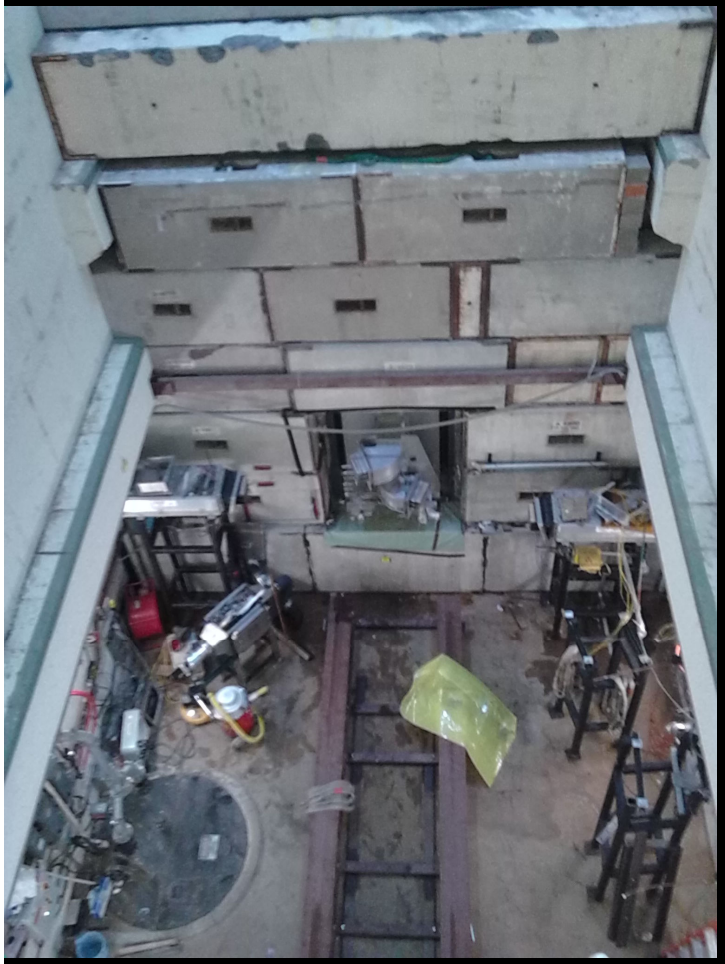
BNB Decay Pipe Inspection and B-field Measurements

