Explorer-II: Long-Range Untethered Real-Time Video & NDE Live Gas-Main Inspection System

Prototype Field Deployment

Brookville, PA – September 13th, 2007

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TOPICS TO BE COVERED

- System Overview – 10,000 ft. View
- Overall Program Status – by Mid-Sep’07
- Endurance Testing Summary
- Testing & Field-Trial Status

Explorer-II
Program Schedule

- X-I Program……..……..->Jan ’00 thru Nov’04

- X-II Program ……..……->Aug’04 thru Sep’07
  - *Kickoff Meeting…….. ……..…….. Aug’04*
  - *Preliminary Design Review…….. ……..…….. Jun’05*
  - *Final Design Review…….. ……..…….. Dec’05*
  - *Prototyping & Testing ……..…….. Jan’06 - Dec’06*
  - *Robot Train Acceptance Demo ……..…….. Dec’06*
  - *Robot System and Sensor Integration ……..…….. Jan’07 - May’07*
  - *System Acceptance Demonstration ……..…….. Jun’07*
  - *System Endurance Testing ……..…….. Jun’07-Aug’07*
  - *Field Trials…….. ……..…….. Sep’07*
  - *Final Reporting ……..…….. Sep.’07*

X-II
Performance Requirements

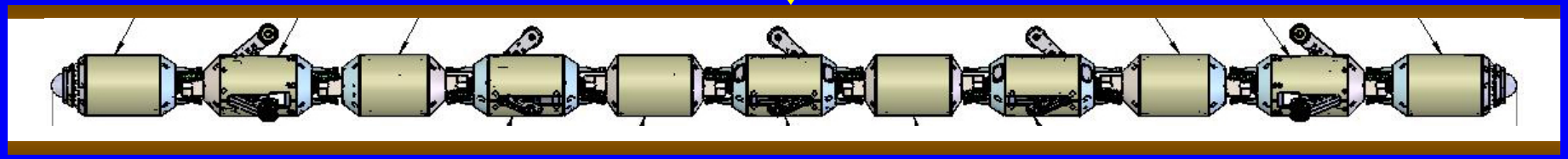
- Access live pipe through angled fitting (not vertical)
- Operate in 6 to/or 8 inch CI/ST pipe in horizontal, sloped, elbowed, T'ed & vertical sections
- Operate at up to 750 psig and (minimal) flows
- Integrate an NDE-sensor from SwRI; Specify generic electro-mechanical & software interface
- Minimize length and weight
- Operate on sequential daily shift(s)
- Inspect at speed (4 in/sec) & range (2,500 ft.+) while minimizing down-/recharge-time
- Provide wireless interface and GUI similar to X-I, including NDE-data transfer port

