3.4 Fast-Response Isotopic Alpha Continuous Air Monitor (CAM)

Keith D. Patch (**kpatch@tecogen.com**; 781-622-1022)
Frederick E. Becker (**fbecker@tecogen.com**; 781-622-1059)
Thermo Technologies
45 First Avenue
Waltham, MA 02454-9046

Dr. Mark D. Hoover (**mhoover@lrri.org**; 505-845-1040)
F. Morgan Cox (**morgancx@swcp.com**; 505-471-1370)
Lovelace Respiratory Research Institute
P.O. Box 5890
Albuquerque, NM 87185-5890

Abstract

The U.S. Department of Energy (DOE) must ensure that on-site worker health and safety is not compromised by airborne radioactive contamination. In addition, the DOE must ensure that effluent air and gas streams leaving DOE sites and waste treatment facilities do not negatively impact public safety or health. Alpha-emitting radioisotopes, such as U-238/U-234 and Pu-239, are rated by the U.S. Environmental Protection Agency (EPA) as class A carcinogens. Alpha-emitting radioisotopes have very low regulated upper limits in air and process gas streams. Uranium also has a high chemical toxicity. The development of improved airborne alpha monitoring technology ranks as one of the top priorities of the DOE Decontamination and Decommissioning (D&D) Focus Area, based on the five needs currently listed by various DOE Site Technology Coordinating Groups.

To meet this D&D need, Thermo Power Corporation is developing and testing a novel Continuous Air Monitor (CAM) for monitoring alpha-emitting radionuclides. This CAM technology can also be applied to Continuous Emission Monitoring (CEM) of thermal treatment system off-gas streams. The CAM instrument will have very high alpha spectral resolution and provide real-time, on-line monitoring suitable for alerting workers of high concentrations of alpha-emitting radionuclides in the ambient air and for improved control of decontamination, dismantlement, and air emission control equipment. In addition to being very cost-effective, the instrument will greatly improve data reliability by eliminating the self-shielding associated with filter-based assay instruments, and excellent isotopic resolution will permit operation in areas with high background radon levels.

The technology involves a proprietary, patent-pending method of collecting and measuring airborne radioactive species. Employing a novel integration of technologies, it first accumulates and preconcentrates radioactive airborne or gasborne particulates from a very large sample volume by electrostatic precipitation onto a slowly-moving non-porous film. This allows for

rapid quantification of the specific alpha-emitting species using high-resolution solid-state silicon detectors. The sensitivity of this technique using the laboratory instrument is a factor of seven beyond the required 0.002_pCi/l of Pu-239 (1_DAC) in 8_hours prescribed by DOE in 10CFR835. The used film can be archived to meet DOE requirements.

In addition to being applied to Continuous Emission Monitoring (CEM) of alpha emitters in thermal treatment system off gas streams, this new method can be modified to incorporate air or off gas analysis by conventional methods (i.e., x-ray fluorescence, laser-induced fluorescence, particle size distribution, etc.) Furthermore, a two-stage version of this device would go beyond the sensitivity required for implementing the Comprehensive Test Ban Treaty (CTBT), and allow the U.S. to meet future monitoring challenges (such as the proposed Fissile Materials Cutoff Treaty and the International Atomic Energy Agency's (IAEA) Strengthened Safeguards System.)

Phase I work involved successfully developing and testing a Laboratory Prototype CAM. This prototype CAM was well characterized, including measuring its performance for over twenty-five hours of continuous operation. The design and fabrication of a more compact Advanced Prototype instrument is underway. Plans are being made to perform a field test of the Laboratory Prototype instrument at the Los Alamos National Laboratory storage and disposal area, TA-54. An alternative field test of the Laboratory Prototype instrument is being investigated, which would measure depleted uranium aerosols resulting from live fire testing on US Army tanks and armored personnel carriers. A future independent performance test of the instrument using characterized plutonium aerosols is planned at the Lovelace Respiratory Research Institute. Future manufacturing plans for deployment of the instrument are being addressed.

Acknowledgments

Thanks are due to the NETL Contracting Officer's Representatives on this program, Richard Bush, Vijendra Kothari, William Huber, and Peter Klemkowsky; Bob Bedick and the Industrial Programs Office at NETL and the DOE Decontamination and Decommisioning (D&D) Focus Area; Paul Hart and the NETL Office of Environmental Management & Defense Programs; and to the Characterization, Monitoring and Sensor Technology (CMST) Crosscutting Program.

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(DE-AR26-98FT40365)

Thermo Technologies

Industry Partnerships for Environmental Science and Technology Conference

October 17 - 19, 2000

National Energy Technology Laboratory (NETL), Morgantown, WV

Presented By:

Keith D. Patch

Thermo Technologies

45 First Avenue

Waltham, MA 02454-9046

Telephone: 781/622-1022

Telefax: 781/622-1025

E-mail: kpatch@tecogen.com

Program Participants

- **U.S. Department of Energy — National Energy Technology Laboratory & Decontamination and Decommissioning Focus Area**
- **Thermo Technologies**
- **Lovelace Respiratory Research Institute (LRRI)**

