DOE Research on PM Hazardous Components

Funding: ***U.S. Department of Energy, Office of Fossil Energy (FE)***

Program Management: ***National Energy Technology Laboratory (NETL)***

William W. Aljoe, NETL

DOE Office of Fossil Energy

- **Primary Mission:**
  - "Ensuring that we can continue to rely on clean, affordable energy from our traditional fuel resources."

- **PM from coal power plants represents a threat to FE's mission**

National Energy Technology Laboratory

- **Only DOE national lab dedicated to fossil energy**
  - Fossil fuels provide 85% of U.S. energy supply
- **One lab, five locations, one management structure**
- **1,200 Federal and support-contractor employees**
- **Research spans fundamental science to technology demonstrations**

Alaska

Oklahoma

Oregon

Pennsylvania

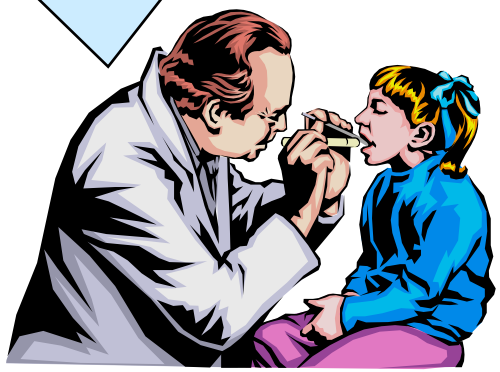
West Virginia

Overall Research Objective

- **Clarify the link between coal power plant emissions and PM-related health effects**
- **Support NRC Research Topic #5**
  - What is the role of physicochemical characteristics of particulate matter in eliciting adverse health effects?

Emissions

NAAQS Compliance



Health Effects

Background: Coal Plants, PM, & Health

- **Sulfates & Nitrates (secondary $PM_{2.5}$)**
  - 25 – 50% of ambient $PM_{2.5}$ mass in eastern U.S.
  - Coal plants are largest SO_2 source (2nd largest NO_x source)
  - Ammonium sulfate/nitrate is relatively "non-toxic"
    - No information on the toxicity of actual secondary particles formed through SO_2 & NO_x conversion in the atmosphere
    - Acid catalysis of SOA?
- **Fly ash (primary $PM_{2.5}$)**
  - Low percentage (~1%) of ambient $PM_{2.5}$ mass
  - Laboratory studies suggest toxicity via metal content, acidity