X-II

System Diagram

OCS w. GUI

NDE Sensor Processor

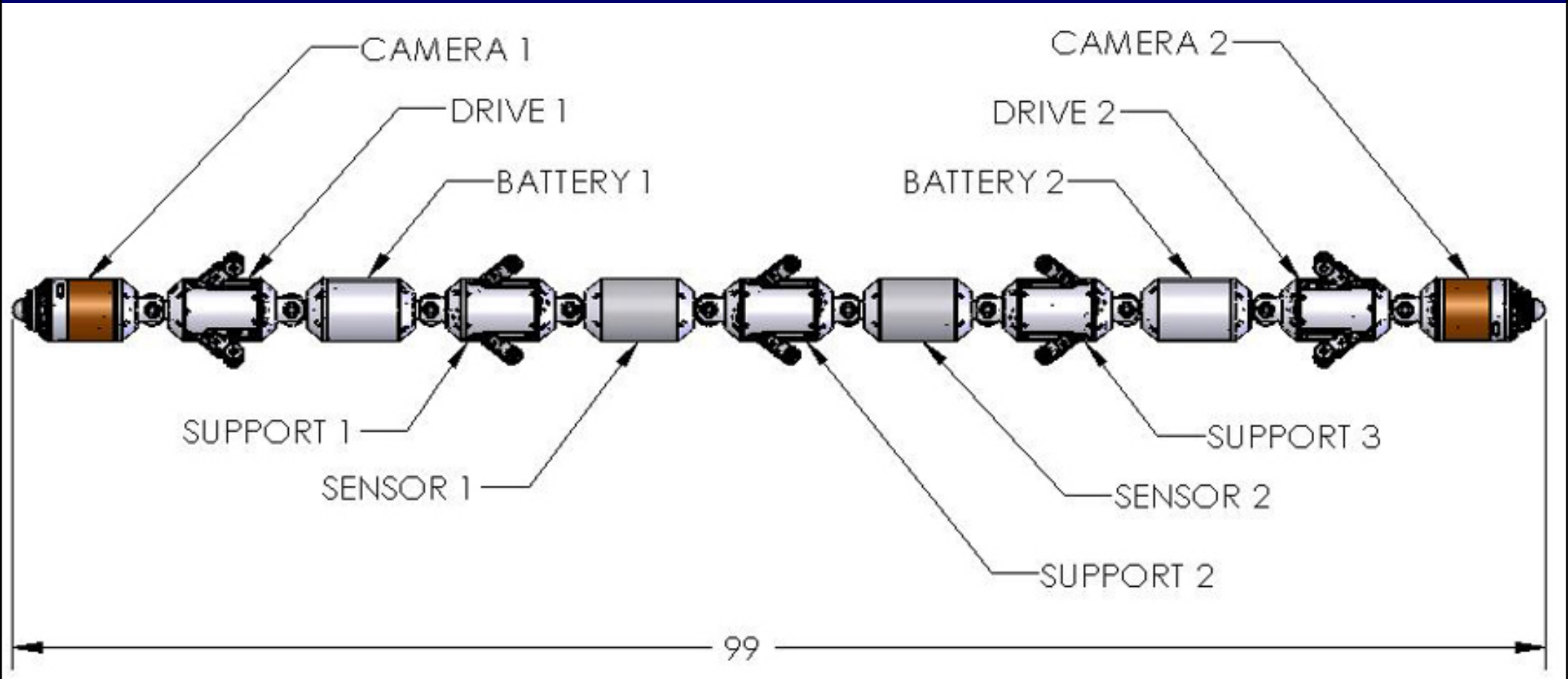


X-II Crawler with NDE Sensor

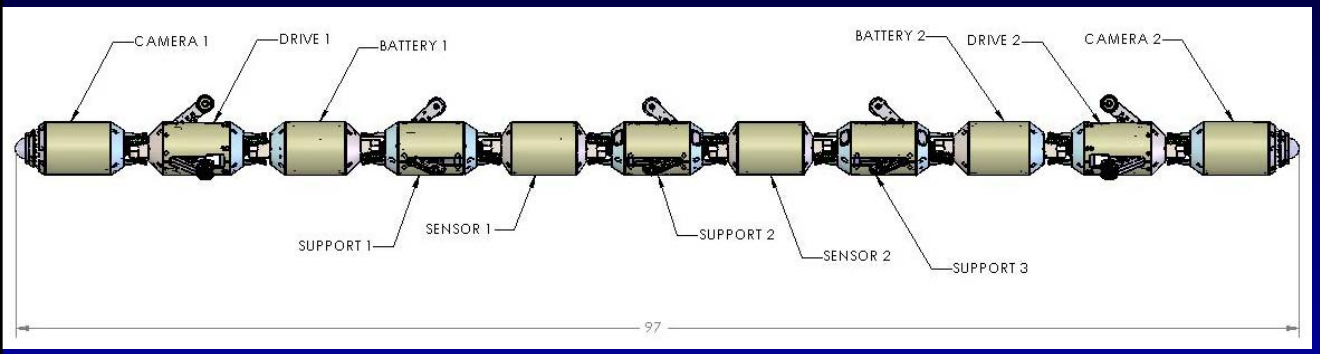
X-II
System Specifications

- Physical
  - Length: 99” (~ 8.3’)
  - Weight: 63.5#
  - # Modules: 11
  - Drive (2), Support (3), Battery (2), Camera (2), Sensor (2)
  - Interconnecting Steering-Modules: 10 (Roll=2; Pitch=10)
  - Power: Li-Polymer Custom packs with safety charge/discharge circuitry
  - Electronics: Multi-8-bit processors with dual 32-bit embedded CPUs
  - Bus: Internal Power- & CAN (2.0b) Data-Bus; External WB-link
  - NDE-Sensor: RFEC or UT
  - Feedback: Odometer, Angle, Inclination, Position (Sonde)
- Operational
  - Endurance/Range: 3,500 ft. RT; 6,000 ft. one-way over 8 hrs.
  - Launcher: Weld-on angled pipe-section(s) w. valve and full-bore cutout
  - Comms & Control: Wireless & GUI w. joystick
  - Real-time video & multi-mode NDE data-transfer
  - Safety: Open electronics-/battery-volumes with evacuation/purge in launcher