Needs Statement

ThermoTechnologies

- **Critical Needs Exist for Instruments to Monitor Low Level Radioactivity in**

  - Workplace Breathing Environments
  - Thermal Treatment System Off-Gas

- **Must Rapidly Identify Very Low Levels of Alpha-Emitting Radionuclides**

Project Goals

- **Meet DOE's Critical Instrumentation Need for**
  - Improved Alpha Continuous Air Monitoring (CAM)
  - Using Technology that Applies Towards Alpha Continuous Emissions Monitoring (CEM)
- **These Needs Identified by DOE's D&D, Mixed Waste, and Plutonium Focus Areas**
- **The CAM Instrument Should Provide:**
  - Improved Operation in Areas With High Radon Background Levels
  - Low Pressure Drop, Low Power Consumption, Low Noise Levels

Technical Approach: Air Monitor Concept

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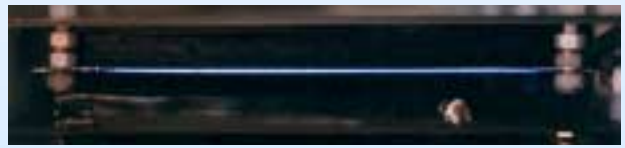
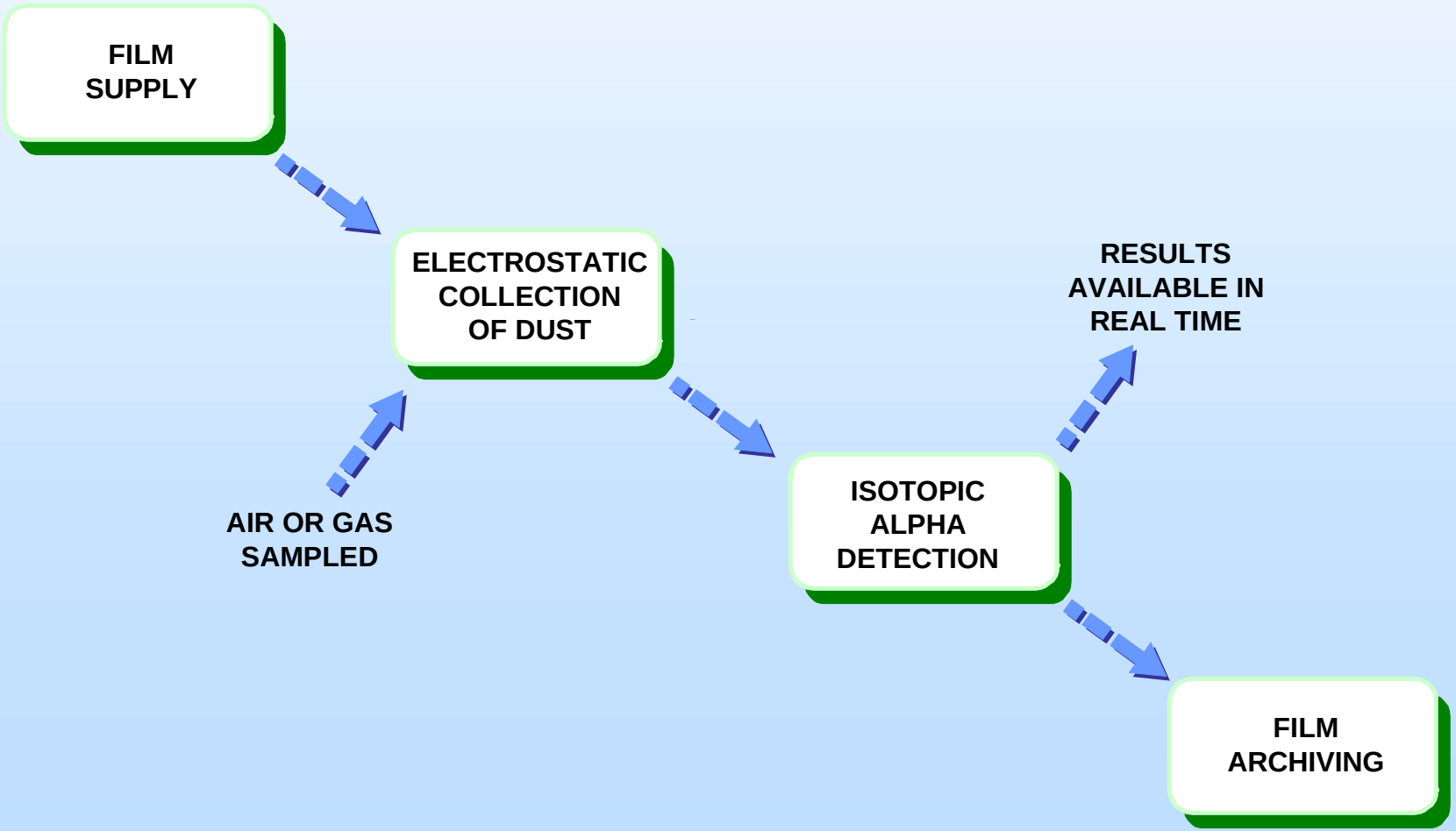
- **Collect Radionuclides from Air/Gas Stream**
  - Using Electrostatic Precipitation
  - On Smooth-Surfaced Film



- **Automatically Analyze Film Using Large Area Solid State Detectors**
- **Archive Film per Data Quality Objectives**

- **This Technology Can Be Used For**
  - Air or Flue Gas
  - Particulate Solids Preconcentration for Analysis by Conventional Methods (I.E. XRF, LIF, PSD, Etc.)

