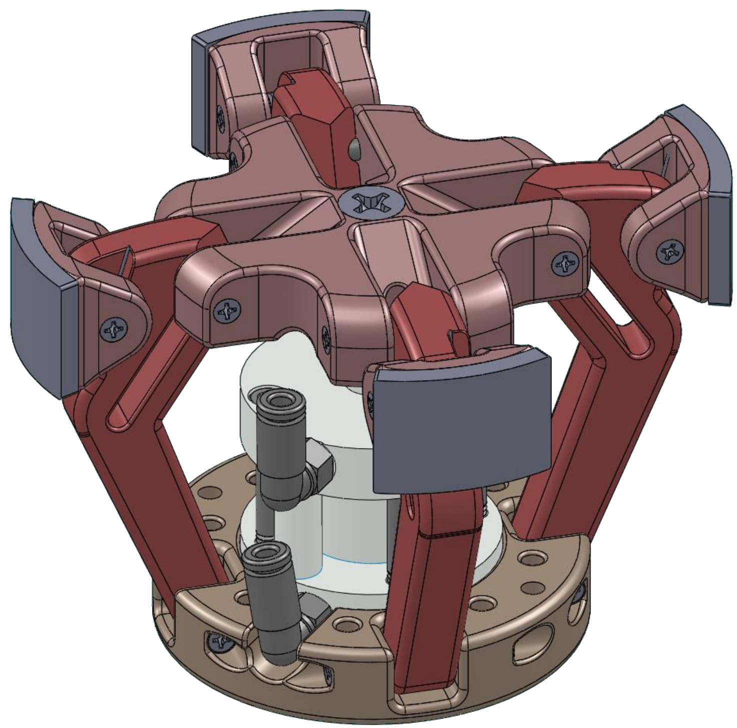
Gripper Modul

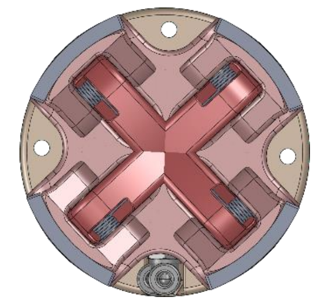


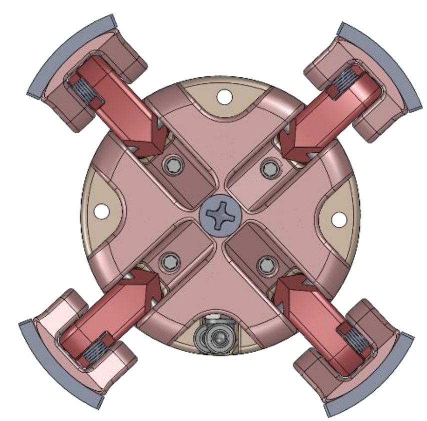
Maximizing the strength of the gripper is a major factor in the design of the peristaltic crawler.

A stronger grip would allow the device to carry additional modules, and to inspect longer pipelines.