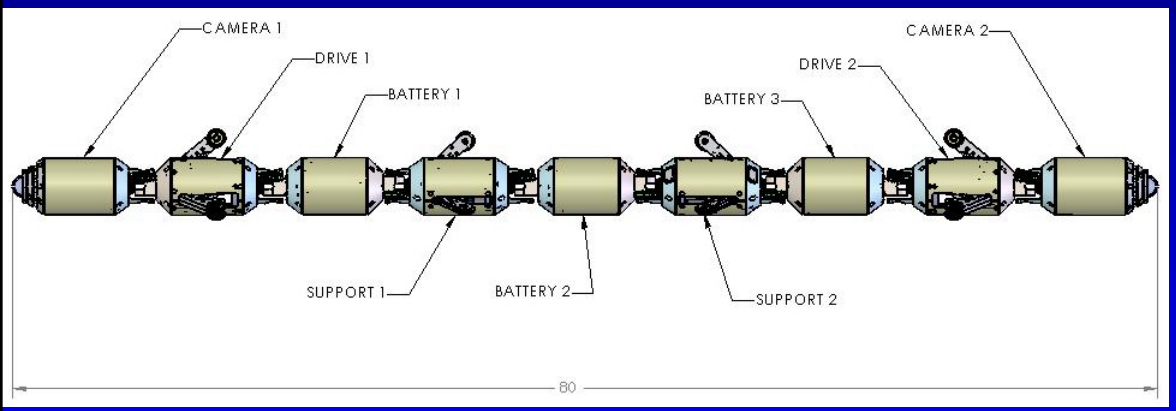
X-II Layout - Crawler



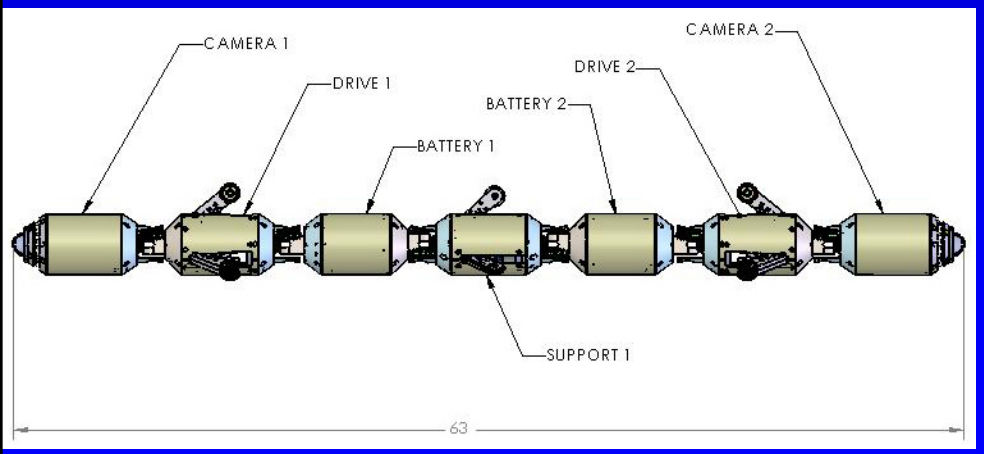
X-II Layout – Crawler Options



- X-II with 2 Sensor Modules



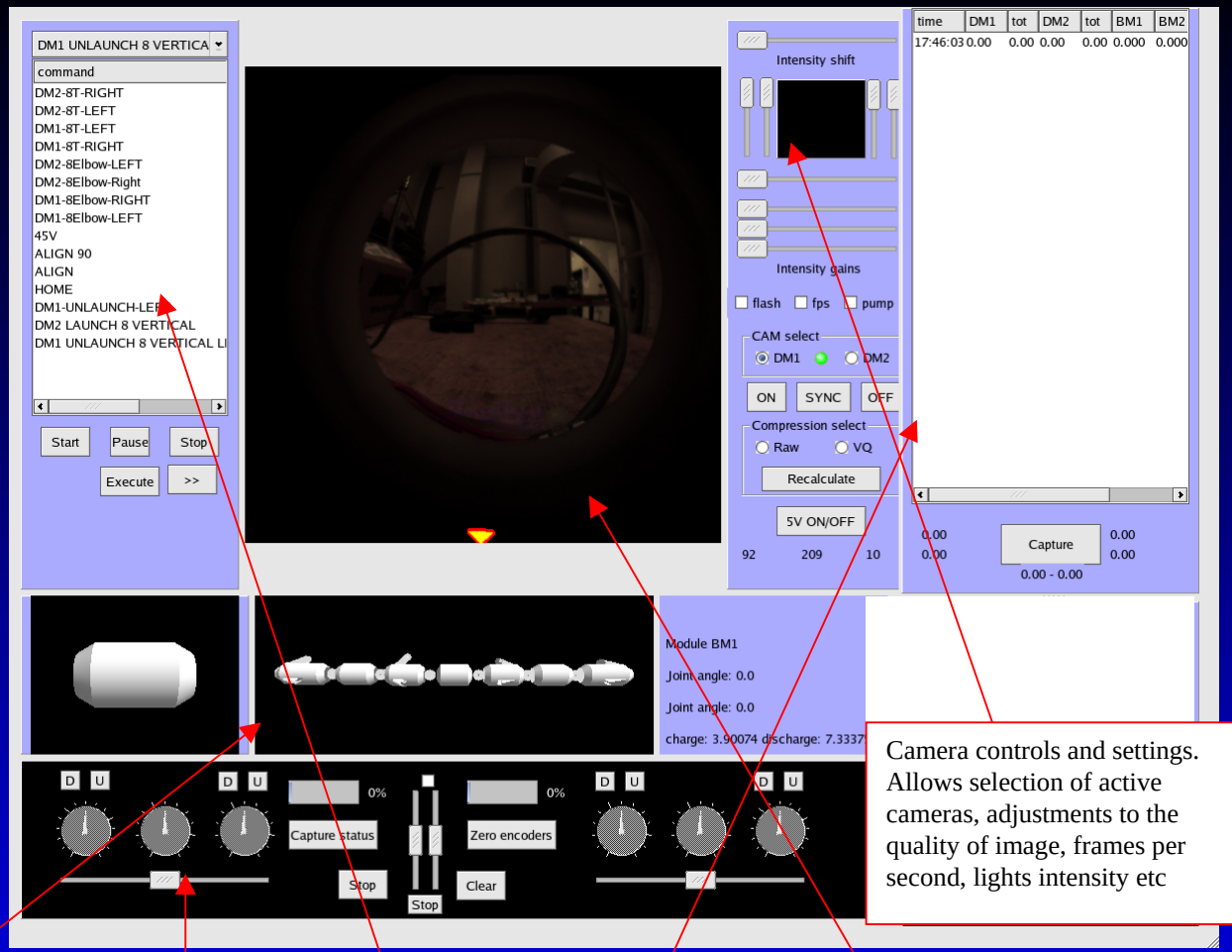
- X-II w/out Sensor Mod.s
  Long Range Inspect.