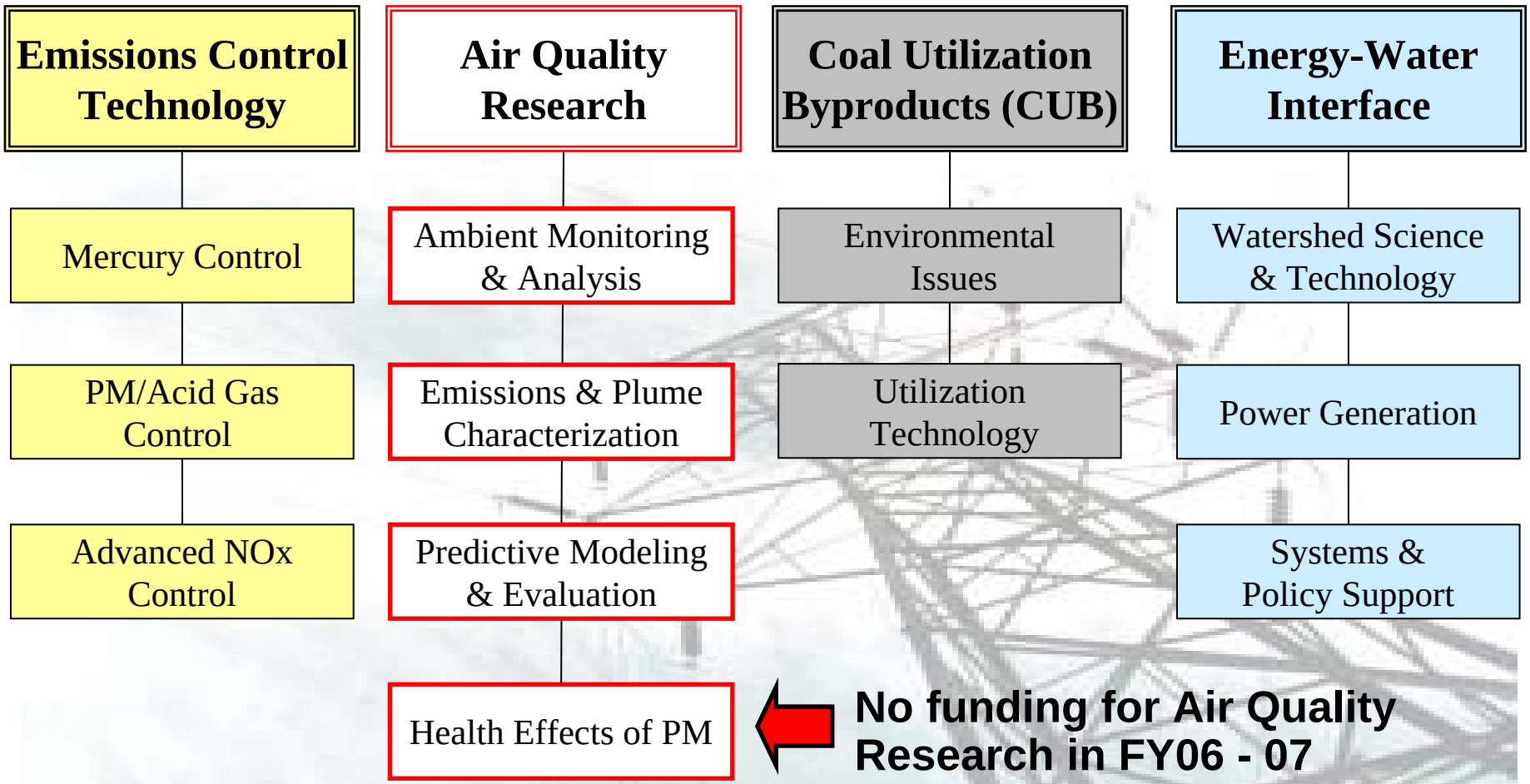
Application: Policy Development

- **Improved models of "externalities" of power plant emissions**
  - Used to estimate benefits of air pollution reductions
- **Current paradigm:**
  - Health Effects = f(PM_{mass}, Gases, …)
- **New (better) paradigm:**
  - Health Effects = f($PM_{sulfate}$, $PM_{nitrate}$, PM_{EC}, PM_{OC1}, PM_{OC2}, PM_{Metal1}, PM_{Metal2}, …)

Application: Technology R&D

- More efficient SO_2 emission control technology (currently >95%)?
- More efficient (or more selective) primary PM emission control technology (currently >99.5%)?
- Cost-effectiveness compared with alternative coal utilization technologies (gasification)?