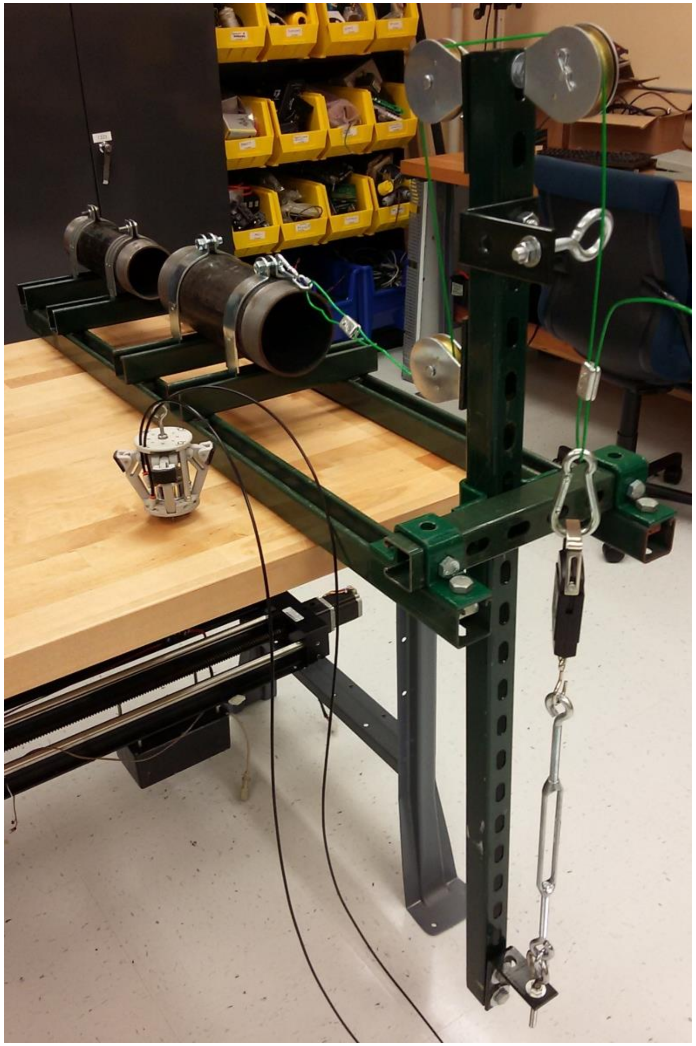


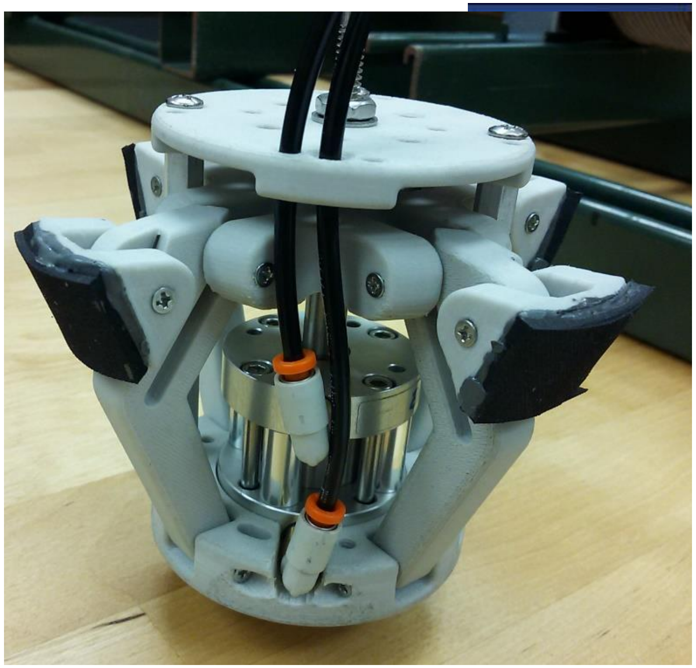


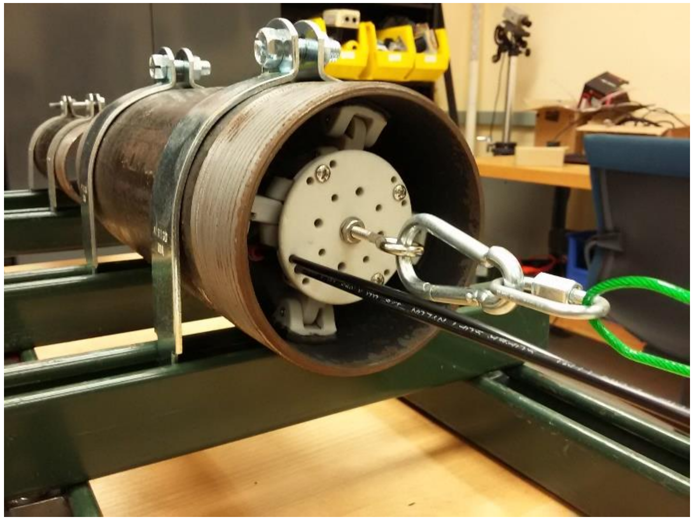
Bench Scale Testbed

The current grippers are able to provide a maximum gripping force of ~ 40 lbs.