- X-II without Sensor Modules
  Base Range Inspector

X-II Design

- Controller - GUI



Camera controls and settings. Allows selection of active cameras, adjustments to the quality of image, frames per second, lights intensity etc

Robot status display:

shape and orientation
odometry
battery information and voltage

Automated mode selector.

Enables automated behaviors. Displays high-level generic controls, particular to each automated behavior.

Streaming video.
640x480 resolution, 15fps.
Maybe two simultaneous streams from both cameras at lower resolution. Displays current gravity vector and accepts operator input for alignment adjustments.

Manual control:

Allows fine manual control of individual actuators.

Operator data logger:

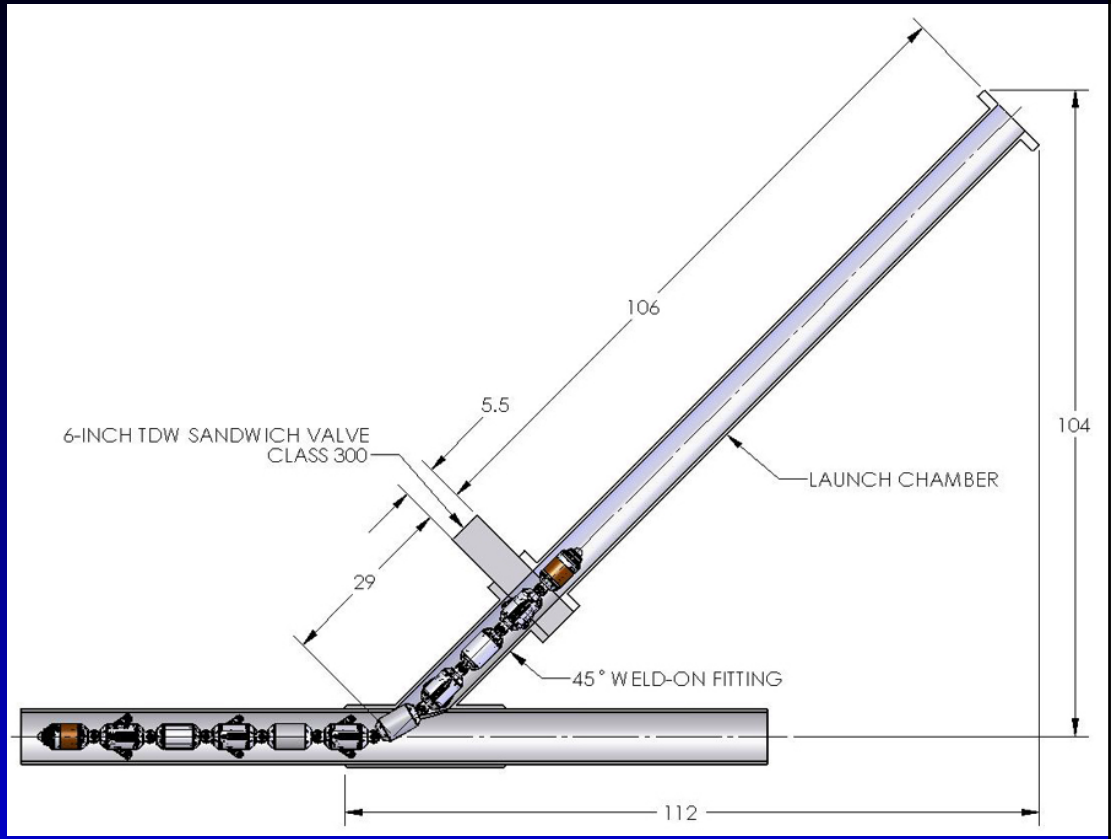
Timestamped odometry and battery information with operator's notes and snapshots.

