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# Secure Wireless Tritium Air Monitoring Cart Development

*PDRD Projects #SR13020, SR14058*

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Research and Development Engineering

*Tritium Focus Group Meeting*

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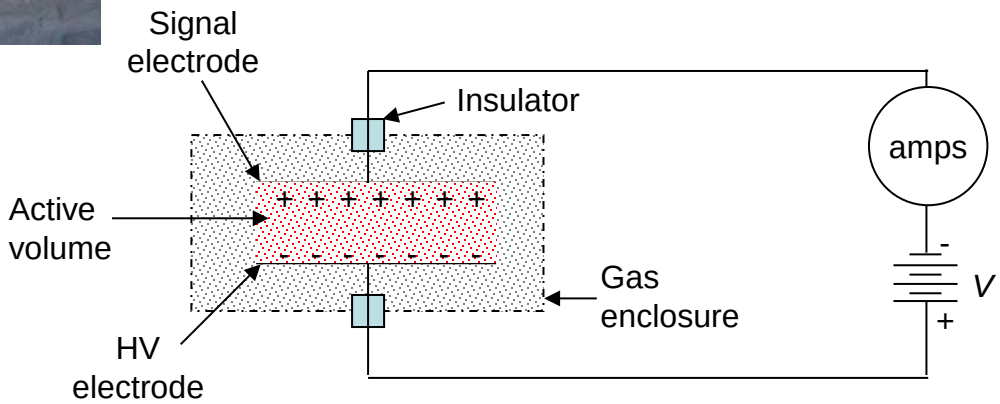
# Existing Tritium Air Monitoring System – Opportunity for Improvement

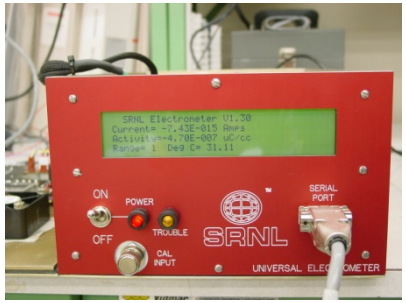
- Complexity of the System
  - Ion Chamber
  - Pico-ammeter
  - Sequenced Sampling
  - Solenoid Sample Valves
  - Pumps
  - Tubing
  - Flow Switches
  - Electronics
  - Over 100 monitoring points in one facility alone
  - Reliability affected by the complexity of the system
- Issues
  - Nuisance Alarms
  - Surveillances – Technical Safety Requirement Risks
  - Managing Limiting Condition of Operation (LCO) Requirements
  - Preventative Maintenance and Corrective Maintenance Costs (many moving parts)
  - Replacement Item Evaluation (RIE) & Commercial Grade Dedication (CGD)
  - Complexity of Alternate Monitoring

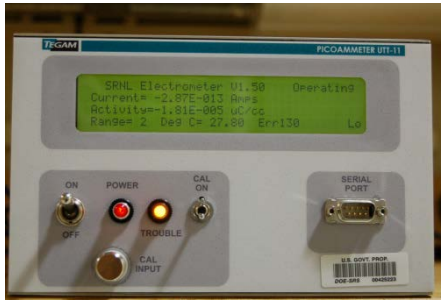
# Purpose

- Meets a Technological Need
  - Tritium Technology Management Council SRDI Sensor Technology Need:
    - Develop sensors that take advantage of newly-approved equipment certified for wirelessly transmitting classified data.
    - Improve reliability and reduce complexity of tritium air-monitoring and glovebox atmosphere monitoring systems.
- Provides Capability that is not Currently Available
  - Mobility / Portability
  - Hot-Swap Capability
  - Small Footprint
  - Less Complex Design (no pump, no solenoid valves, fewer components to maintain)
  - Real-time Continuous Monitoring
- Built Upon Existing Developed Technology
  - Universal Tritium Transmitter (UTT) ←PDRD
  - Screen Wire Ion Chamber ←PDRD
  - Secure Wireless Project Y-556 ←Groundwork from PDRD

# Universal Tritium Transmitter (UTT) & Screen Wire Ion Chamber

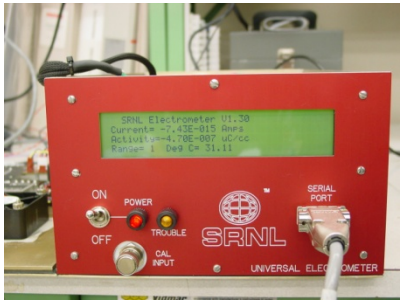


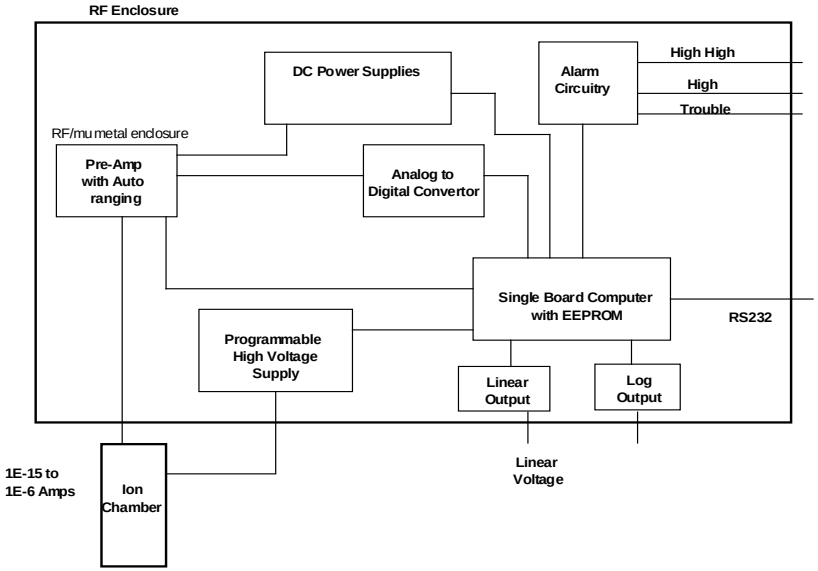



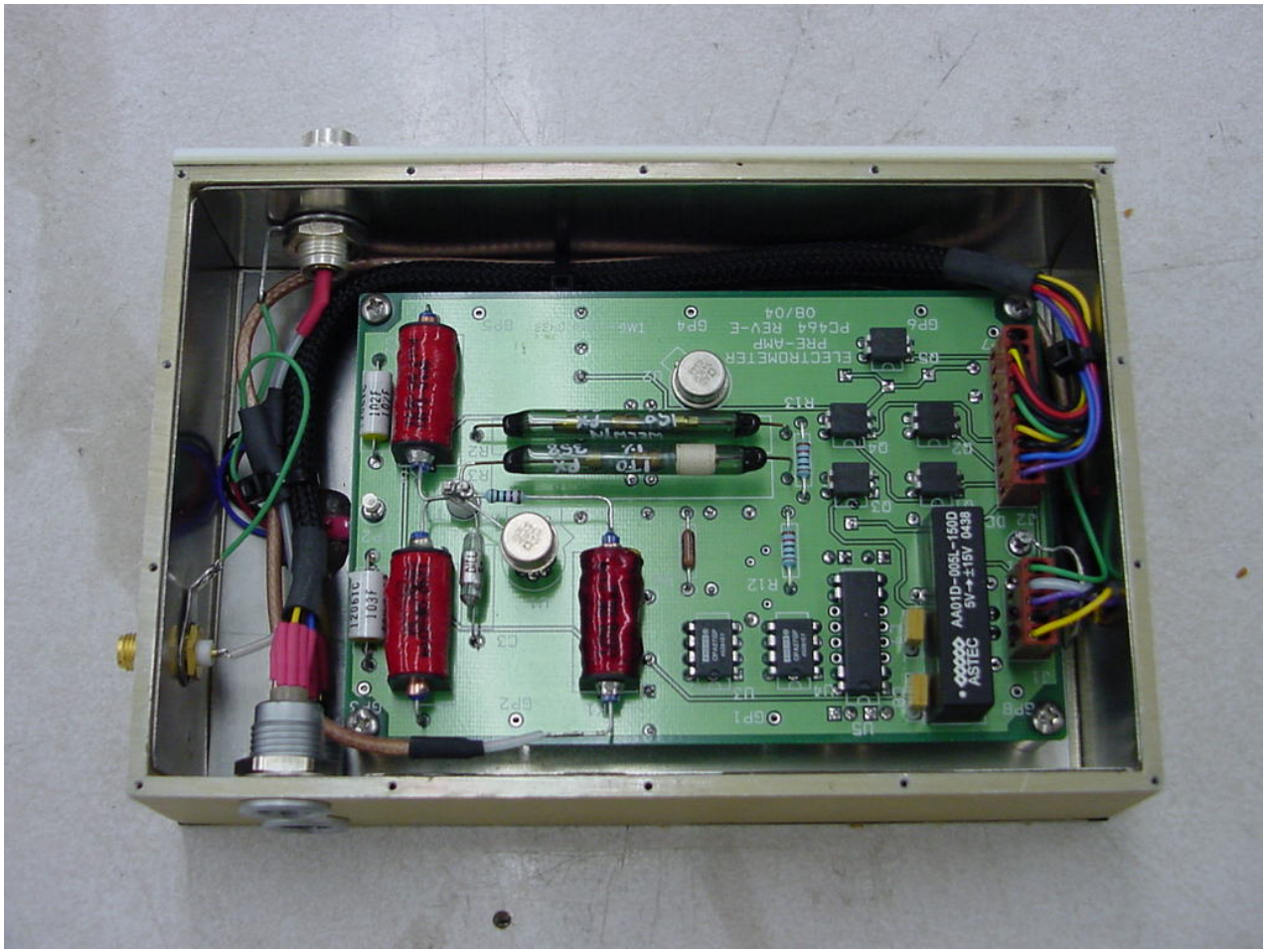
# Universal Tritium Transmitter (UTT)