05/07/2015

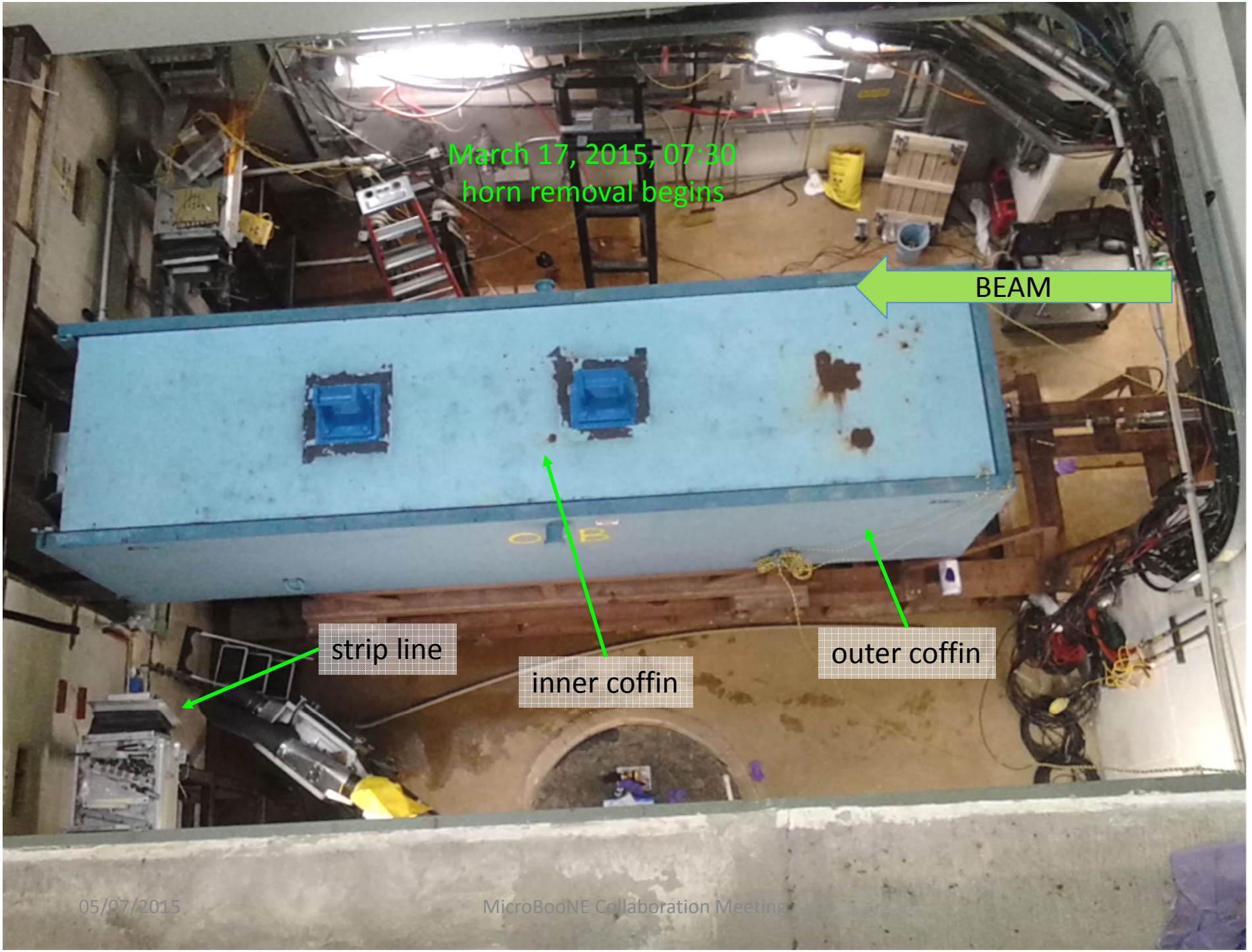
T. Kobilarcik

(most of this lifted from R. Van de Water)

Horn Removal



March 12, 2015
Coffin in target pile.
Shield blocks removed, showing MI12B
Horn rail system (primer brown) and parts of stripline can be seen.


March 17, 2015, 07:30
horn removal begins
BEAM
strip line
inner coffin
outer coffin

Horn2, inside coffin, at final resting place in Target Service Building.

March 17, 2015, 11:30

50m Decay Pipe Inspection

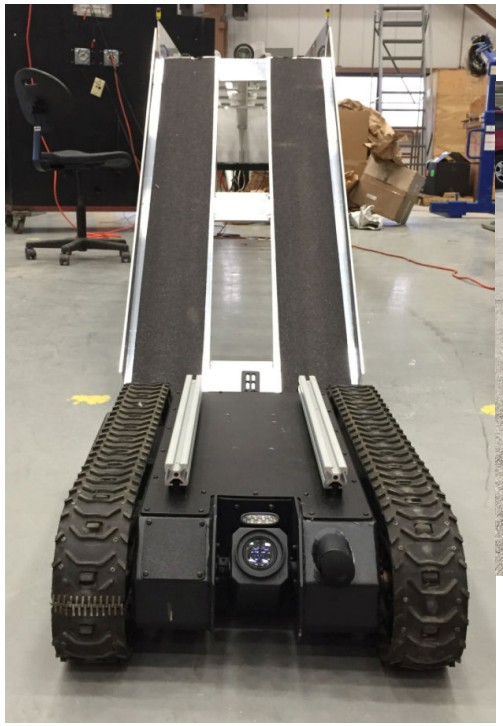
- On April 16 – 18, we successfully inspected and made B-field measurements in the decay pipe.
  - Much work and effort by many from AD-Target Systems (Keith Anderson, Mike Andrews, Frank, Jimmy, and others), Rad Safety (Joel), AD-external beams (Tom, Craig, Mike B), PPD (Rick Ford), Robert Cooper, Zarko, etc
  - Also big thanks to Steve Clayton (P-25 LANL) who designed/built the instrumentation package and DAQ/GUI code.

Robot FRED: Finding Radiation Evidence in the Decay pipe

LT-F Surveillance Robot from SuperDroid Robots

- To see this thing in action, check out video at http://www.superdroidrobots.com/shop/item.aspx/refurbished-prebuilt-lt-f-surveillance-robot-with-new-controller/1681/
- **Using the flippers, it can traverse 20" rise/step**. It should be able to traverse the entire length of the decay pipe.
- Will use a bridge/gateway to traverse the 23" collimator region.
- Robot Dimensions: Total height (floor to top of treads or camera housing): ~7 inches, total width: ~18.625 inches, total length: ~27 inches
- Built in video camera and lights. **Camera is a high quality 27X zoom, and low light capable**