ESP-Based Continuous Air Monitor Concept

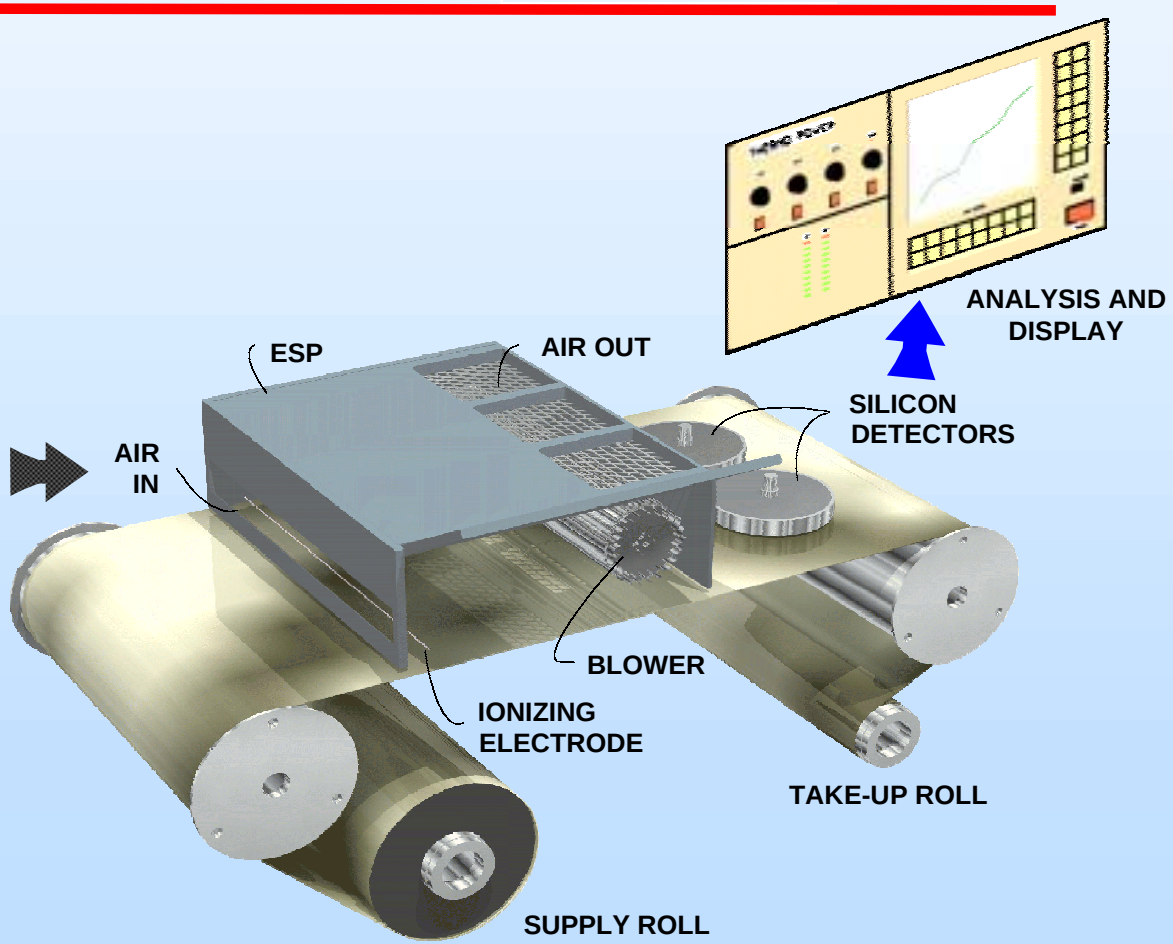


ESP CAM Design Attributes

- **Simple Low-Cost Components (Electrostatic Precipitator, Diode, Film, Etc.)**
- **Compact Instrument Design**
- **High Performance Device**
- **Cost-Effective and Trouble-Free**
- **Reliable**
  - No Plugging in Dusty Conditions
  - Improved Operation in High-Radon Conditions