- Created to be a Universal Electrometer
  - Potential to replace many different models across the facilities
  - Customizable
- Improved upon many of the existing problems with commercial Electrometers
  - Ground Loops
  - Prone to RF noise
  - Poor AC common mode rejection
  - Range Changing errors (erroneous spike in data)
  - No Relay Alarm Circuitry (high, low and trouble)
  - No Watch Dog Timer Circuit
  - No usable linear analog out
  - AC Common Mode noise with long cable runs
  - Hardware and software problems





# UTT Pre-Amplifier Assembly

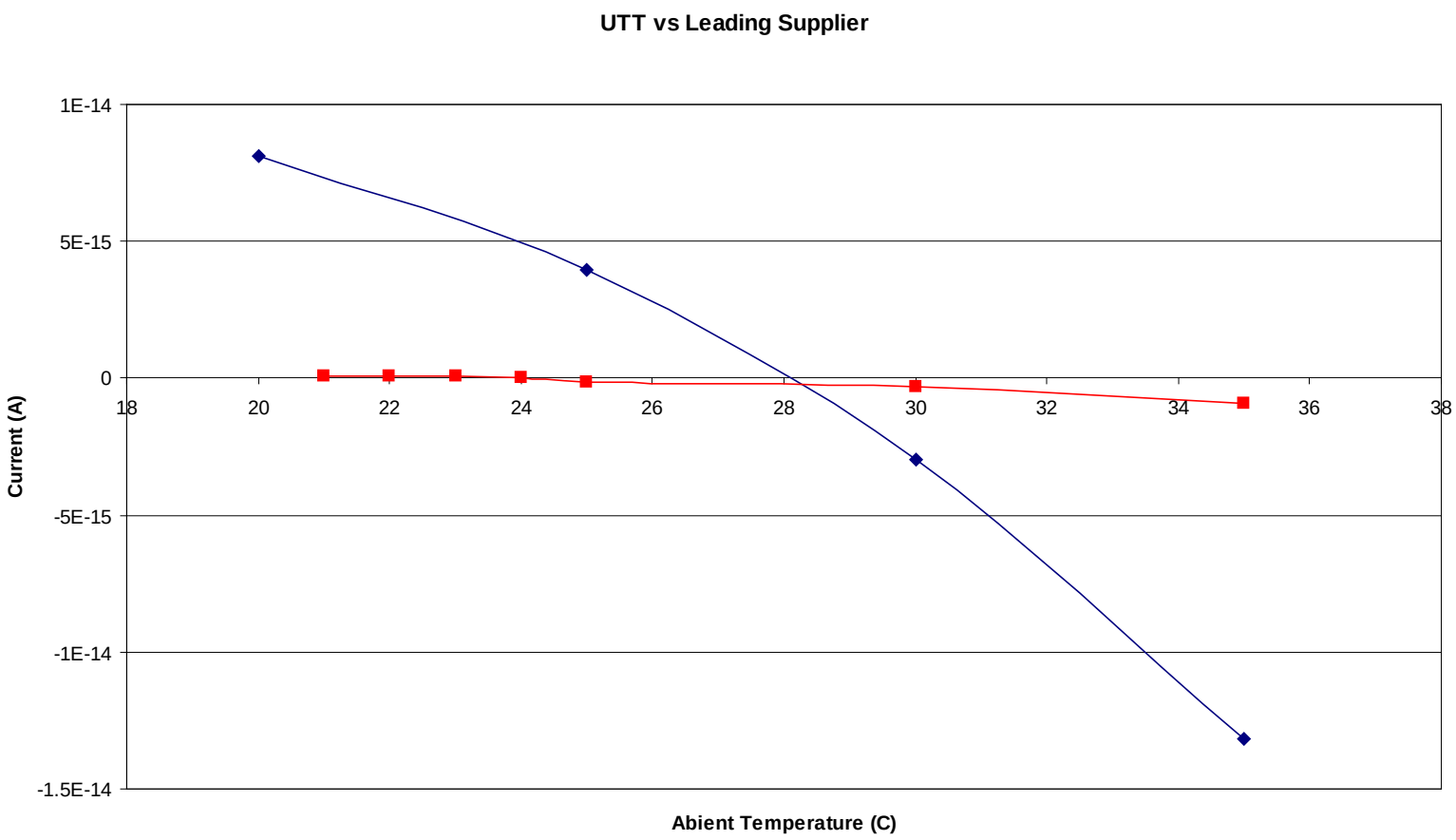



Top View of Pre-Amp

# UTT Specifications

- Electrometer
  - Background Current over required temperature range for SRS Tritium Facility +/- 0.000000000000001 Amps (1E-15 Amps = 1 femto-amp)
  - Six Layer Board, Guarded Traces
  - RF Shield + Magnetic Shield
  - Offset correction circuit
  - Circuit measures current from $10^{-6}$ Amps to $10^{-15}$ Amps
- Background current is a decade less than NRC TA-102 (1 fA)
- Accuracy exceeds NRC TA-102
- Pre-amplifier
  - Floating with respect to ground
  - True differential input
  - Eliminates ground loops
  - Excellent AC common mode rejection
- Impedance matched for up to 200ft RG58 cable with Ion Chamber