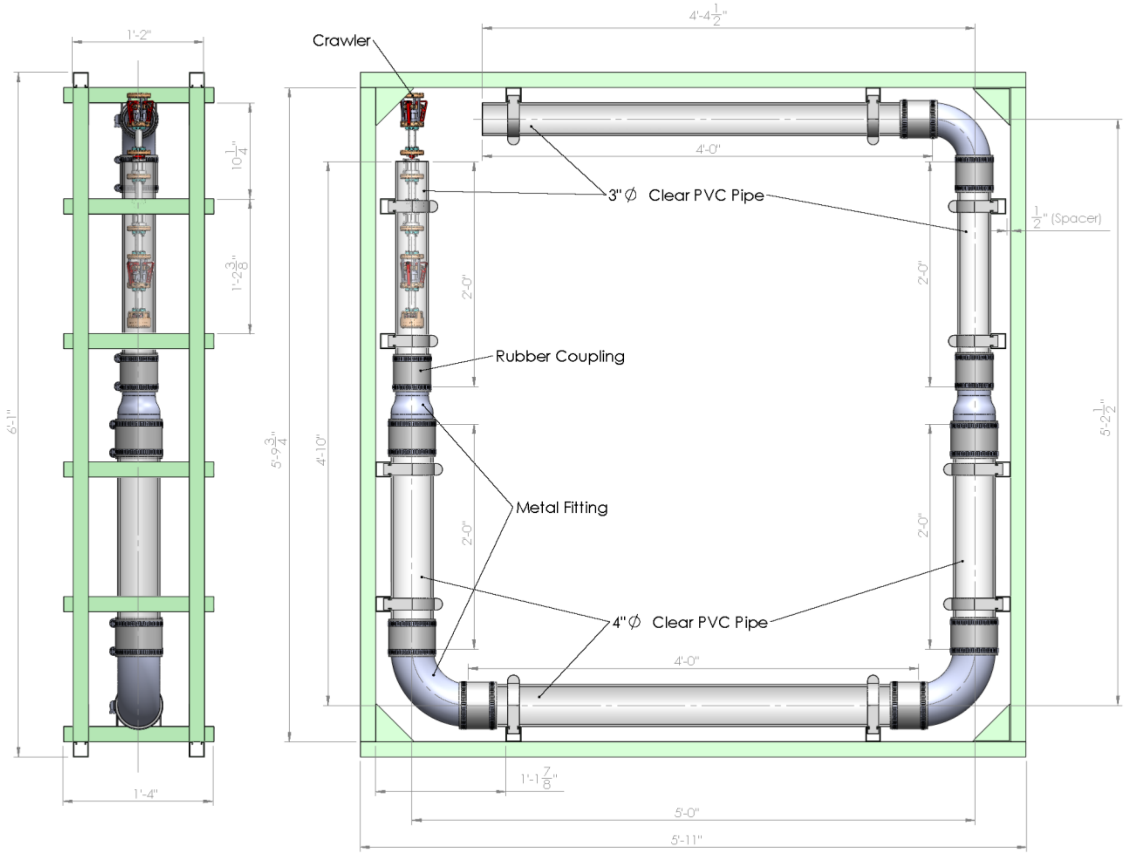
This is also the maximum force with which the mover modules can propel the crawler in the forward direction.