FRED Performed as designed and travelled the entire decay pipe

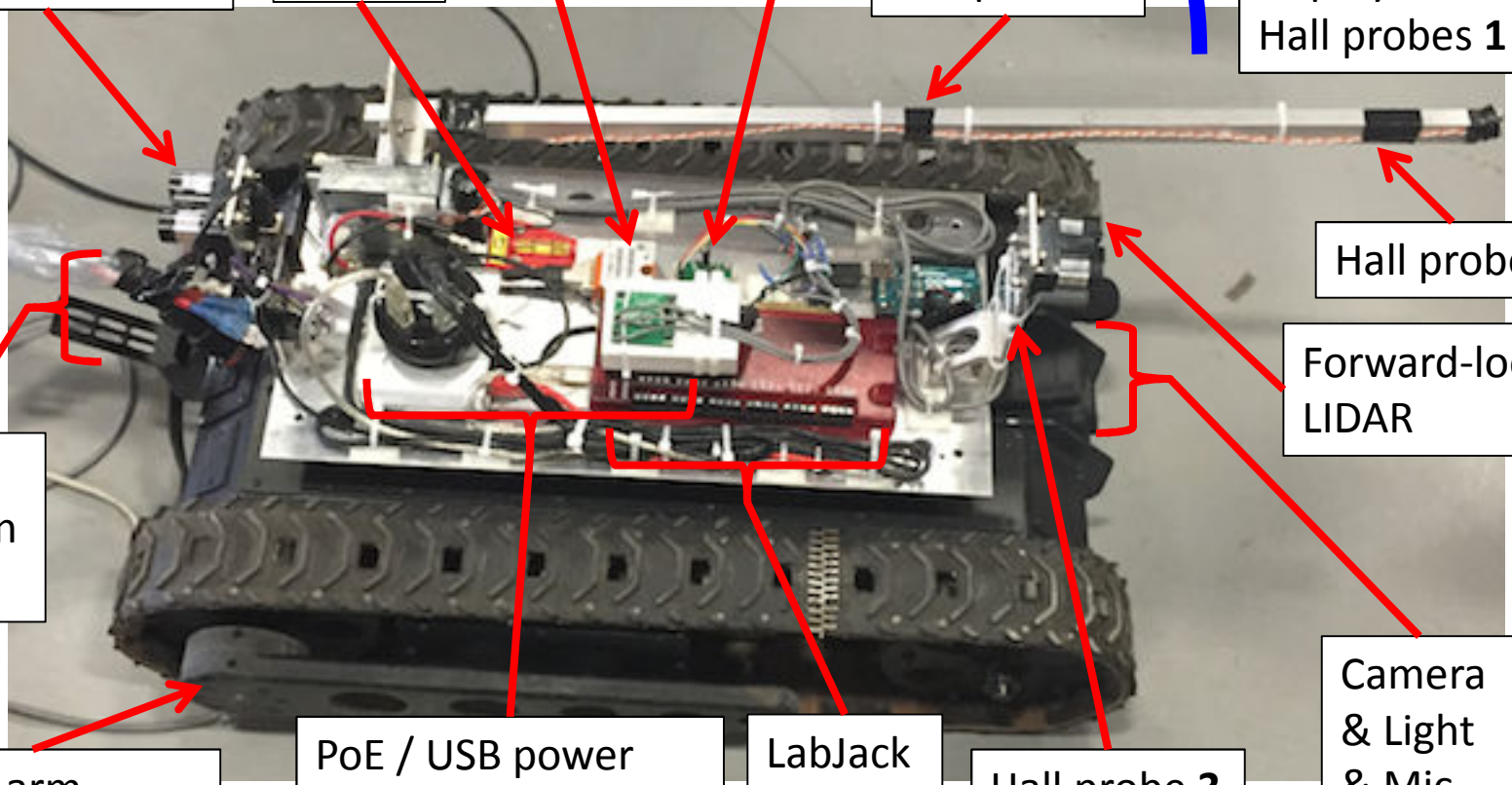


Collimator Deployment Ladder

- Some hiccups in the controller, but ultimately all the systems (flippers, camera, motor, etc) worked and FRED made it to the 50 m absorber.
- Low torque motors and tracks performed well. Flippers got the tank over the 25m step.
- The collimator deployment ladder also worked well after some re-engineering.
- See lots of pics at http://www-boone.fnal.gov/BNBpics_Robot/

Robot FRED: Instrumentation Package

Slide courtesy of R.L. Cooper



Instrument Package
(Steve Clayton/vdwater – LANL)

- The robot was instrumented with:
  - video camera and lights (already on robot)
  - USB to Ethernet read-out of all devices. Power via Ethernet POE
  - Three magnetic field probes (Ametes DMFS-3 Axis, 0-75Gauss range, 3% reading accuracy).
  - Mag probes read out via LabJack analog to digital 16-18+ bit converter, 14 channels -> may add more mag probes…