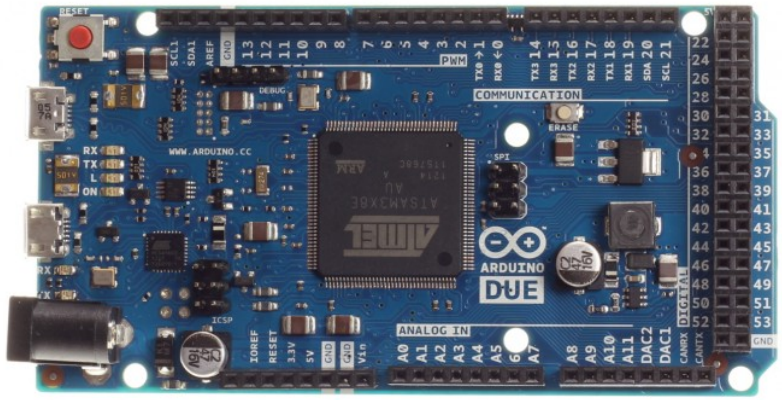
# UTT Zero Drift vs. Temperature

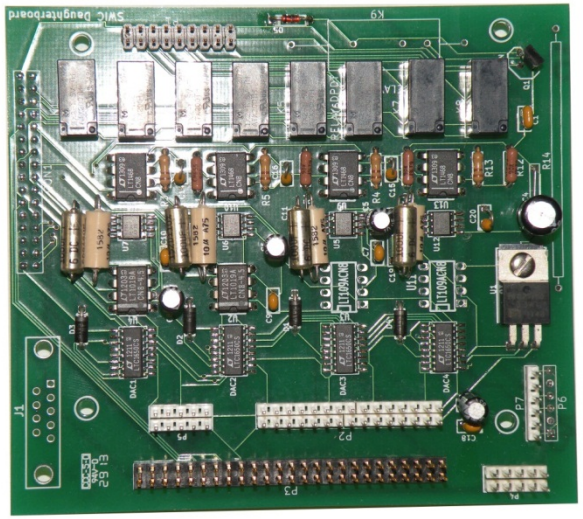



Background Current: UTT in Red, Leading Supplier in Blue

# In-Progress Upgrades to the UTT Platform

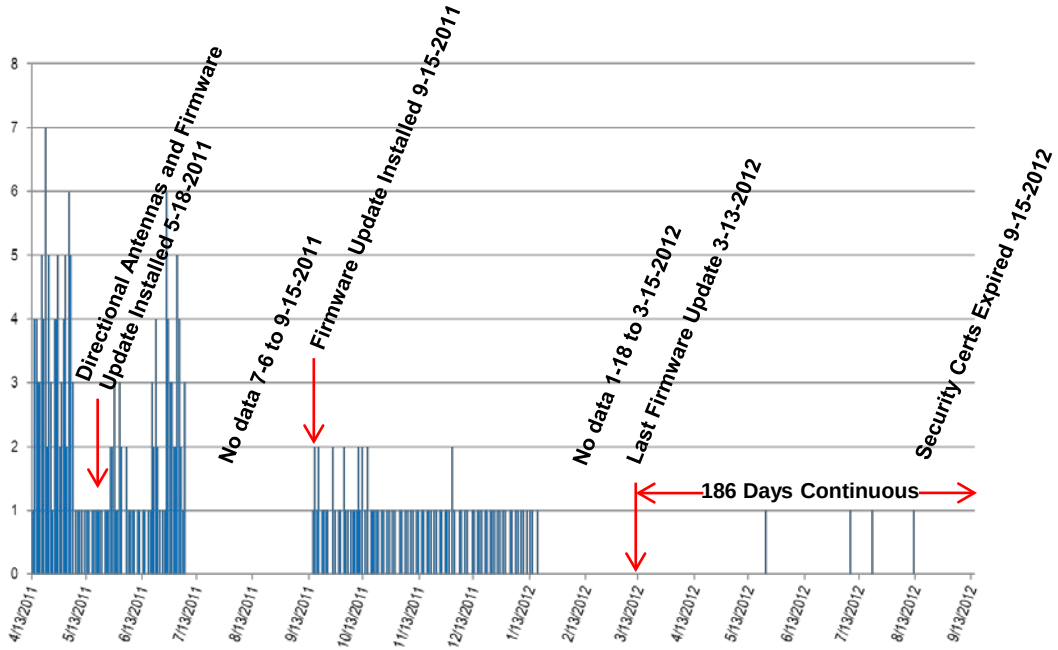
- ATMEL SAM3X8E (84Mhz)
  - Widely used
- No Operating System
  - Software stability
  - Timing
- External IO Interface
  - ADC – SPI
  - DAC – SPI
  - EEPROM – I2C
  - RS232 - UART
  - Relays – DIO
- Daughter Board
  - Interfaces with motherboard
  - DAC (analog signal generation)
  - Amplifiers
  - Relays
  - Output Connectors
  - Calibration Circuit



# Secure Wireless Project Y-556

- Key Elements of this Project
  - Secure Wireless Data Transmission ("Suite B" Encryption for Protection of Classified Info)
  - Screen Wire Ion Chamber Built with Previous PDRD Technologies for Tritium Air Monitoring

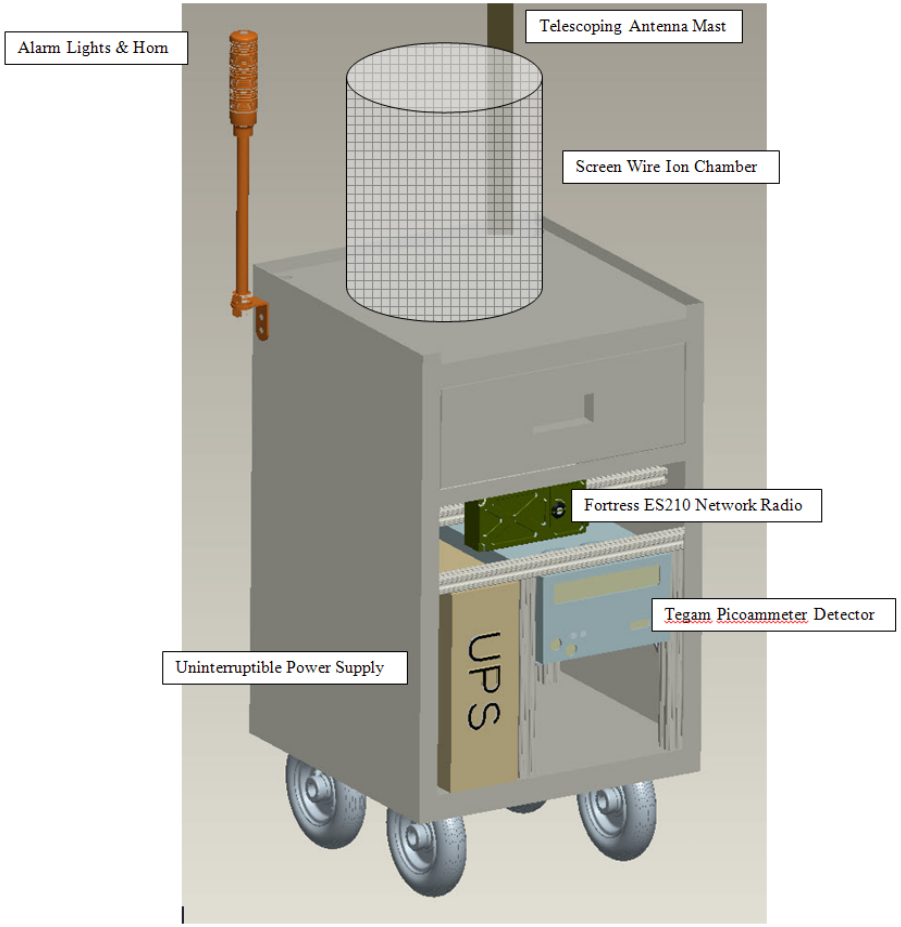


# Project Tasks for FY13 and FY14 Projects

- Design and Construction of the TAM Cart and Control Room Monitoring Console
- Design of a Wireless Communications Network
- Cyber and Technical Security Approvals for the Installation of the Wireless Network and Monitoring Computer
  - Electronic Risk Assessment Management System Entry for Cyber Approval of System
  - Certification & Accreditation Process for Accreditation Boundary Acceptance
  - Radio Frequency Transmitter Security Plan
- Laboratory Testing of the TAM Cart
- Field Radio Frequency Surveys for Background RF Determination and Post-Installation Network Coverage and Performance
- Field Installation
- Post-Installation Field Testing of the TAM Cart and Wireless Network
- Design System Architecture for Safety Significant Operation
- Develop and Test Hardware Interface to the Worker Protection System PLC
- Address Issue of Wireless in Proximity to Classified Systems
- Determine Suitable Commercial Supplier
- Develop ANSI Type Testing Plan

# Wireless TAM Cart Requirements

- Combine UTT, Screen Wire Ion Chamber and Secure Wireless Programs
  - Mobile
  - Small Footprint
  - Local Alarm Indicators
  - Wireless Data Transmission
  - Goal of Safety Significant Functional Classification