R&D Implementation: FE's "Innovations for Existing Plants" Program



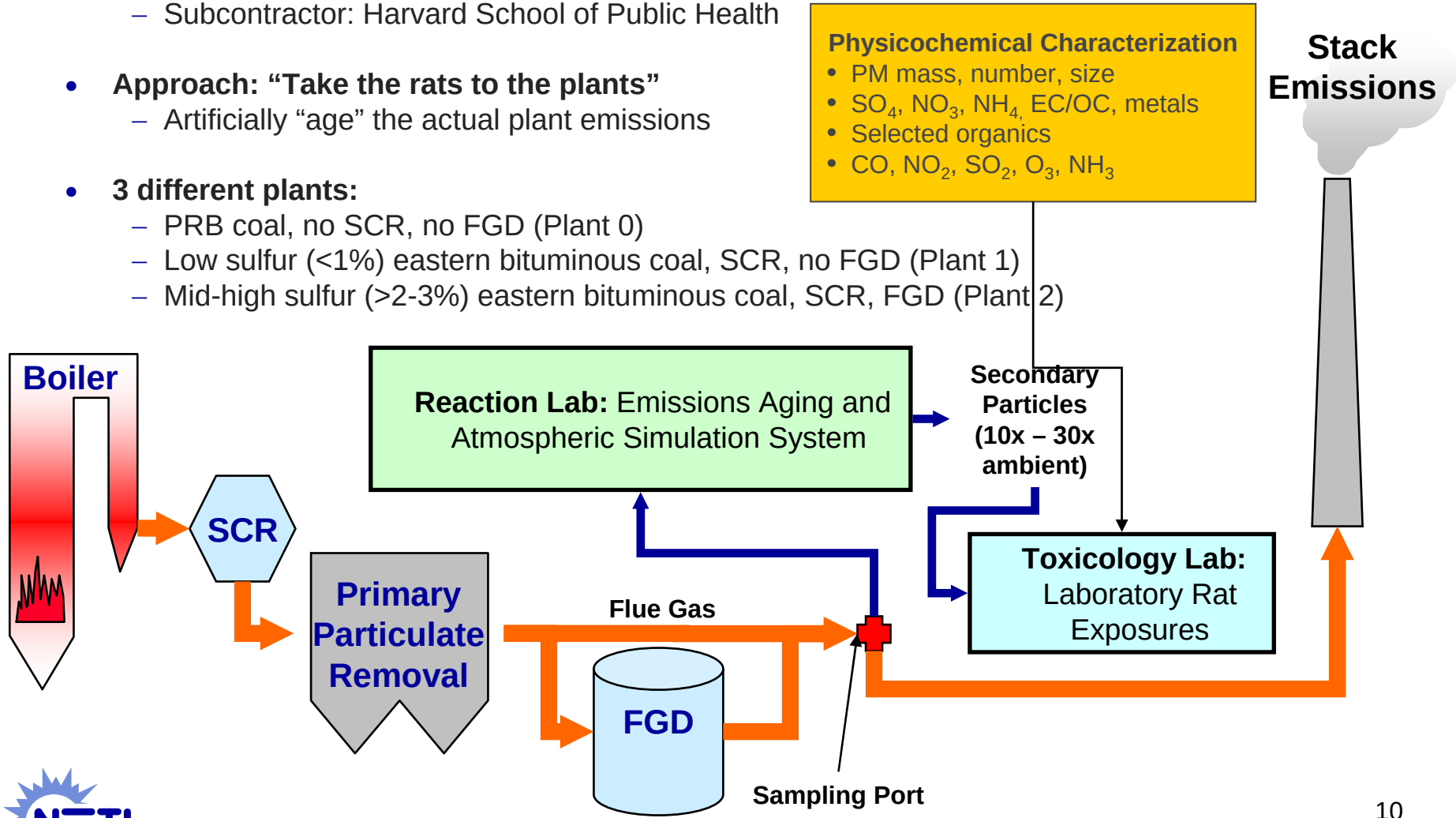
Initial Efforts – FY 2003

- **"Valuing Externalities Workshop" (Feb. 2003)**
  - Focus on PM & Hg externality models
  - http://www.netl.doe.gov/publications/proceedings/03/valuing-ext/v-ext03.html

- **Broad-Based Solicitation for IEP Program**
  - 1 project award (EPRI)
  - TERESA: Toxicological Evaluation of Realistic Emissions of Source Aerosols