3 axis mag probe

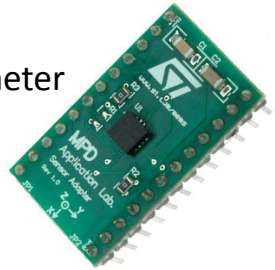
A/D 14 converter

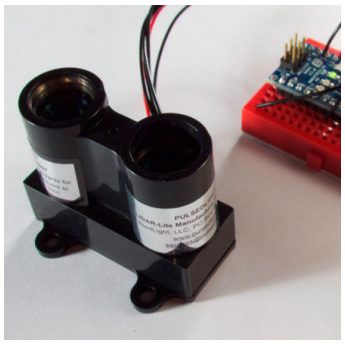
- One mag probe will be fixed to the instrument package, the other two will deployed via a motorized antenna so the probe is in the center of the pipe.
- Probes supplied by regulated 5V, and monitored in the LabJack

Instrument Package (Clayton/vdwater – LANL)

- The robot was instrumented with:
  - 3 Axis gyro (STIM 210) to determine orientation B-field probes.
    - Integrated accuracy 0.5 degrees/hr. Maximum rate 400 degree/s.
    - This is crucial in order to determine the Bx, By, and Bz fields necessary to reconstruct the proton flight path.

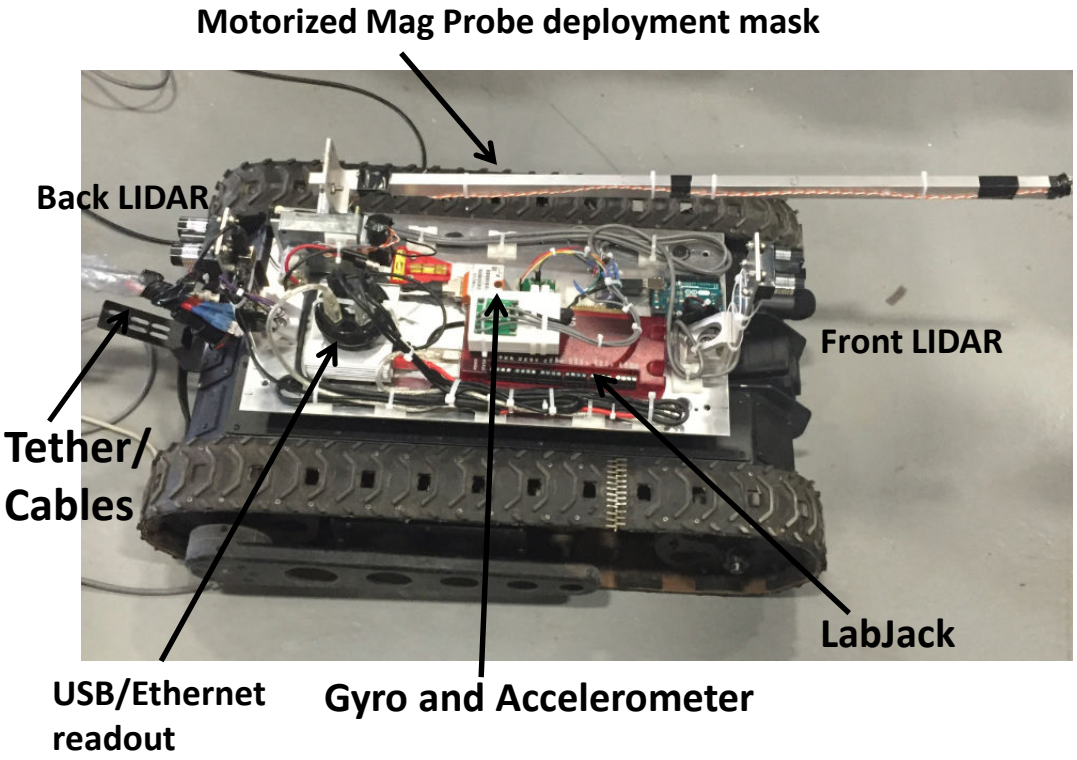
3 axis gyro 

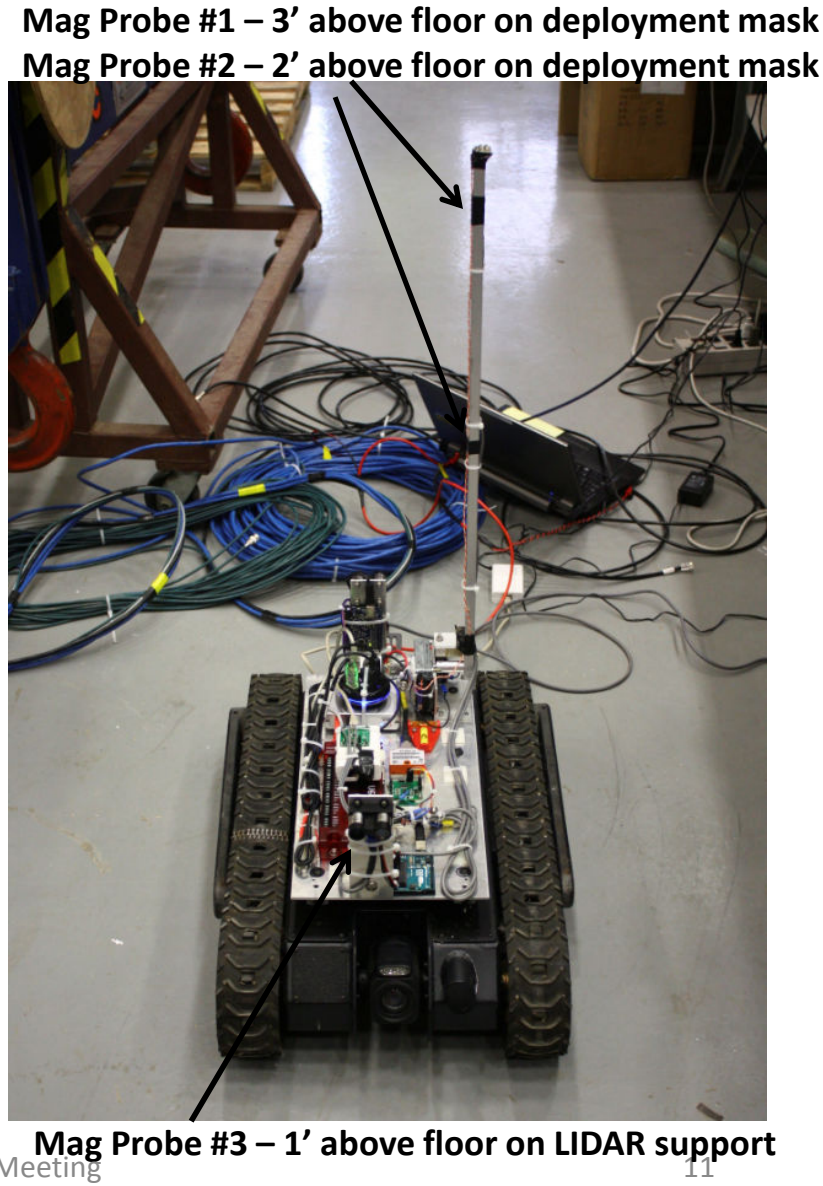
Accelerometer 

Laser Ranger (LIDAR) 

  - Install an accelerometer (STMicroelectronics LIS344ALH) to provide orientation backup to the gyro.
    - Measures vertical axis (relative to gravity). → accurate y-axis
    - Does not integrate, or have maximum rate, so resistant to fast/sudden movement.
  - Installing LIDAR-Lite (IR Laser) in front and back of robot to provide ~cm resolution range to the 50m absorber and collimator.
    - Might install on a rotating platform to give range to side of decay pipe, etc.

FRED Instrument Package
It isn't pretty, but worked extremely well





- All measurements (10-100Hz) were recorded to disk/file with time stamps. Also took snap shots every 3'.
- LIDAR measurements not robust do to reflections. Relied on measuring the tether every 3'