Secure Wireless Tritium Air Monitor Cart Conceptual Design

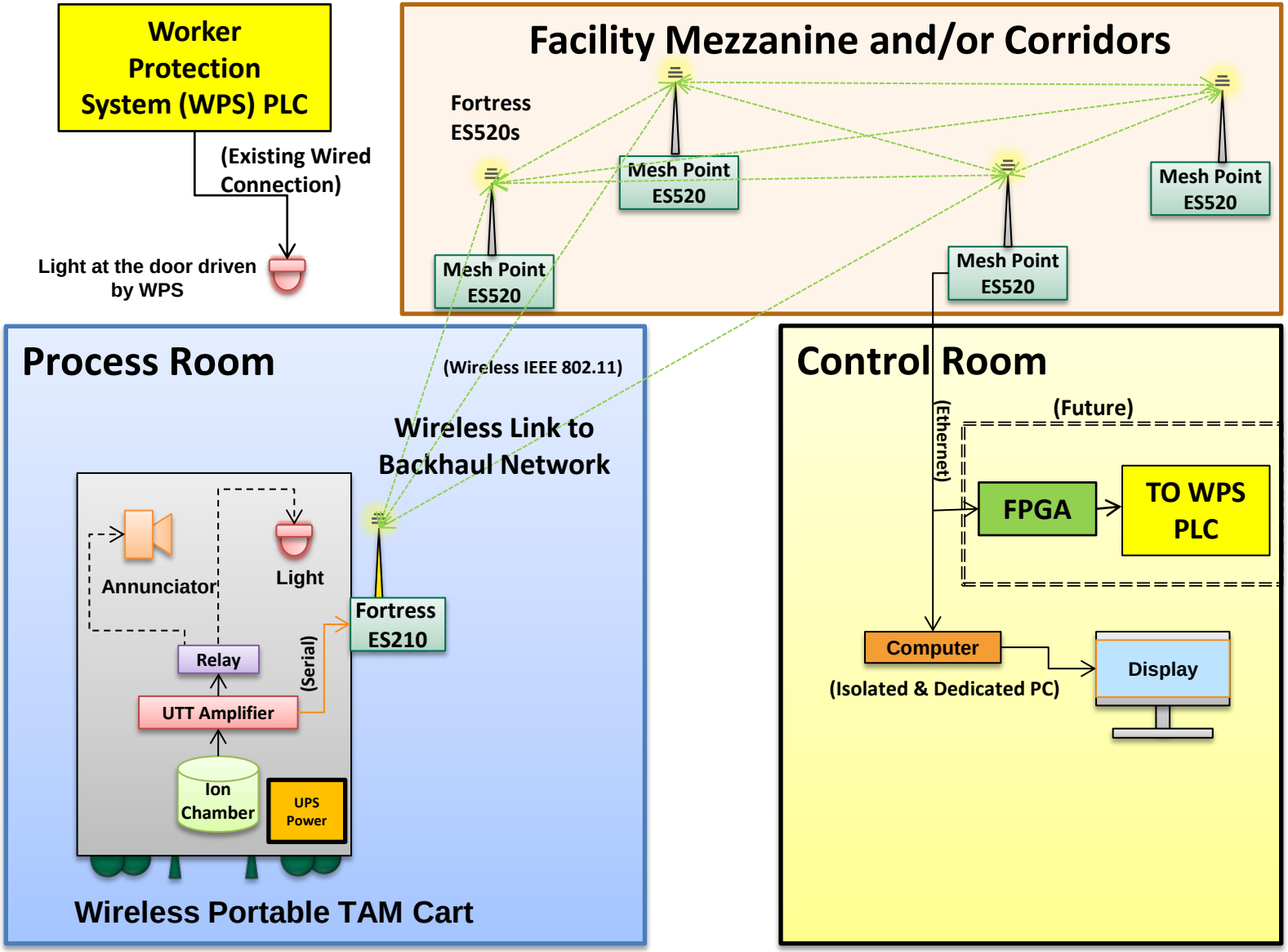
# Wireless Network Components

General Dynamics – Fortress Technologies

ES210 – Tactical Meshpoint

ES520 - Deployable Meshpoint

# Wireless Network and System Design Concept



# Completed Cart and Control Room Console

**Activity, Alarm Status, UTT & Network Diagnostics…**

**Configuration, Calibration Parameters, Network Settings…**

# Wireless Network Infrastructure - Mezzanine

Frequency Band “A” Antenna
(Circular Polarized – Hemi-Omnidirectional)

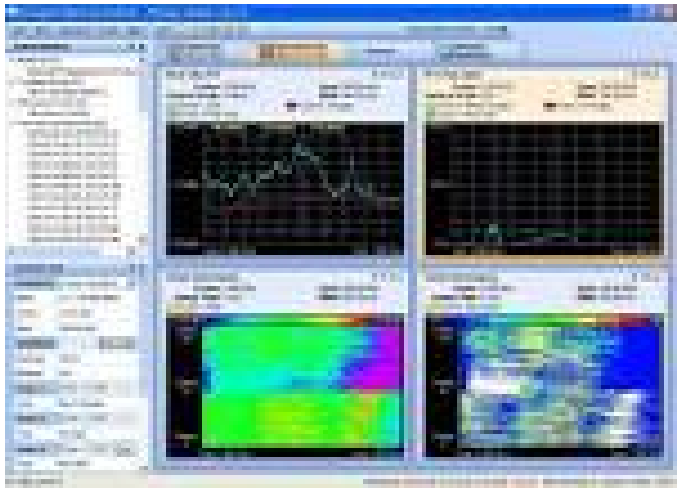
Frequency Band “B” Antenna (optional)
(Circular Polarized – Panel)

1 ¼” EMT Mast – About 5 ft Tall

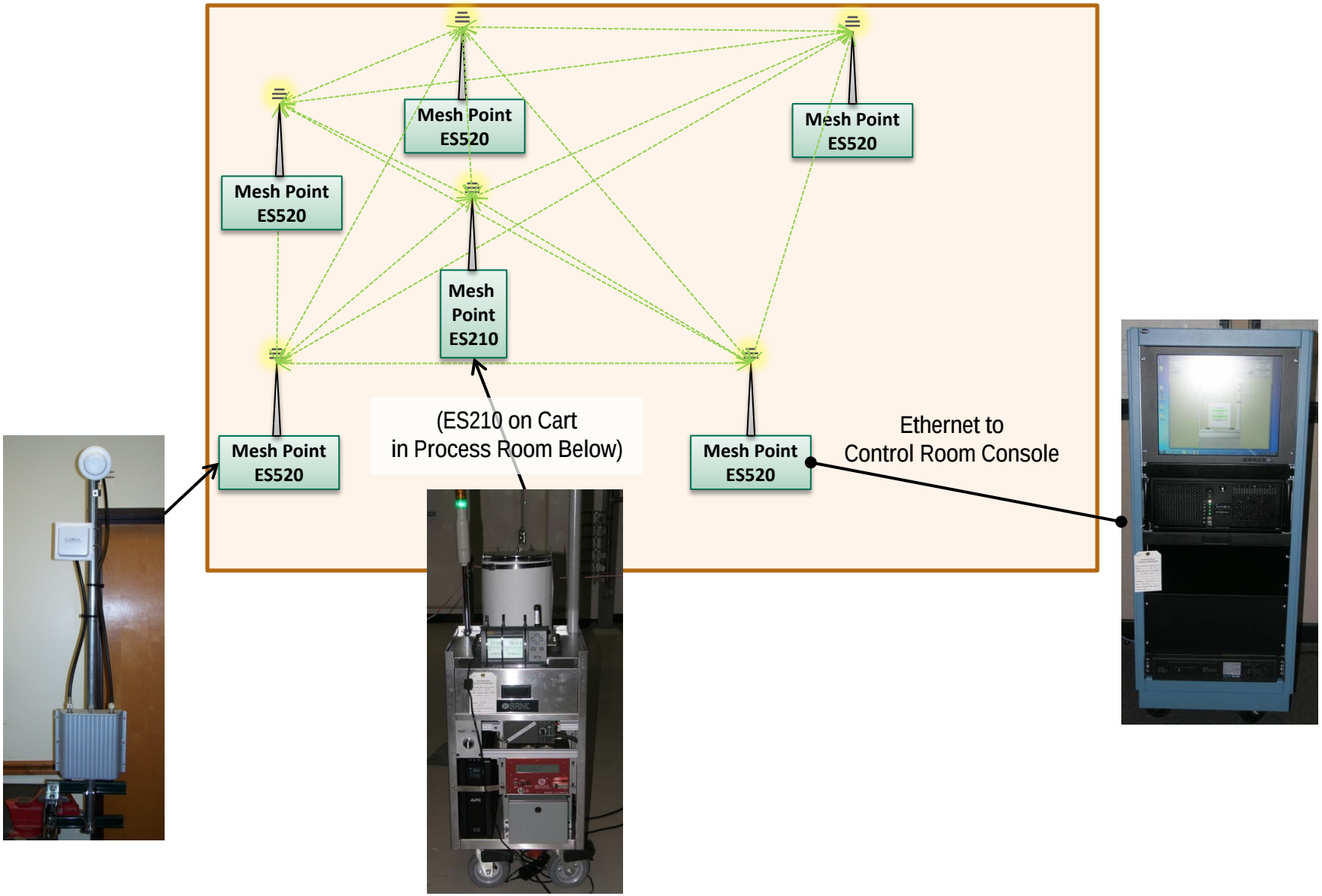
Fortress ES520 Radio

# Background RF Surveys

- Pre-Installation Indoor and Outdoor Background Radio Frequency Surveys Performed
  - Surveys Performed in Both Potential Operating Frequency Bands
  - Identified Potential Sources of Interference
  - Enabled Selection of Specific Clear Communications Channels
  - Highlighted the Need for Facility Radio Frequency Spectrum Management