Air Monitor Concept

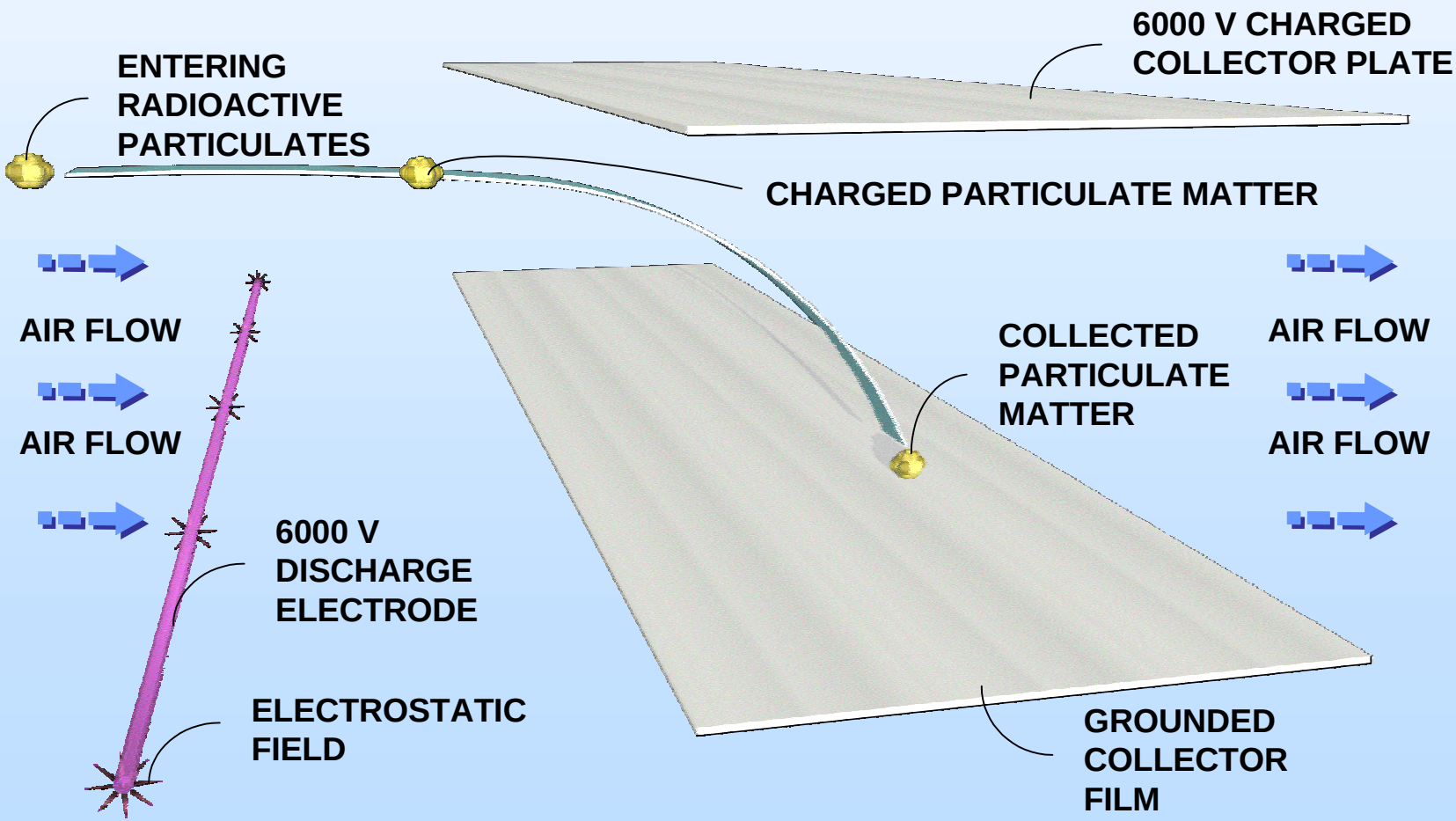
RADIOLOGICALLY
CONTROLLED WORK AREA



Program Plan

- **Phase I: Build and Laboratory Test a Prototype Rapid CAM System**
- **Phase IA:**
  - Conduct Field Test of Laboratory Prototype CAM at LANL TA-53 LSDDP
  - Design and Build an Advanced Prototype ESP CAM
- **Phase II: Continue ESP CAM Development to Meet DOE's Need**