Sample Snap-Shot Measurements with the Instrument Package

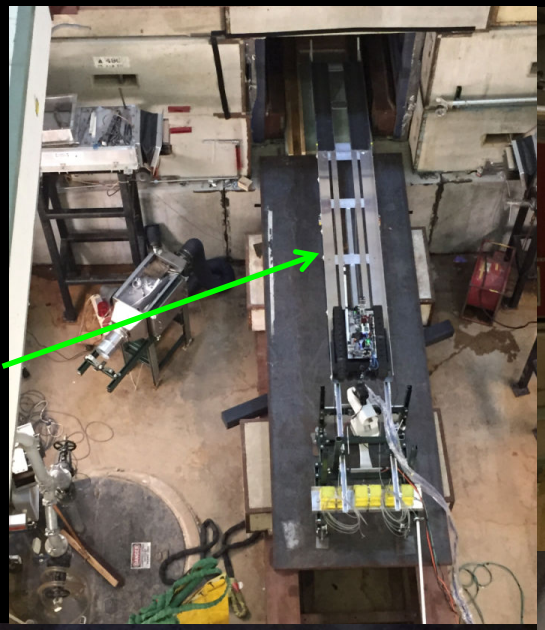
```
##################################################################
>>>Pt25  at 50m absorber!!
##################################################################
Timestamp (POSIX time_t) = 1429366449
Local time = Sat Apr 18 08:14:09 2015
Comment:
Hall Probe 1 = (0.334957, -0.106543, 0.00185714),  offset = (0.075, -0.54, -0.665)
Hall Probe 2 = (0.360457, -0.164743, 0.0998571),  offset = (-0.58, -0.4, -0.244)
Hall Probe 3 = (0.250257, 0.0101571, 0.175157),  offset = (-0.79, -0.782, -0.443)
Hall Probe Vdd = 5.0088 V
External Temperature = -7.8808 C
Labjack Internal Temperature = 22.9431 C
Accelerometer = (-0.0187, -0.0595, 0.9903),  offset = (0, 0, 0)
        Roll = -3.438357594 deg, Pitch = -1.079850308 deg
Gyro = (-4.1918, 6.7601, 2.397),  offset = (0, 0, 0)
Lidar1 d = 13 cm
Lidar2 d = 0 cm
Time since last read:
        Labjack 0.2469348907 s
        Gyro 0.4819998741 s
        Lidar1 0.1014199257 s
        Lidar2 0.04384589195 s
##################################################################
```

All data can be found in: Beams-doc-4825

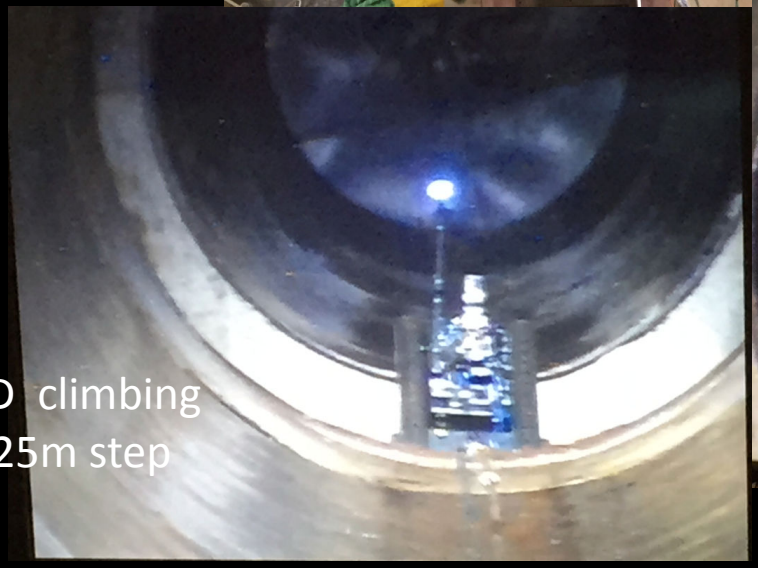
Boldly go where no one has gone…

FRED ready to go into the horn chase

Deployment Ladder



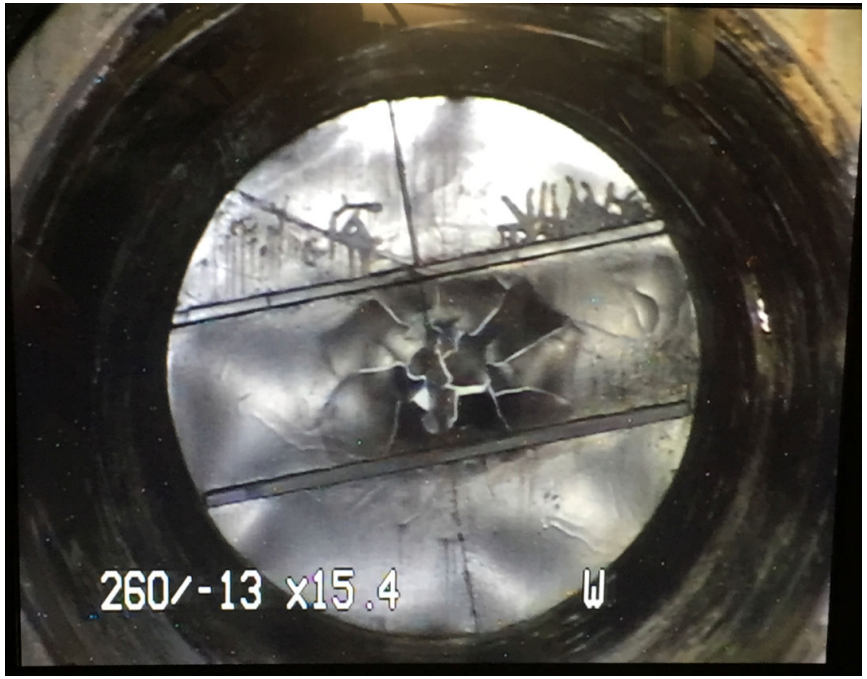
FRED in the collimator



FRED climbing the 25m step

FRED at the 50m absorber, what the heck is that…

50m Absorber End Cap!