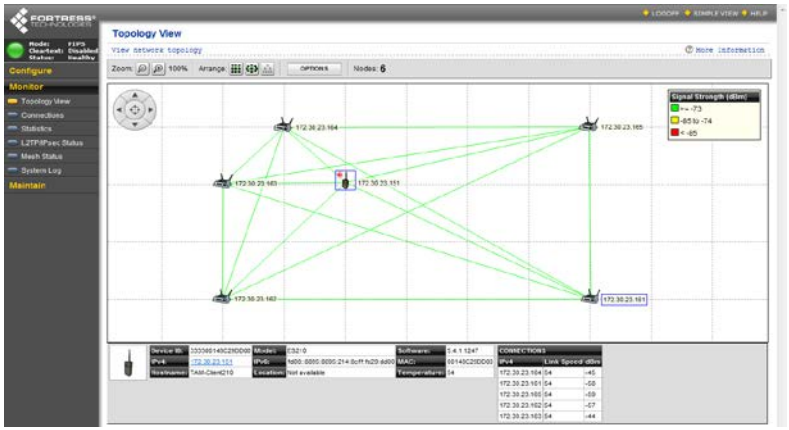


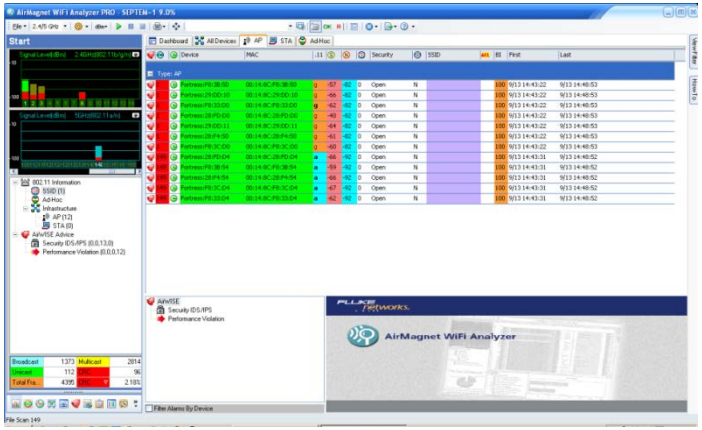
# Mezzanine Network Layout in Facility



# Process Room Location

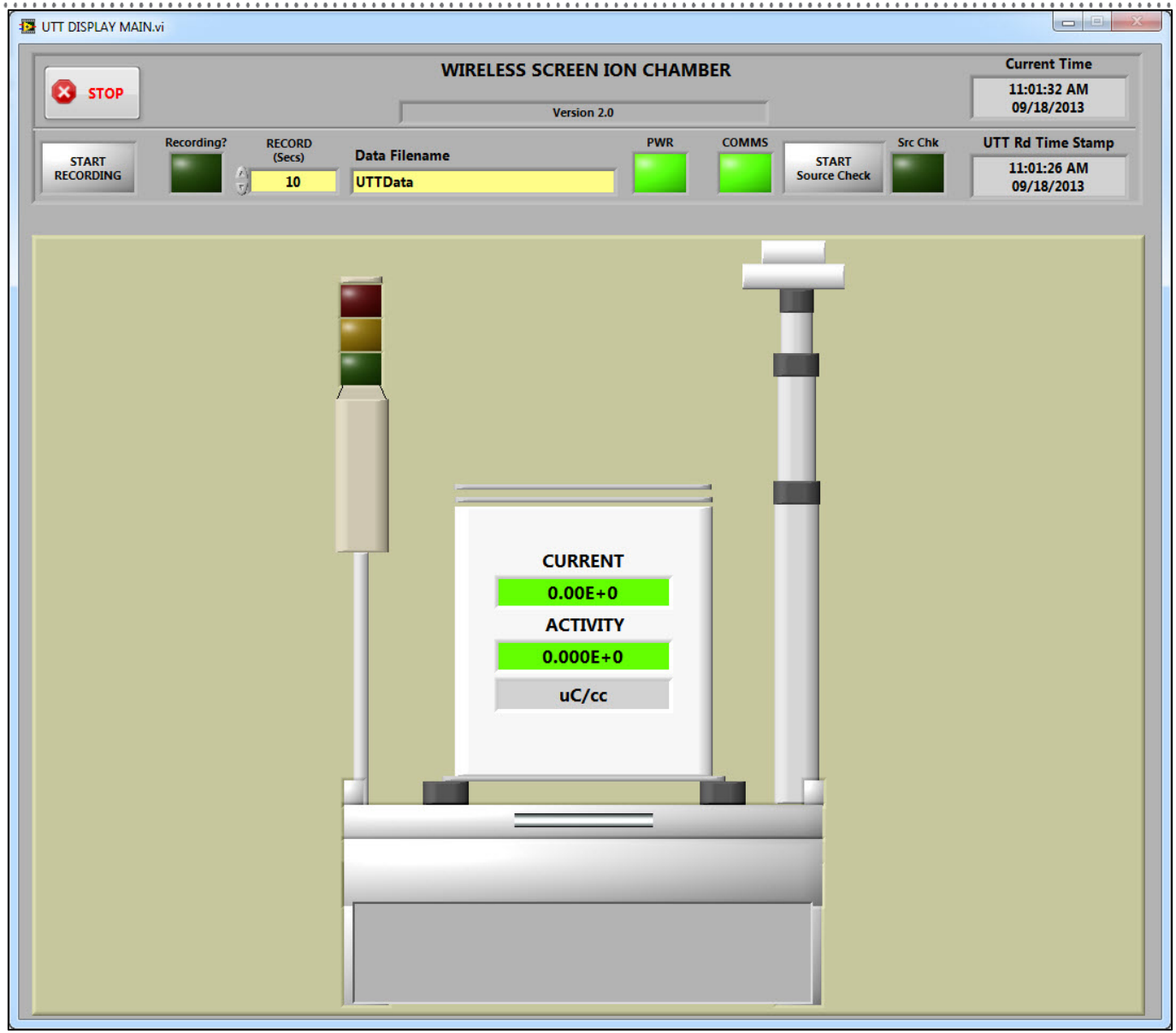
# Post-Installation System Testing



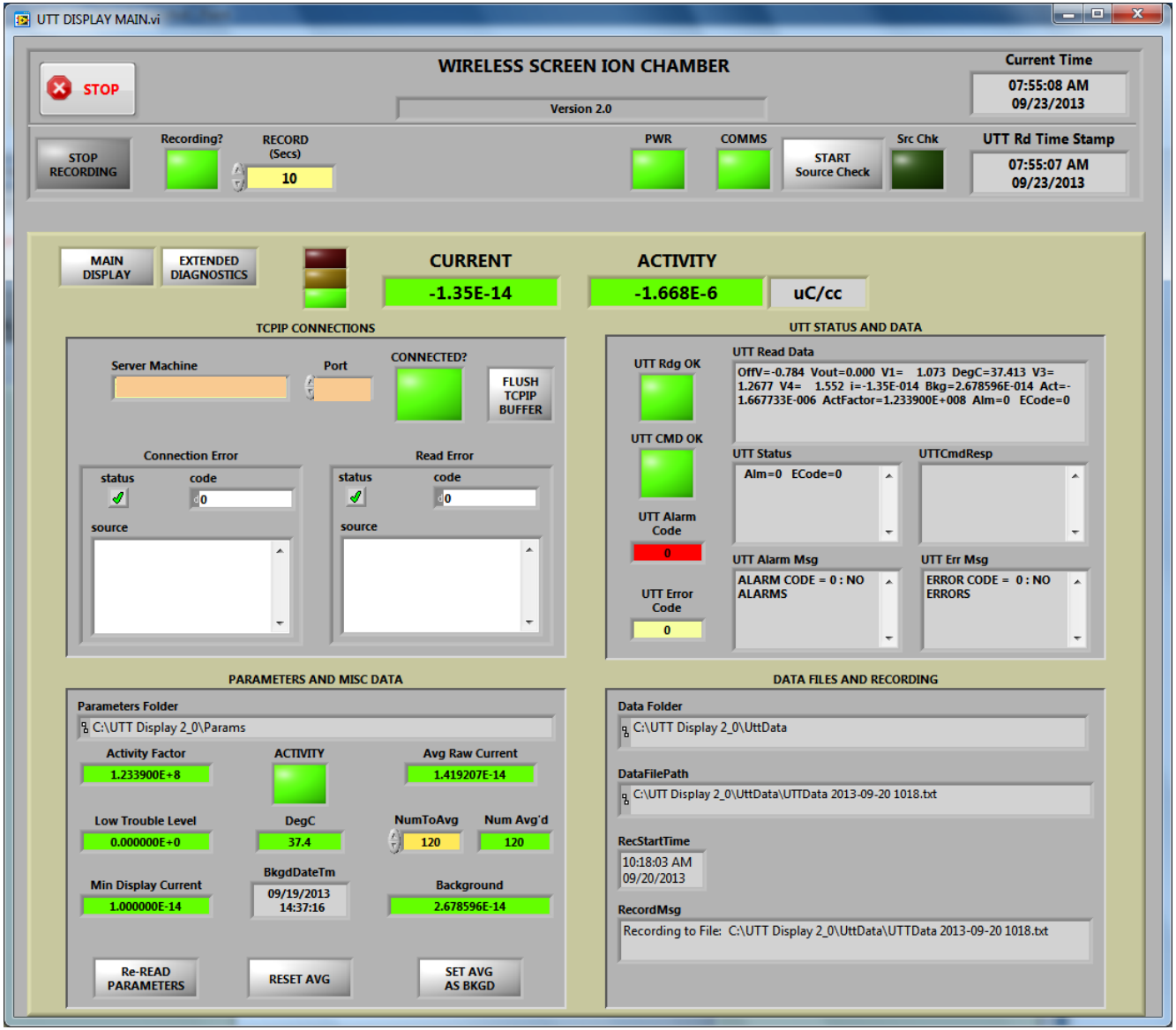




- Network Testing
  - Adequate Network Capacity to Cover 20+ TAM Carts in the Facility
  - Very Good Wireless Network Coverage Throughout the Facility
  - Initial Operation Tested with Frequency Diverse Dual Mesh (Bands “A” and “B”)
  - Currently Configured for Single Frequency Band Mesh Network
  - Current Network Node Availability 99-100% - Tested at 1-Second Intervals
- TAM Functional Testing over One Year Temporary Installation
  - Performing Periodic Radiological Source Checks
  - Monitoring System Performance (false alarms, environmental effects, errors,…)