ESP-Based Collection Concept



Silicon Diode Measurement Concept

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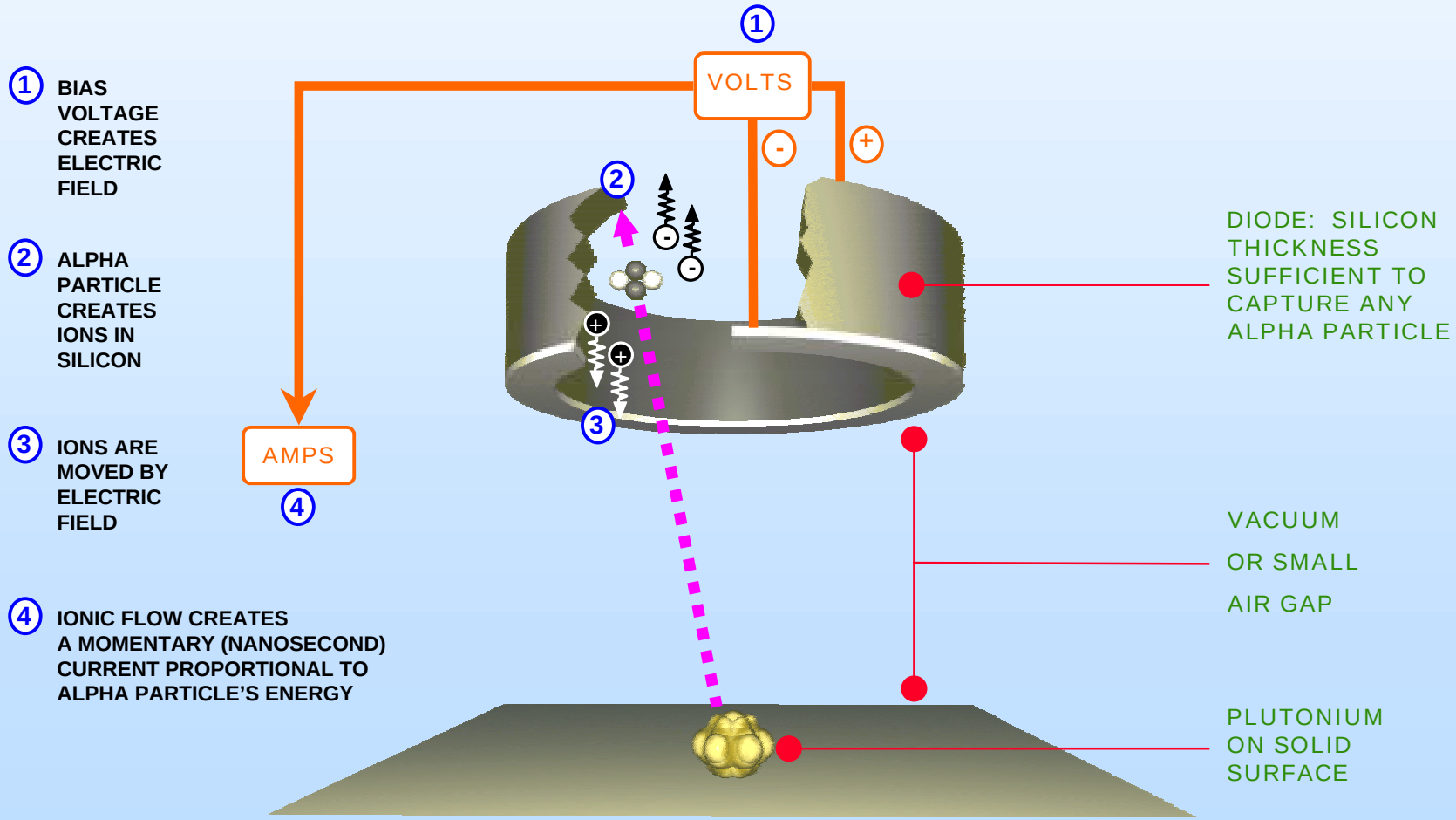
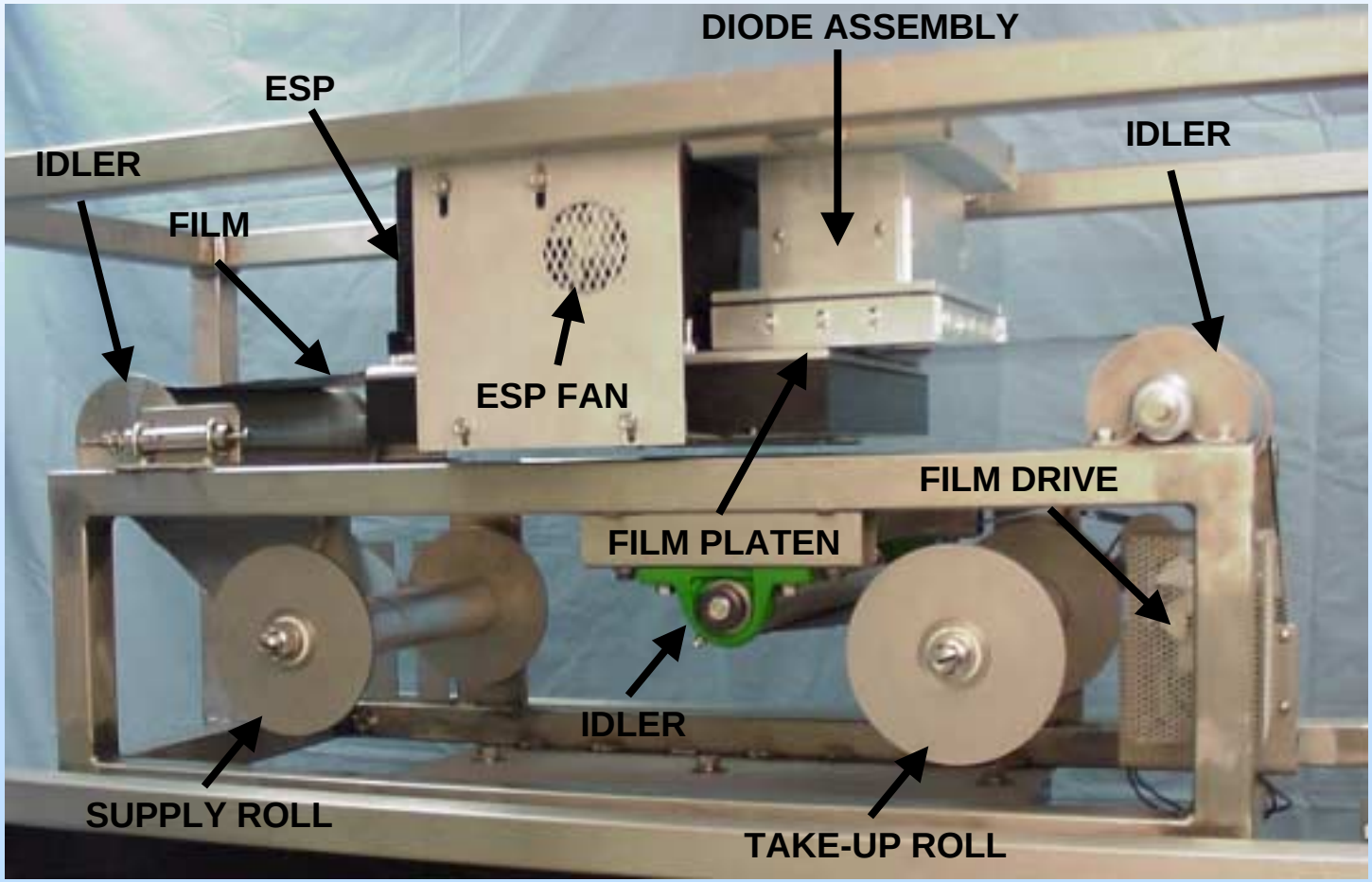