To be added:

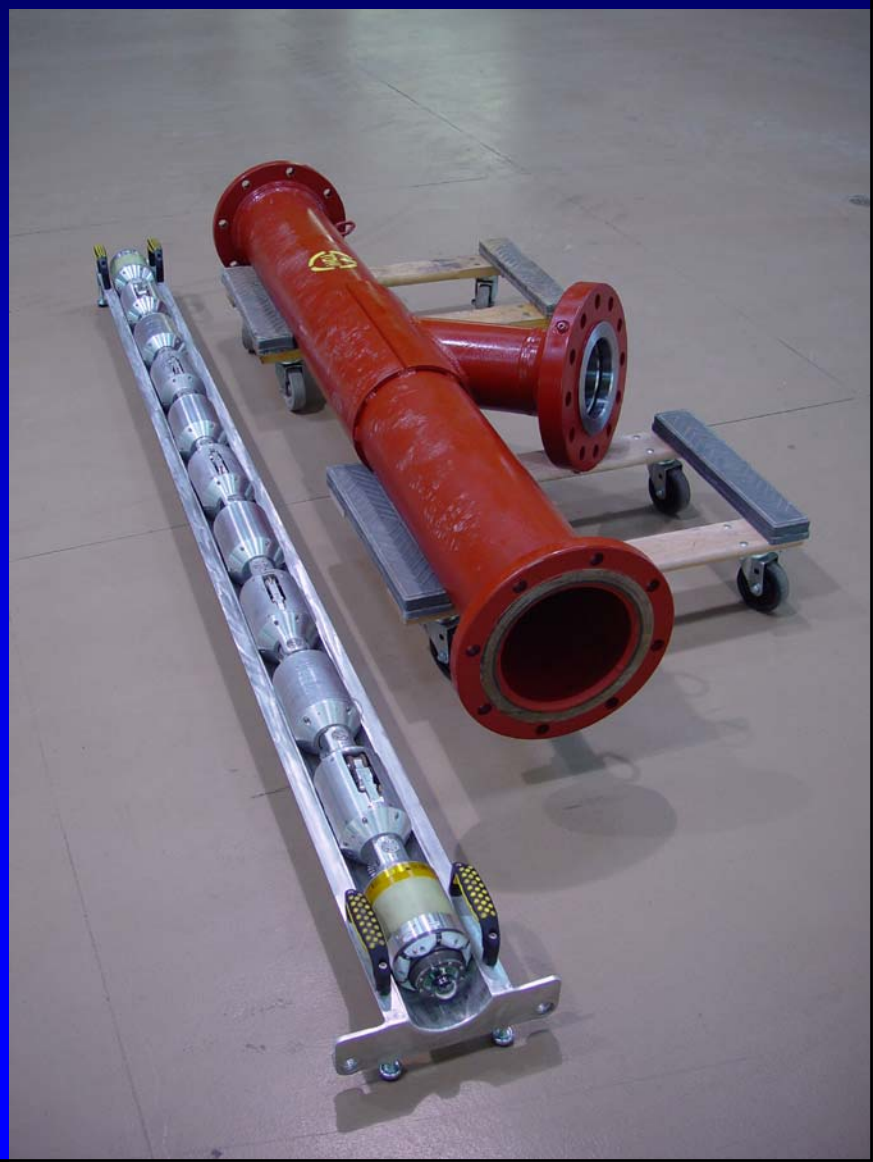
Sensor controls.
Integrated status display.
Automated behavior controls.

X-II Launching

- Fitting Selection
  - Weld-on 45° fitting
  - Removable SW-valve
  - Launch-tube
    - Steel; Pressure-rated to 750 psig
    - Venteable/Purgeable w/ Launching/Parking Latch
    - Cantilevered at fixed angle OR braced off pipe/ground
    - Balanced for jib-crane/excavator handling