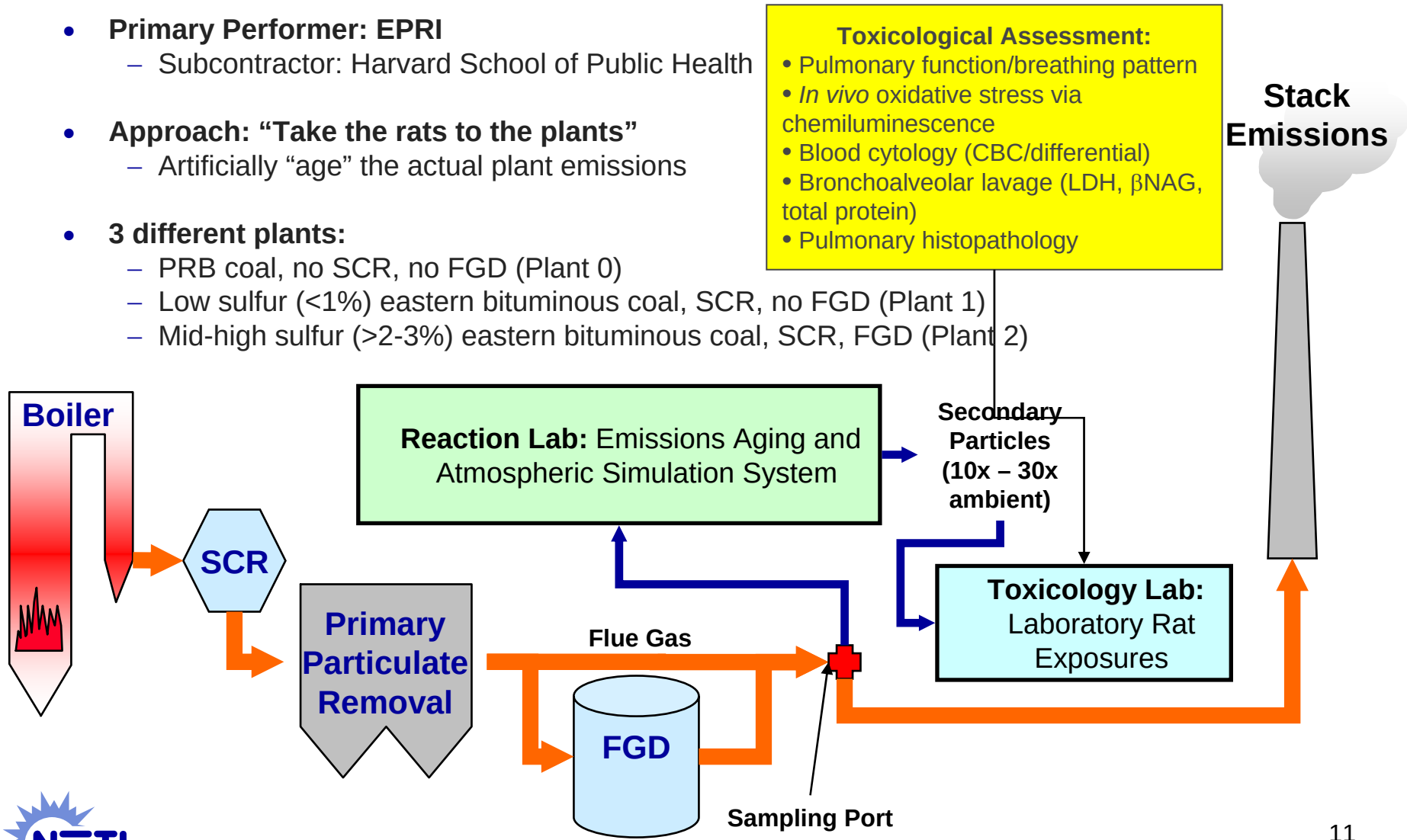
TERESA: Project Schematic

- **Primary Performer: EPRI**
  - Subcontractor: Harvard School of Public Health
- **Approach: "Take the rats to the plants"**
  - Artificially "age" the actual plant emissions
- **3 different plants:**
  - PRB coal, no SCR, no FGD (Plant 0)
  - Low sulfur (<1%) eastern bituminous coal, SCR, no FGD (Plant 1)
  - Mid-high sulfur (>2-3%) eastern bituminous coal, SCR, FGD (Plant 2)



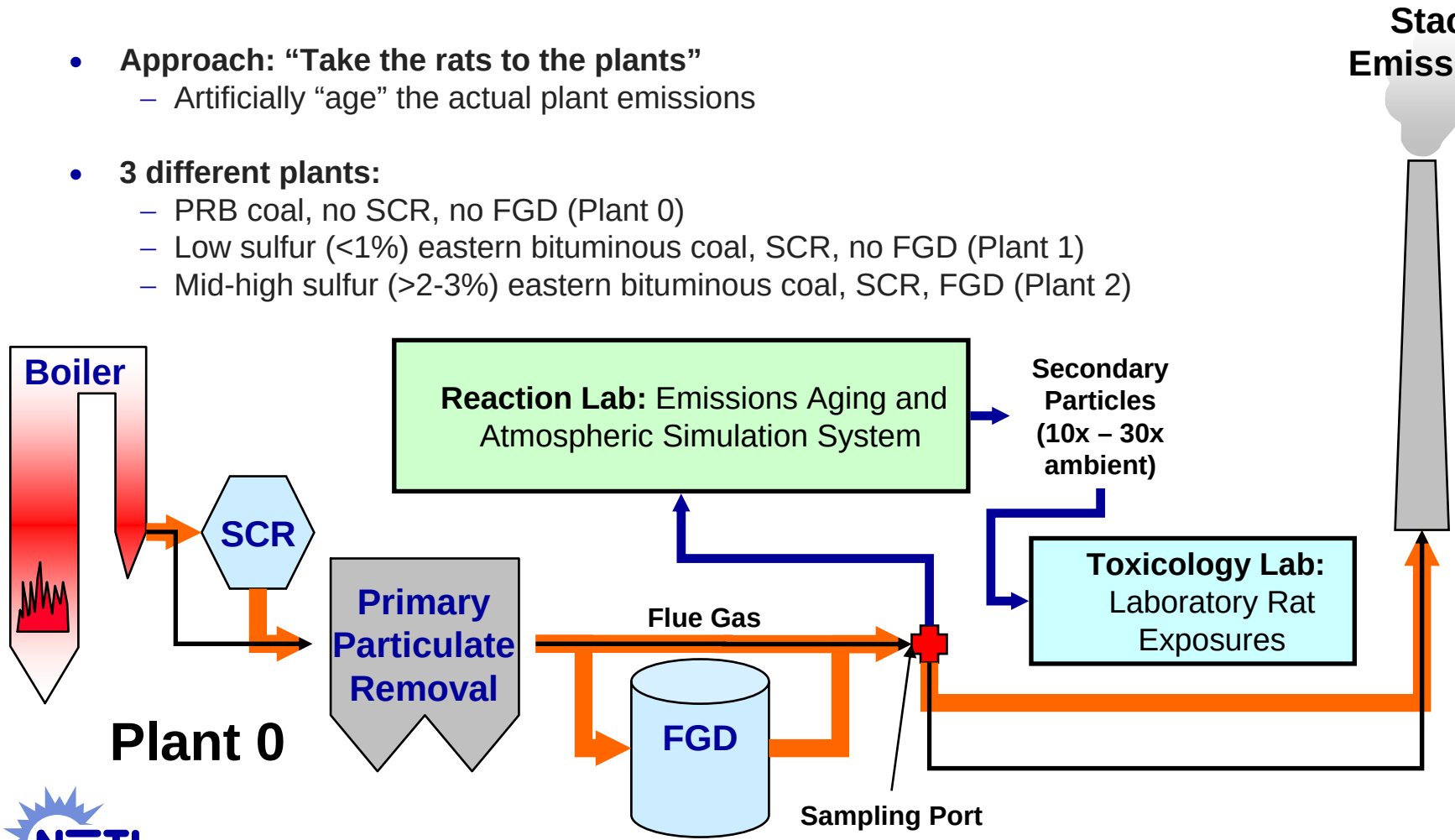
TERESA: Toxicological Assessments

- **Primary Performer: EPRI**
  - Subcontractor: Harvard School of Public Health
- **Approach: "Take the rats to the plants"**
  - Artificially "age" the actual plant emissions
- **3 different plants:**
  - PRB coal, no SCR, no FGD (Plant 0)
  - Low sulfur (<1%) eastern bituminous coal, SCR, no FGD (Plant 1)
  - Mid-high sulfur (>2-3%) eastern bituminous coal, SCR, FGD (Plant 2)