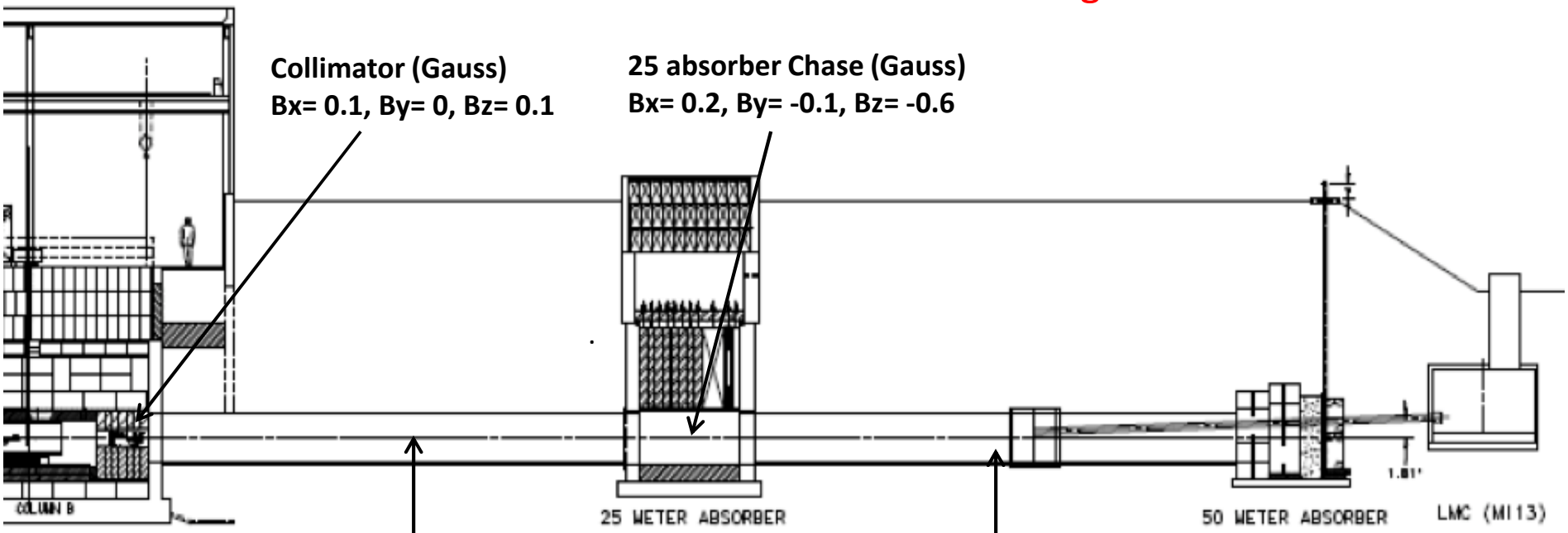
More pictures at:
http://www-boone.fnal.gov/BNBpics_Robot/

- The construction diagrams show an end cap, but nothing about composition or thickness.
- Burn marks and cracking of surface coating evident (galvanized steel?). Beam burn marks centered on the decay pipe – that is good!
- Up to a 4” air gap or filled gravel gap between end cap and 50m absorber.
- Tyler is working on beam simulations variations.
- We are brainstorming if we can learn anything else about alignment and measurements we could make as the horn chase region is accessible for the next few weeks.

Initial Results on B-field Measurements

- **+Bx = forward along beam line**
- **+By = Left of beam forward**
- **+Bz = Up**

- Within each region, B-field mostly stable/constant
- Gyro/Accelerometer recorded tank centered on desired axis with < 5 degrees