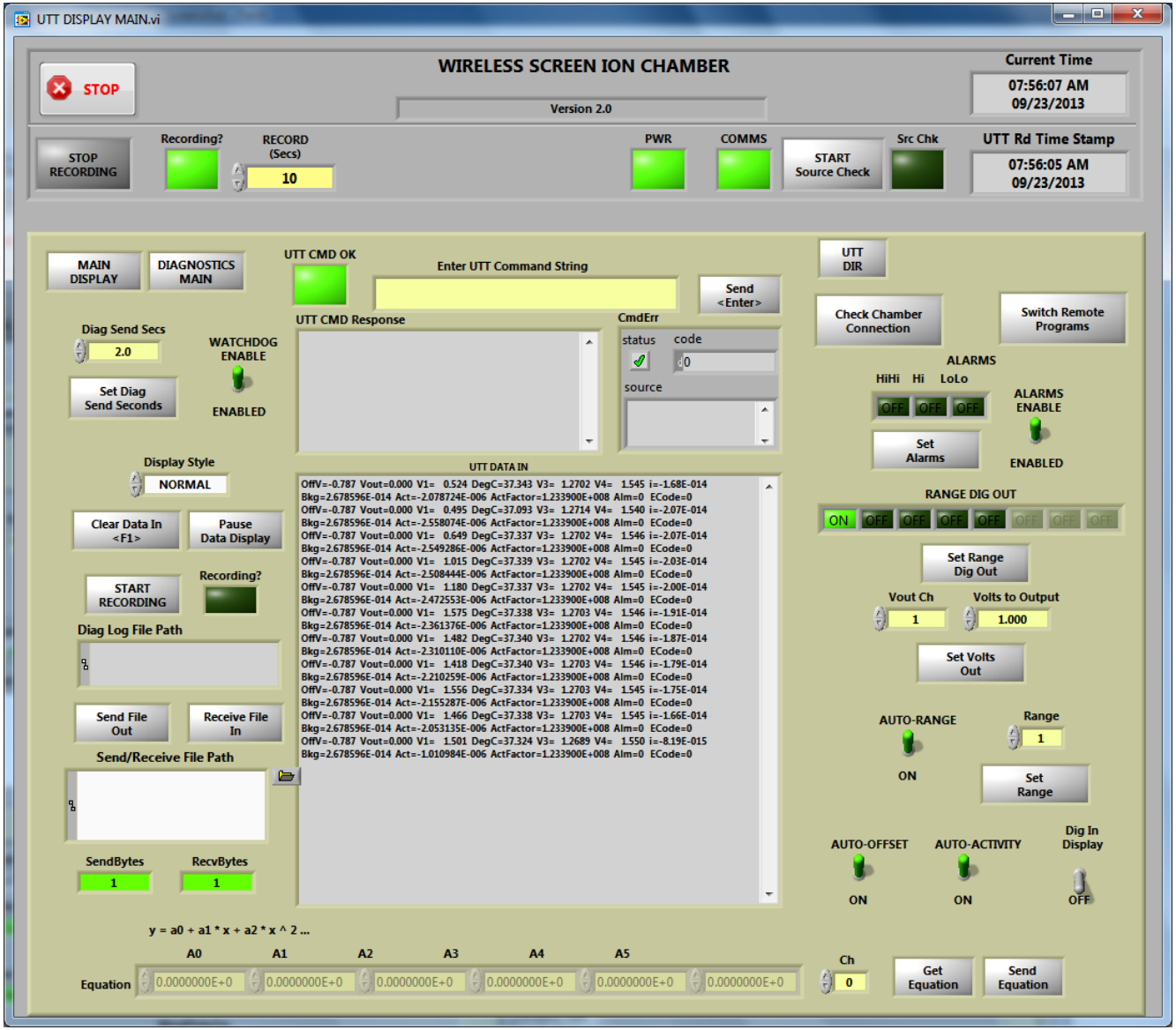
# Control Room Console – Main Display



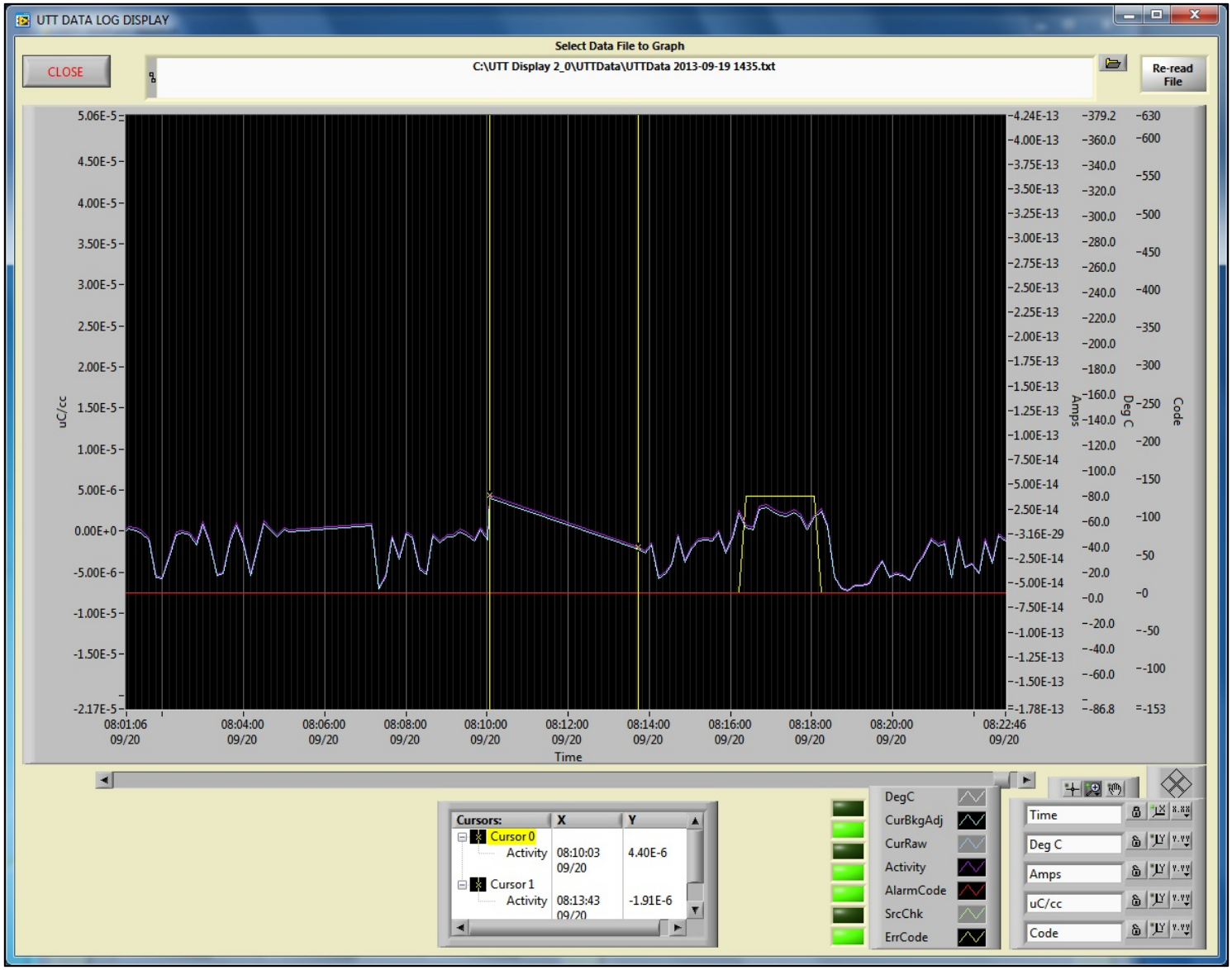
# Control Room Console – Main Diagnostics Screen