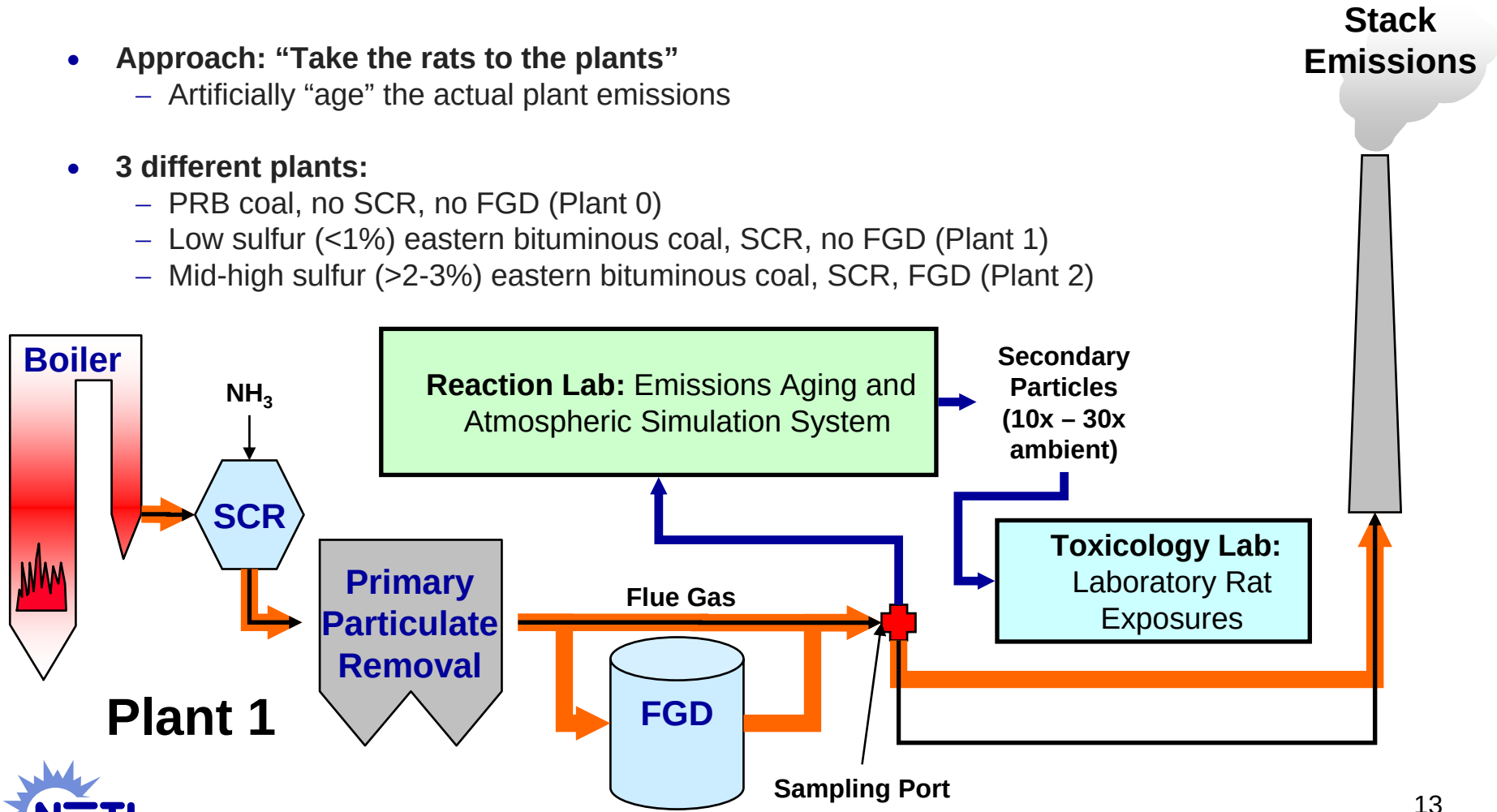
TERESA: Plant 0 Flue Gas Treatment

- **Primary Performer: EPRI**
  - Subcontractor: Harvard School of Public Health
- **Approach: "Take the rats to the plants"**
  - Artificially "age" the actual plant emissions
- **3 different plants:**
  - PRB coal, no SCR, no FGD (Plant 0)
  - Low sulfur (<1%) eastern bituminous coal, SCR, no FGD (Plant 1)
  - Mid-high sulfur (>2-3%) eastern bituminous coal, SCR, FGD (Plant 2)