Explorer-II
Launcher Setup Pictures



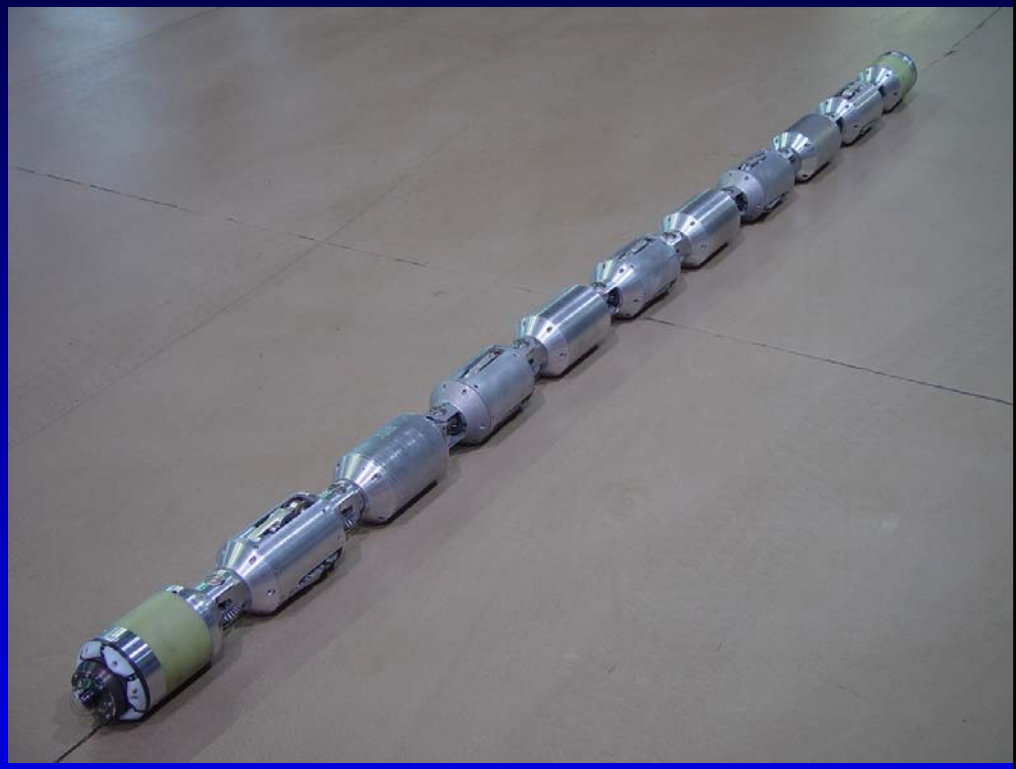
Explorer-II
Final System

- Overall Specifications
  - Applicable Pipes: 6” – 8 “
  - Obstacle Handling: 90-elbows, Ts, Ys
  - Train
    - Weight: 63#, Length: 99” , Modules: 11, Towing: 120#
  - Power
    - Li-Poly Battys, 15.6 A-hrs.
  - Mission
    - Endurance: 8+ hrs. @ 4 in/sec
    - Comms range: Varies, 1 mile (ea. way) exp.

Explorer-II

Overall Program Status – Sep. '07

- Prototype System
  - Fully assembled and operational
    - Wireless and on battery
    - Integrated RFEC sensor modules
- Prototype Robot Testing
  - Indoor/Outdoor network (8")
    - Endurance Testing
      - Planar Elbow, T-turn and Y-turn
      - Launcher: Deploy & Receive
  - Air Pressure-Tested (750 psig)
  - NG Pressure-Tested (502 psig)
  - NG Field Test (110 psig)