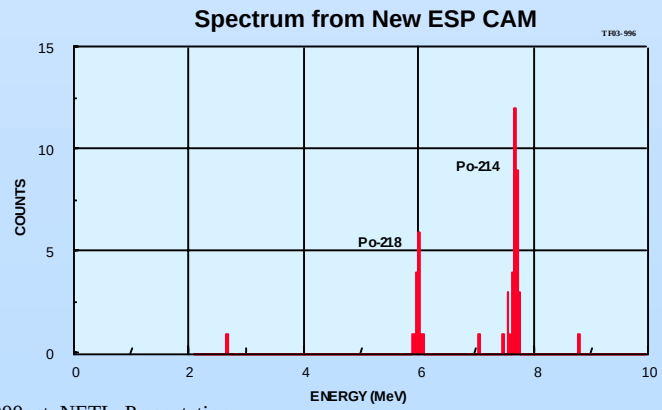
1. BIAS VOLTAGE CREATES ELECTRIC FIELD
2. ALPHA PARTICLE CREATES IONS IN SILICON
3. IONS ARE MOVED BY ELECTRIC FIELD
4. IONIC FLOW CREATES A MOMENTARY (NANOSECOND) CURRENT PROPORTIONAL TO ALPHA PARTICLE'S ENERGY

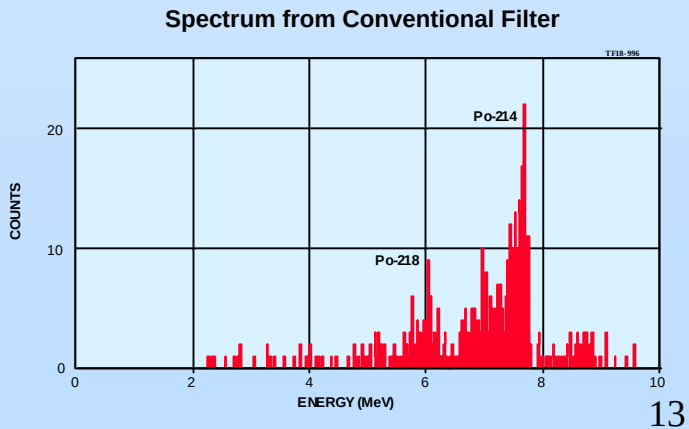
Laboratory Prototype Air Monitor Overall View



Performance Advantages Compared to Baseline Technology

- **No Filters — Uses a Smooth Surfaced Film**
  - ESP Deposits a Monolayer of Particles on Top Surface of Film
  - Detector can be Placed Extremely Close to Film
  - Provides Excellent Isotopic Resolution
  - Provides Improved Operation in Areas With High Radon Background Levels
  - Better Operation in Dirty/Dusty Environments (Air & Flue Gas)





Performance Advantages Compared to Baseline Technology (continued)

- **High Volumetric Flow Collects Large Number of Particles, Yielding High Sensitivity**
  - Low Pressure Drop
  - Low Power Consumption
  - Low Noise Levels
- **Film Permits Unattended Operation for 30+ Days**
- **Particle Size Distribution Capability**
- **Integrated Calibration**
- **Sample Archiving System**
- **Can Perform High Temperature Flue Gas Sampling**