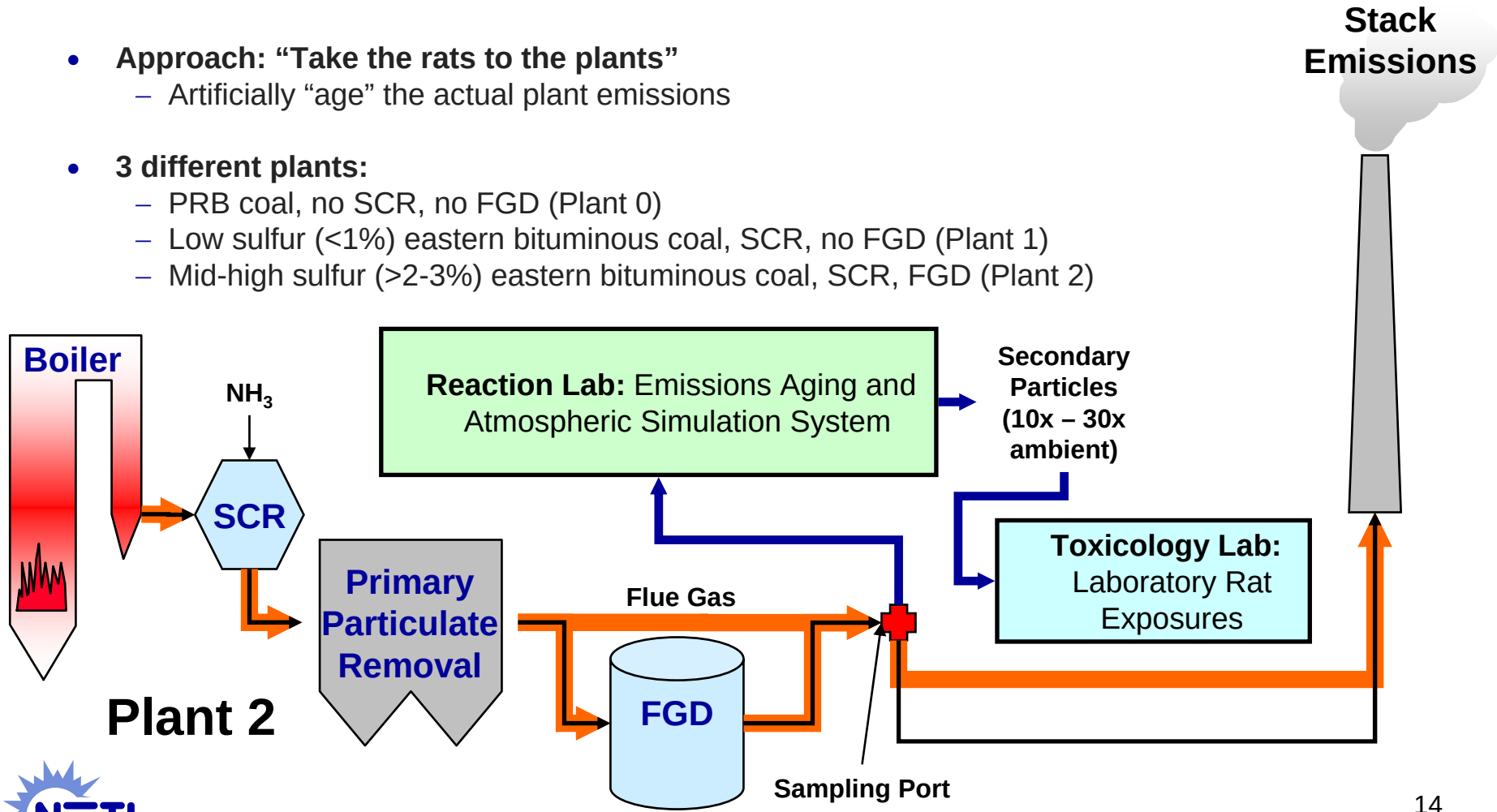
TERESA: Plant 1 Flue Gas Treatment

- **Primary Performer: EPRI**
  - Subcontractor: Harvard School of Public Health
- **Approach: "Take the rats to the plants"**
  - Artificially "age" the actual plant emissions
- **3 different plants:**
  - PRB coal, no SCR, no FGD (Plant 0)
  - Low sulfur (<1%) eastern bituminous coal, SCR, no FGD (Plant 1)
  - Mid-high sulfur (>2-3%) eastern bituminous coal, SCR, FGD (Plant 2)