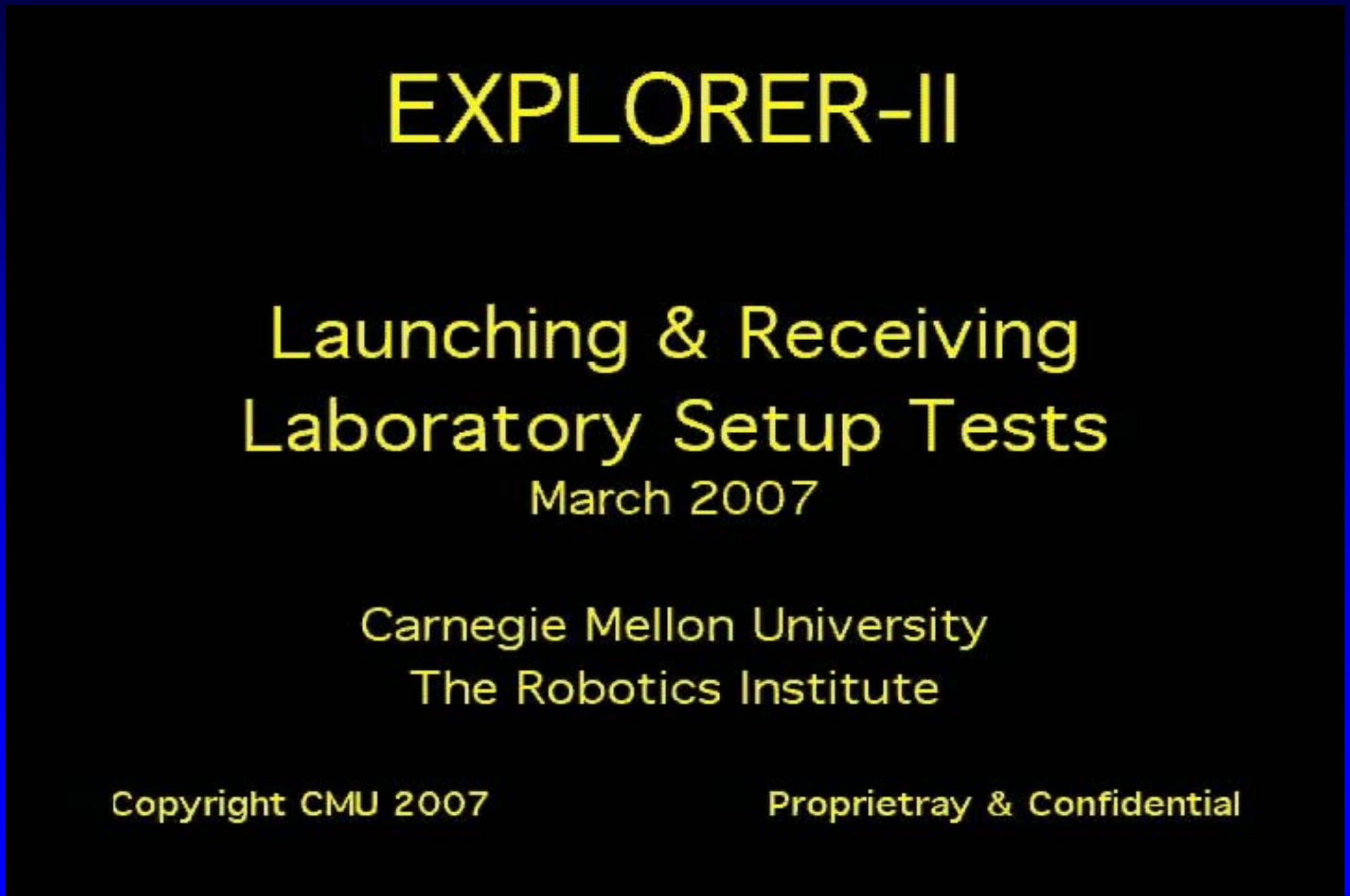


Explorer-II
Endurance Data to-date (Sep'07)

Endurance Data (10-3-07)	
Launch/Unlaunch	80
T turns	35
Elbow Turns (90s & 45s)	41
Distance Travelled	10,490 ft.

Explorer-II
Indoor Pipe Network – Dec. '06

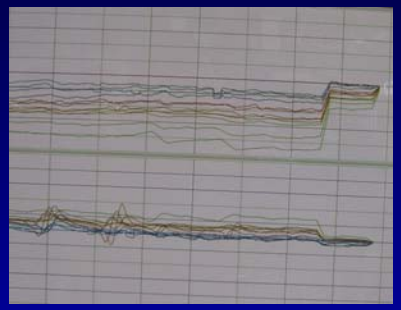
Explorer-II
Launch/Recovery – Mar. ‘07

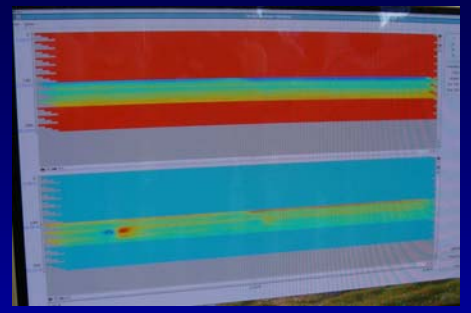


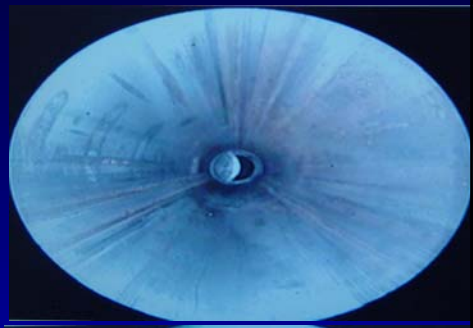
Explorer-II
CMU Acceptance Demo (Jun'07)

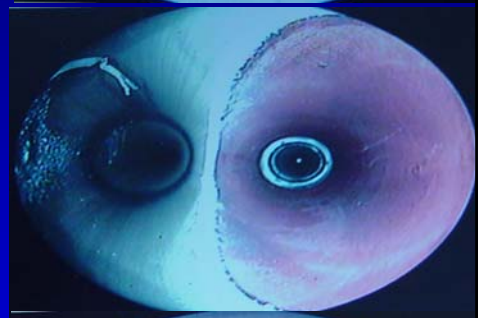
Explorer-II
NG Pressure Testing (Aug'07)
Henderson Station, National Fuels

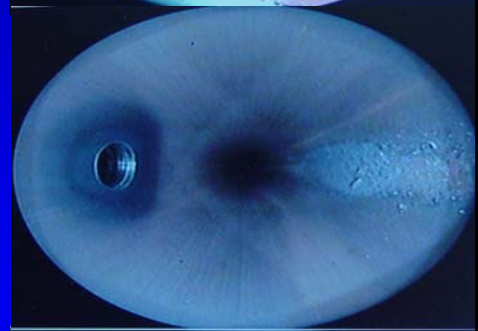
X-II Live Pipe Trials
Nat. Fuels - Brookville, PA (Sep.'07)