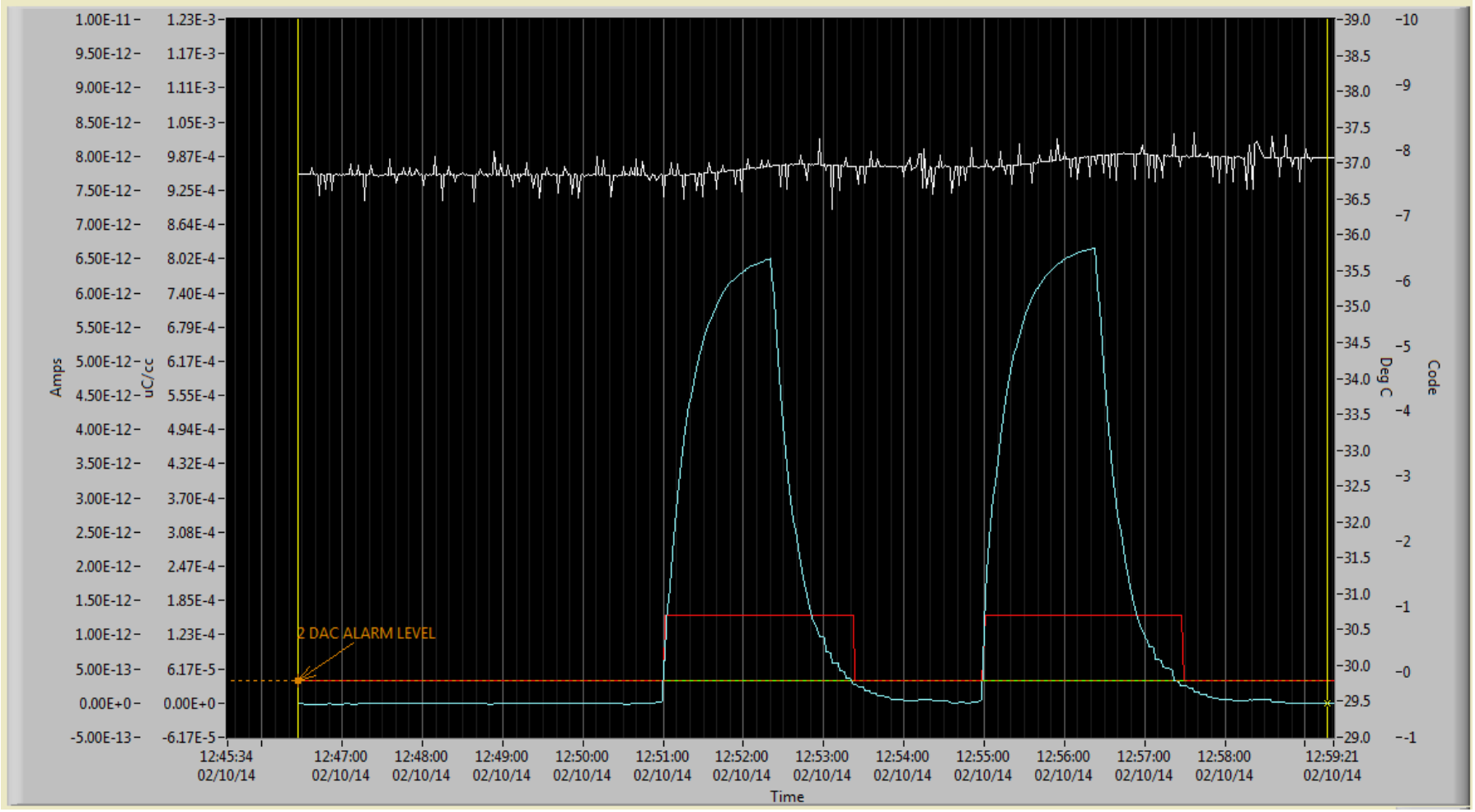
# Control Room Console – Extended Diagnostics Screen



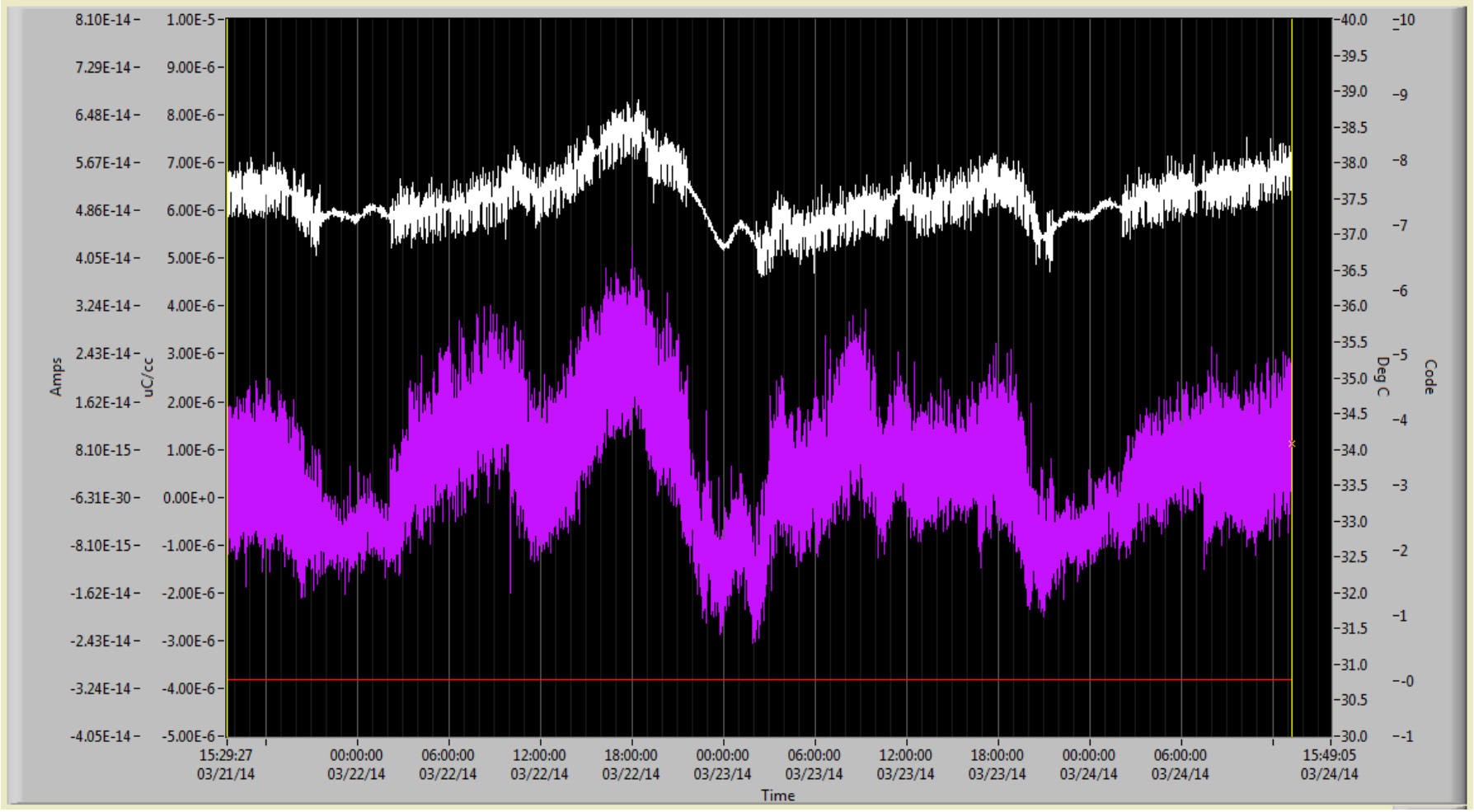
# Control Room Console – Data Log Viewer