Integrating B-field over distance Gauss-meter

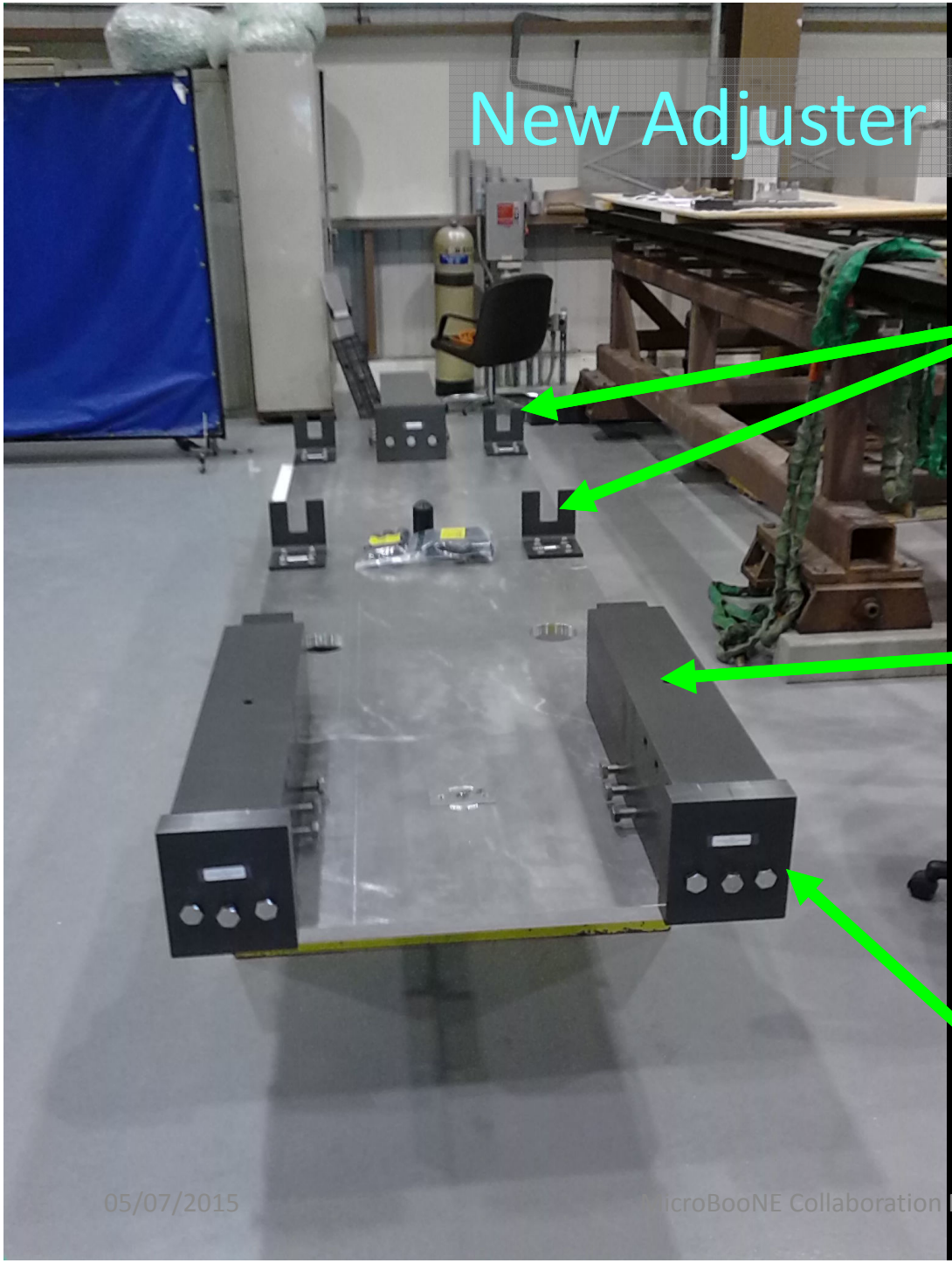
+Bx = forward along beam line, +By = Left of beam forward, +Bz = Up

- Collimator (2m):
  - Bx= 0.2, By= 0, Bz= 0.2 G-m
- Collimator to 25m Absorber(20m):
  - Bx= 8.0, By= -2.0, Bz= -2.0 G-m
- 25m Absorber Chase (5m):
  - Bx= 1.0, By= -0.5, Bz= -3.0 G-m
- 25m to 50m Absorber(20m):
  - Bx= 6.0, By= -2.0, Bz= 0.0 G-m
- Integrating over entire length:
  - Bx= 15.2, By= -4.5, Bz= -5.2 G-m
- **Figure of merit: 250 G-m will produce a 1 mRad beam deflection**

Summary of Decay Pipe Inspection

- Decay Pipe inspection and B-field measurements were a complete success!
- Visual inspection found no problems/concerns with the decay pipe. Normal wear and tear.
- The only surprise was the end cap at the end of the 50m pipe. Need to determine composition/thickness and add to beam simulations.
- Magnetic field measurements found no significant B-fields throughout entire decay pipe/collimator regions.
  - B-fields induced beam deflection < 0.1 mRadians

New Adjuster Module



Brackets to hold push rod

Top plate of new adjuster module

Moving parts are anodized

Lifting Wedge

Another view

No work is scheduled for weekends – this time will be used to make up slippage.

This schedule is aggressive.

We would receive 20 days of beam.