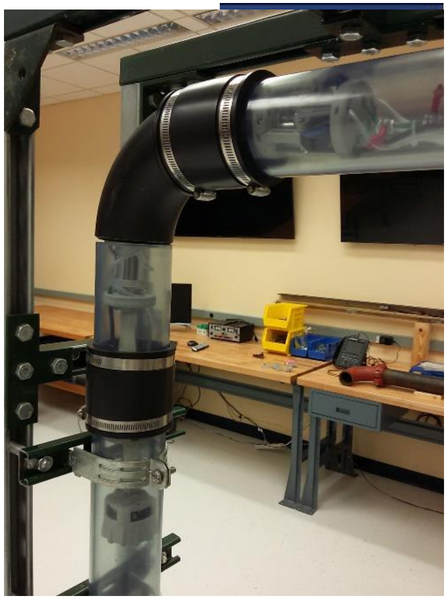


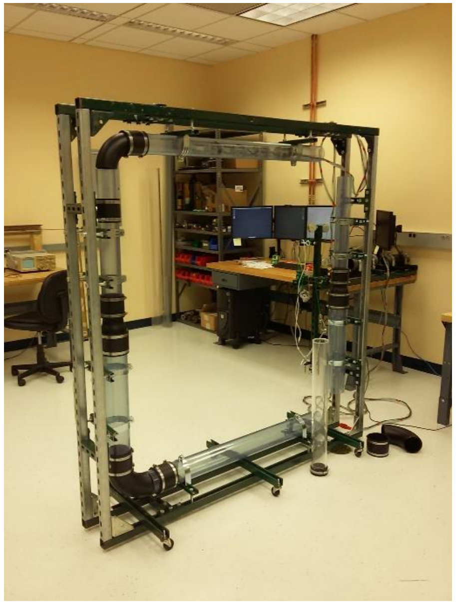




Bench Scale Testbed

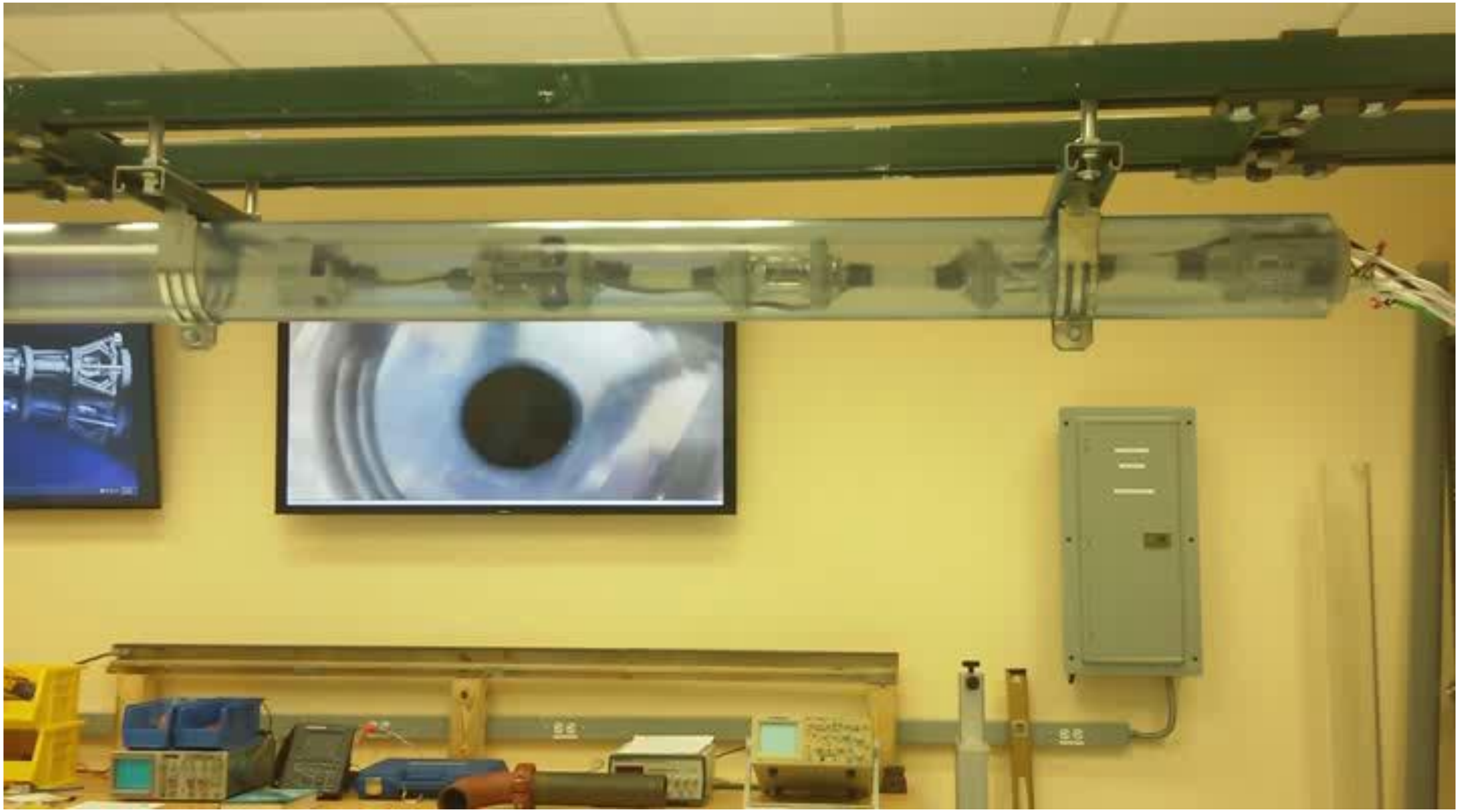






Based on maneuverability bench scale tests, the crawler has great potential to accomplish the proposed inspection.