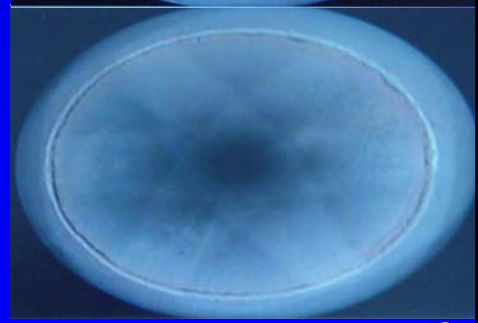






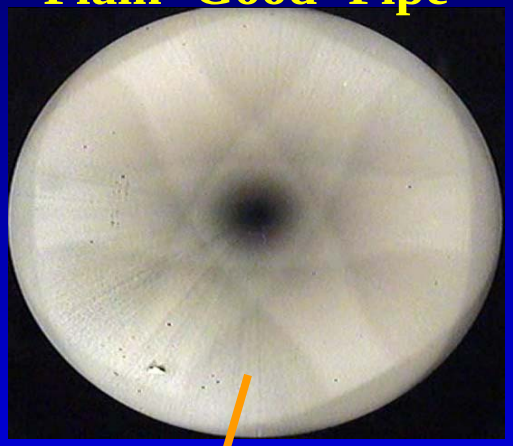


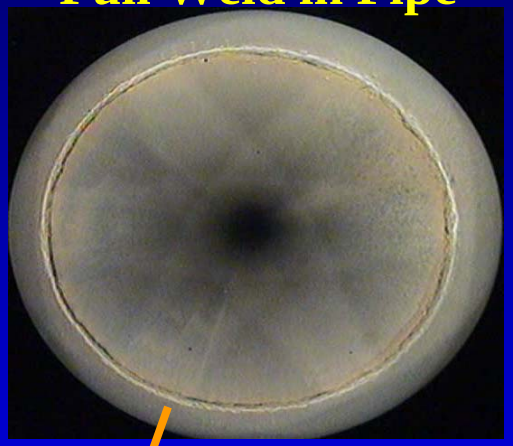
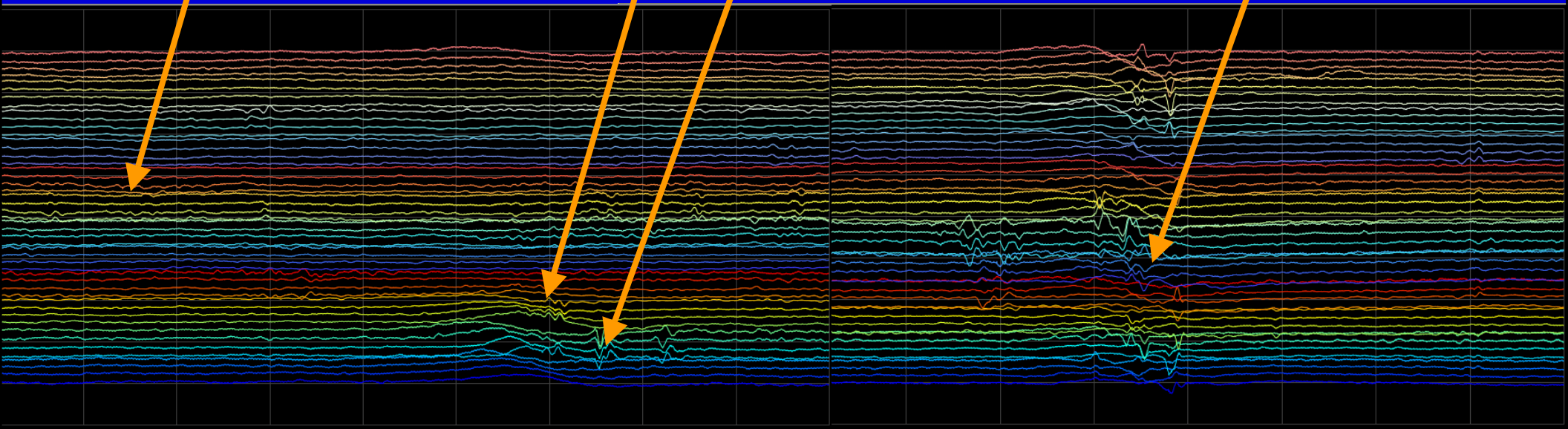




X-II Live Pipe Trials
National Fuels - Brookville, PA
RFEC (48-channel) NDE Data

Plain 'Good' Pipe



Heat & Tap in Pipe

Full Weld in Pipe