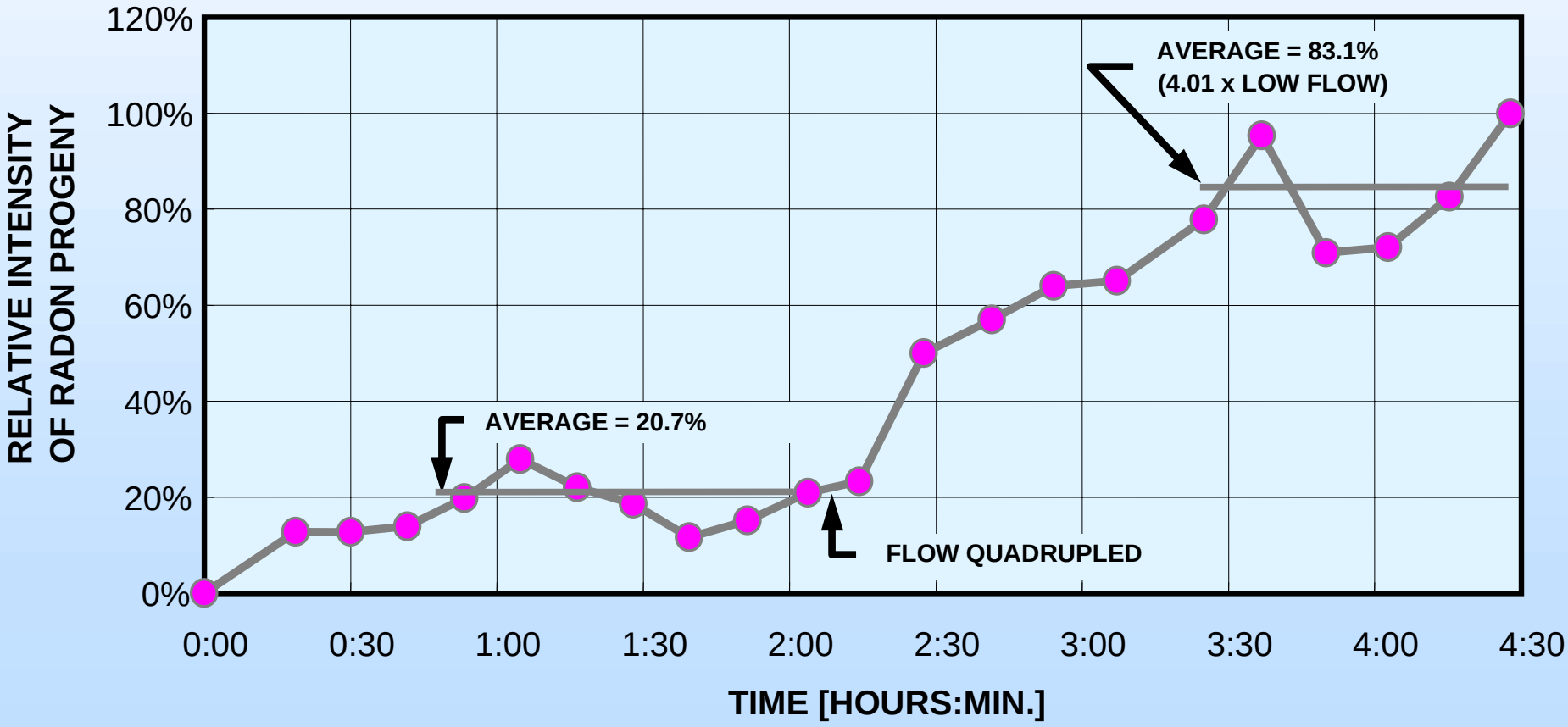
Additional Performance Advantages

- **Cost Reduction — In Both O&M Labor and Lost Work Time**
- **Schedule Acceleration — Better Control of Operations, Fewer False Alarms**
- **Reduced Public and Occupational Health Risks — Improved Radon Discrimination Yields Dose Reduction**
- **Reduced Environmental Impacts — Improved ALARA Operations**

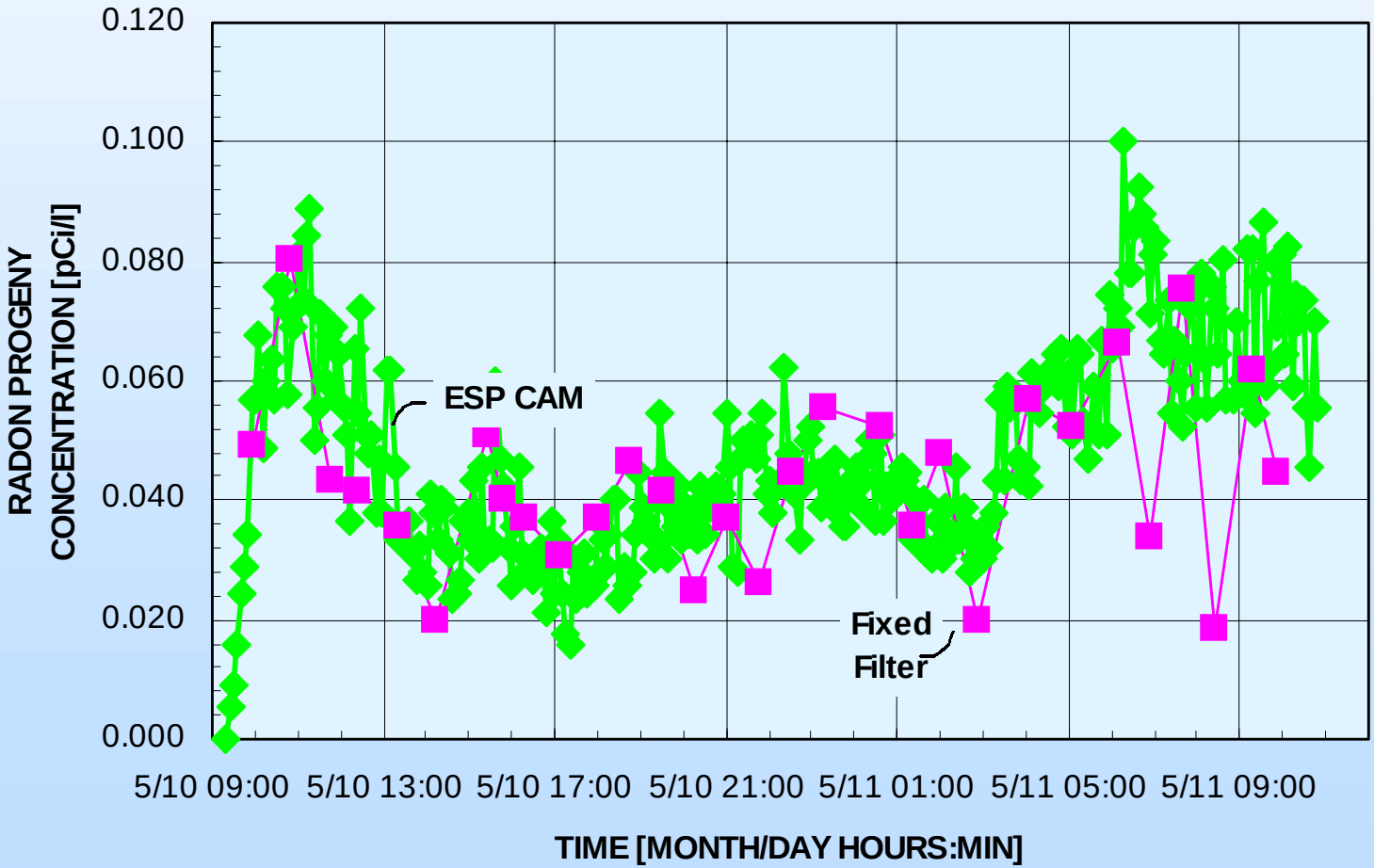
Project Status

- **Phase I Successfully Completed**
  - Significant Interest From LANL, WIPP, SRS, Hanford
- **Fabrication/Testing of Laboratory Prototype Instrument Complete**
  - Meets all Design Criteria, Including Sub-One Min. Response
  - Sensitivity Exceeds Regulatory Requirements by 7X
  - Excellent Lab Test Results
- **Now Conducting Phase IA — Field Test of Laboratory Prototype ESP-CAM and Design/Build Advanced Prototype Instrument**