Peristaltic Crawler



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Path Forward

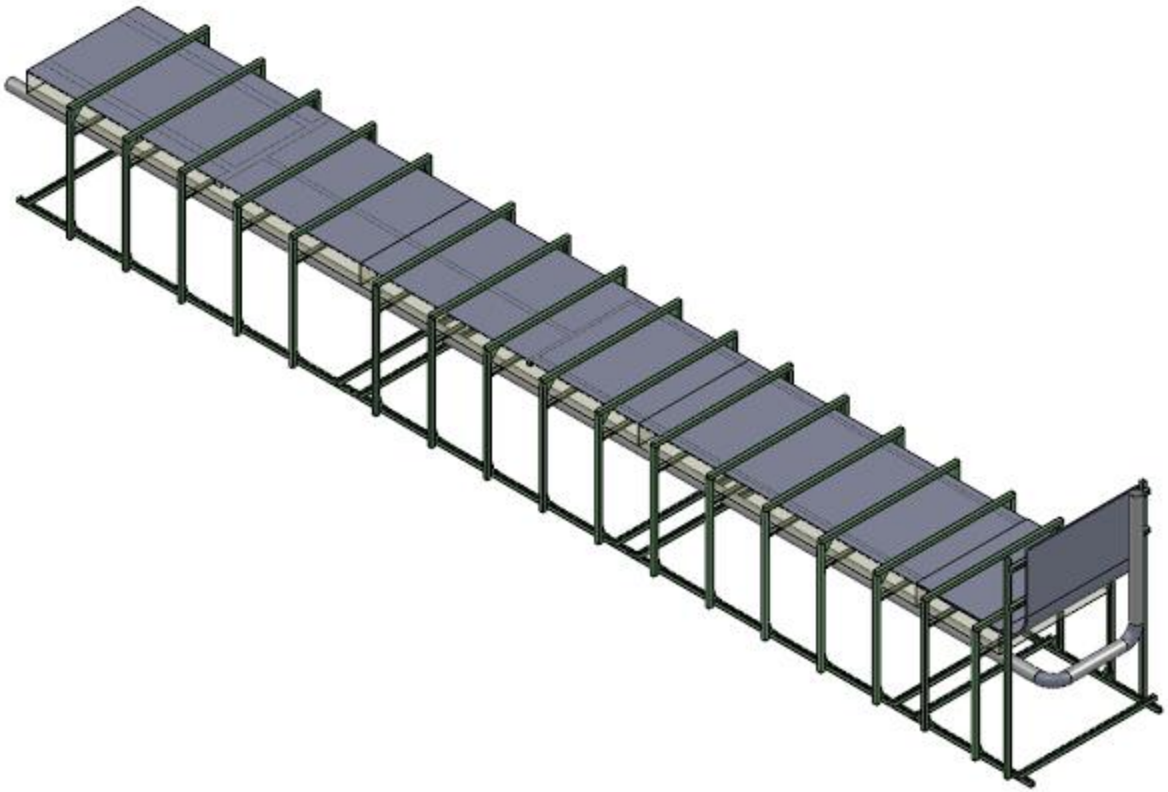
Crawler

- Develop full-scale mock up test bed
- Develop delivery mechanism for easy deployment
- Provide feedback of other inspection parameters (temp, rel hum, rad)
- Redesign a radiation hardened version using electric actuators
- Scale the design for inspection in smaller pipe sizes

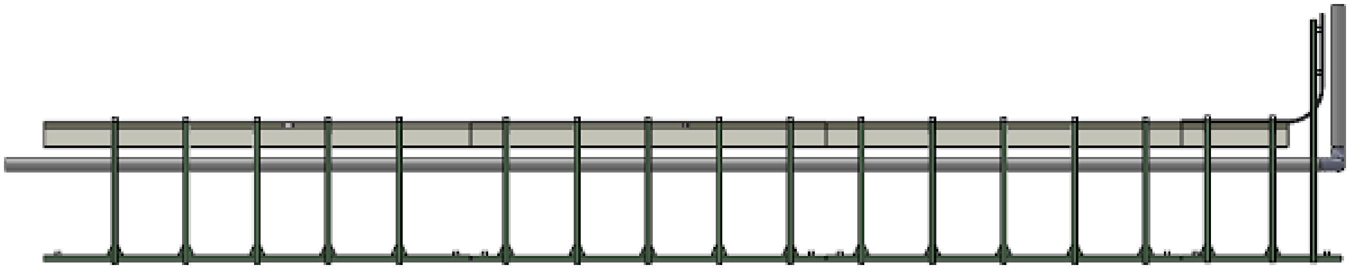
Rover

- Develop full-scale mock up test bed
- Develop delivery mechanism for easy deployment
- Provide feedback of other inspection parameters (temp, rel hum, rad)
- Redesign a radiation hardened version

Full Scale Mockup



Full Scale Mockup



Full Scale Mockup