# Field Source Check of TAM Cart



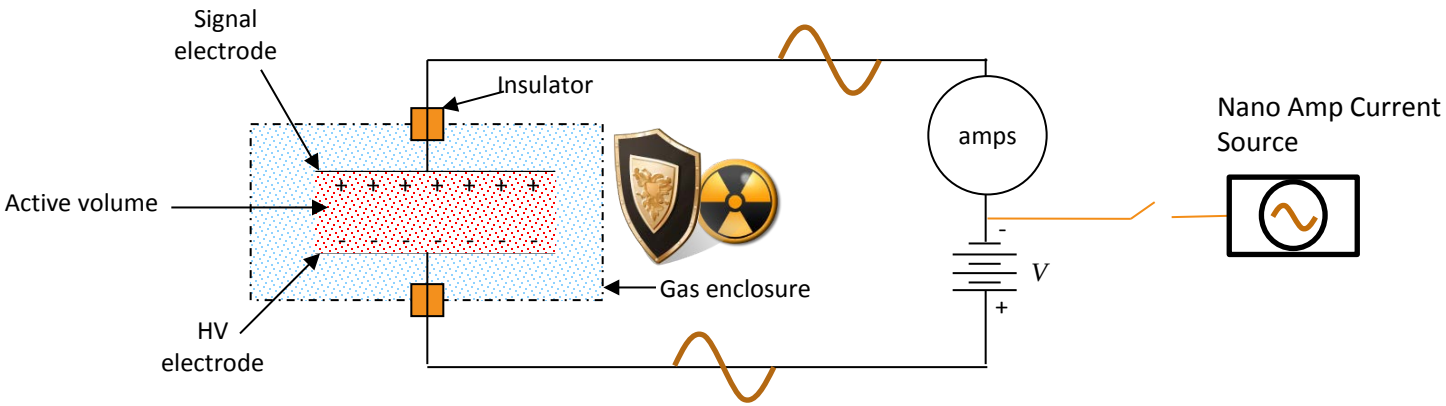
# Field Background Activity Level



# Safety Significant (SS) – How to Meet

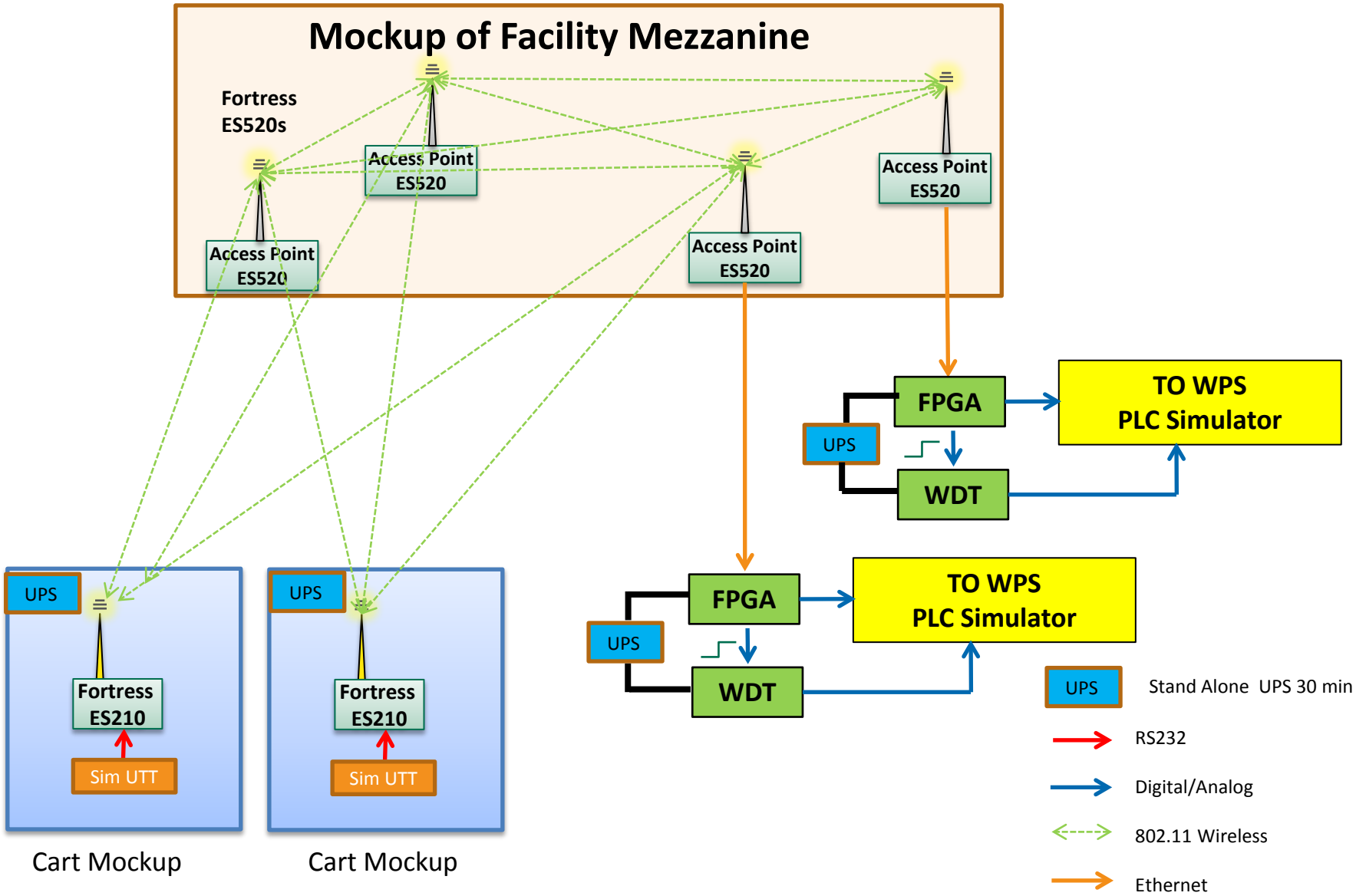
- Working with Tritium Technology Management Council TAM Working Group
- Fail Safe
  - Independent Watch Dog Timer Circuits in UTT and at Wireless Receiving End
  - Continuous Monitoring of Wireless Link (Activate Trouble if Timeout Exceeds 10 Seconds)
  - Robust Self Healing Wireless Mesh Network
  - Main Power Loss will Activate Trouble Alarm
  - Documented with Failure Mode Analysis
- Periodic Self Check of the UTT/Chamber
  - Internal Current Source to Supply Two Excitation Levels (Below and Above Alarm Set Point)
  - Chamber Loop Check
  - On-Board Source Check
- FPGA Connection to the WPS for SS Alarm, Trouble and Activity
- Procurement per 3E Manual
- NQA1 Qualification of Vendor
- Review of System Level Design by the SRS Engineering Standards Board Committee on Instrumentation, Controls and Ergonomics (ICE)
- ANSI "Type Testing" against Performance Requirements

# Functional Checks of Ion Chamber, UTT and Entire System Loop




- Automatic Source Check with Radioactive Source Installed on Cart in Shielded Housing with Solenoid Driven Window
- Goal to Eliminate Periodic Manual Checks
  - Manual Monthly Source Check of Every Ion Chamber by Radcon
  - Monthly Check with Current Source by TMO
- Provide Immediate Indication of Entire Loop State

# Mockup in SRNL R&DE Lab of Critical SS Components and Networks



# Proximity of Wireless to Red Cables/Conduits

- DOE Telecommunications Security Manual (DOE M205.1-3) Specifies Separation Requirements
- Challenge to Find Locations in Process Rooms that do not Violate this Distance due to the Extent of Red Cables/Conduits and Process Equipment Cabinets
- Mitigating Factors
  - Draft NSA Document Provides Technical Justification for Reduced Distances
  - Wireless Network Design is “Low Power”, Short Range
  - Directional Antennas Focus RF only where it is Necessary for Communications
  - Process Buildings Provide Large Level of RF Attenuation
- Briefings conducted with NSNA-SRSO Technical Security Oversight Manager and DOE Technical Security Program Director
- Guidance Obtained for Permanent Building-Wide System
  - Submit Transmitter Security Plan
  - DOE HQ Approval of Plan
  - DOE HQ to Perform or Delegate Physical Radio Frequency Testing of System and Facility

# Path Forward

- Prioritize Remaining Project Tasks Based on Risk
  - Mockup Testing
  - ANSI Performance Type Testing
  - Commercial Vendor Selection and NQA1 Qualification
  - Review of Design and Test Results by ICE Committee
- Execute High Priority Tasks Based on Available Funding
- Develop Project Documents for Deploying Core System in a Single Process Room
- Core System Includes:
  - Two Tritium Air Monitoring Carts with SS UTT per Process Room
  - Existing Wireless Backhaul Network Located in Facility Mezzanine
  - FPGA and WDT Circuitry
  - Software Modifications to the WPS to Read FPGA and WDT Signals
  - Production Support Level Monitoring System for System Health and Diagnostics

# Summary

- Designed, Constructed and Installed a Prototype Tritium Air Monitoring Cart and Control Room Monitoring Console in a Tritium Production Facility
- Designed and Installed a Wireless Communications Network in the Facility
- Approvals in Place to Operate the System under a Temp Mod for 1 Year
- Completed Radio Frequency Background Surveys and Post-Installation Network Coverage and Performance Measurements
- Completed Design Drawings and a Project Report for FY13
- Continuing Network and TAM Cart Performance Monitoring in FY14
- TAM Working Group Developed Path Forward for Larger System Deployment
- Design of SS Version UTT in Progress
- Hardware on Order for System Mockup Testing
- Obtained Guidance from NNSA-SRSO and DOE HQ for Wireless Proximity Approvals
- Pursuing System Design Rated for SS Service
- Test Plan Drafted for ANSI Performance/Type Testing

# Questions?