Linear ESP CAM Response To Changes In Sampling Flow Rate



25 Hour Test Results Demonstrate Endurance



Design of Rack-Mounted Production Unit

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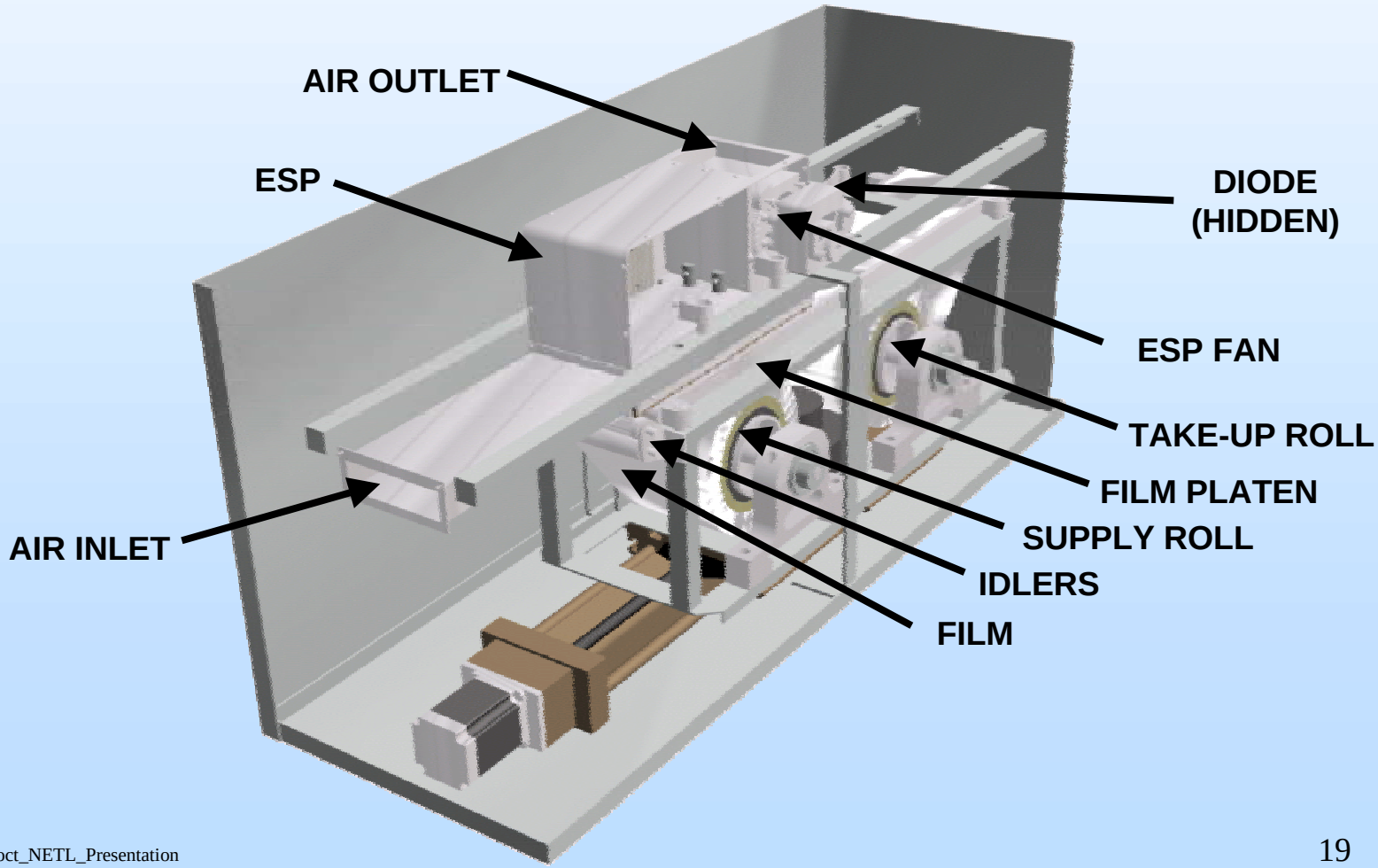

Future Plans: Phase IA

ThermoTechnologies

- Conduct Field Test at Los Alamos TA-53
- Design and Build Advanced Design CAM Instrument For Future Tests
- Continue Receiving Feedback from DOE Health Physics End Users
- Phase IA to Continue for 4 More Months

Conclusions

- **Proof of Concept in Lab**
  - Technology Approach Verified
  - Excellent Lab Test Results
  - Meets all Design Criteria, Including Sub-One Min. Isotopic Response
  - Sensitivity Exceeds Requirements by 7X
- **Significant DOE Site Interest in Initial Results (LANL, WIPP, SRS, Hanford)**
- **Development Work Continues**