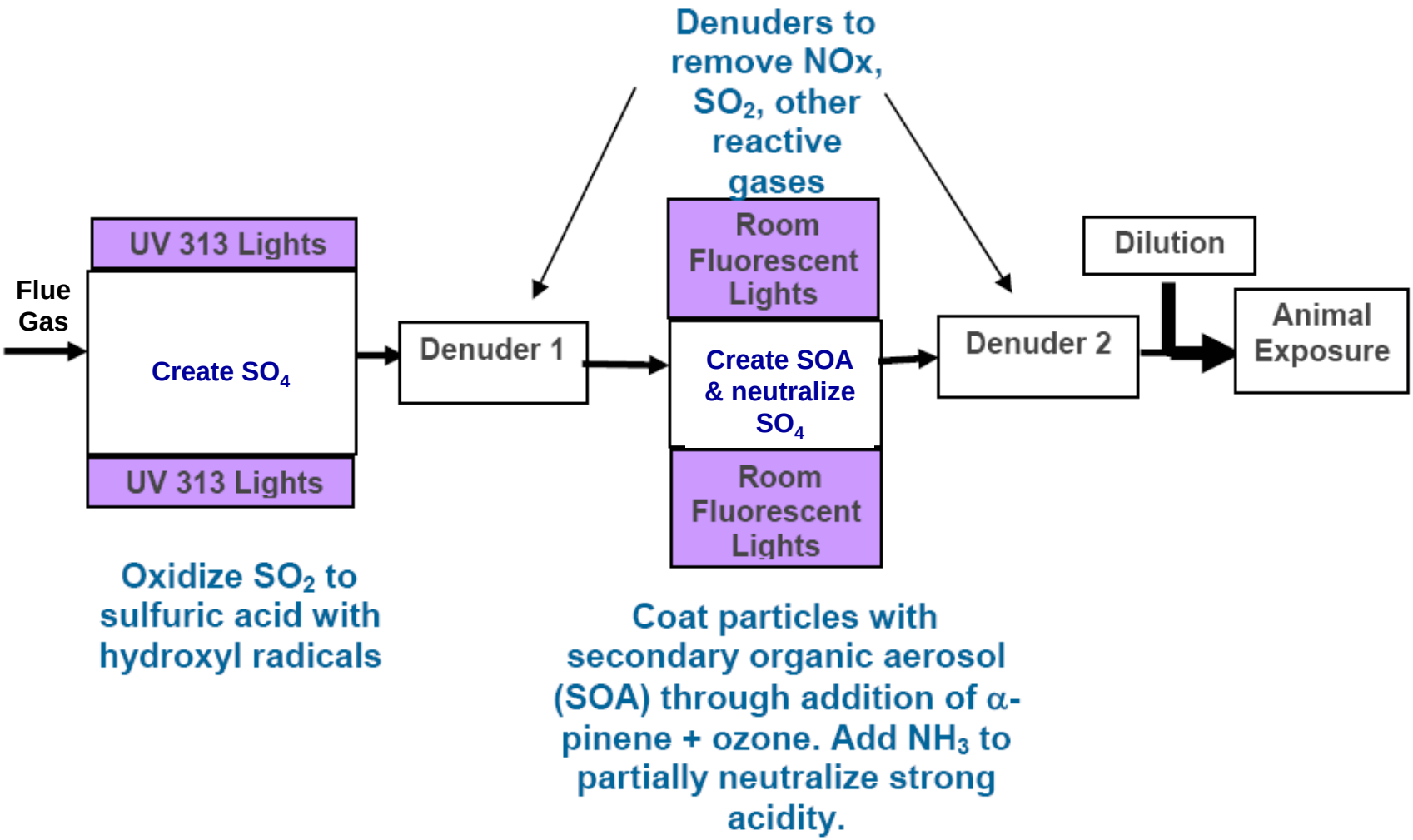


TERESA: Plant 2 Flue Gas Treatment

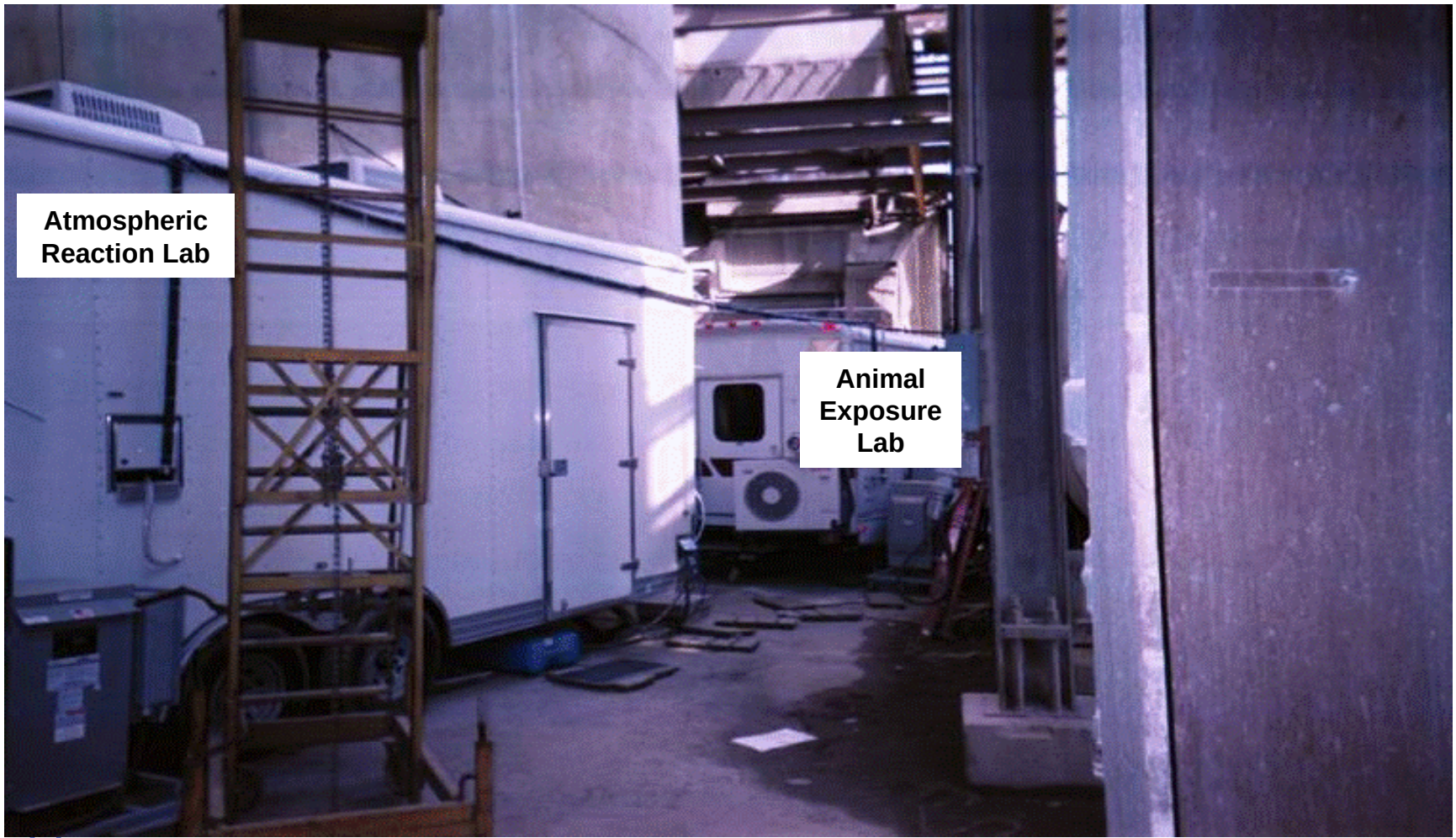
- **Primary Performer: EPRI**
  - Subcontractor: Harvard School of Public Health
- **Approach: "Take the rats to the plants"**
  - Artificially "age" the actual plant emissions
- **3 different plants:**
  - PRB coal, no SCR, no FGD (Plant 0)
  - Low sulfur (<1%) eastern bituminous coal, SCR, no FGD (Plant 1)
  - Mid-high sulfur (>2-3%) eastern bituminous coal, SCR, FGD (Plant 2)



TERESA: Emissions Aging and Atmospheric Simulation System



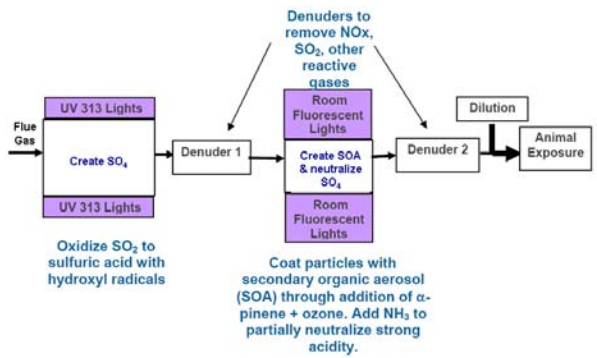
TERESA: Field Setup at Plant 0



TERESA: Exposure Scenarios

#	Code	Composition	Simulated Atmospheric Condition
1	---	Gas- and particle-free air	Sham exposure
2	P	Primary (un-aged) emissions diluted using clean air	Primary stack emissions only
3	PO	Primary emissions + hydroxyl radicals	Sulfate aerosol formation from nucleation
4	PON	Primary emissions + hydroxyl radicals + ammonia	Sulfate aerosol, partially neutralized
5	POS	Primary emissions + hydroxyl radicals + VOCs	Sulfate aerosol plus SOA from biogenic emissions
6	PONS	Primary emissions + hydroxyl radicals + ammonia + VOCs	Mixture of neutralized sulfate aerosol and SOA from biogenic emissions

- **Short-term exposures:**
  - 2-4 consecutive days
- **Stage 1: Normal rats**
- **Stage 2: "Compromised" rats**
  - Simulated MI condition



TERESA: Results and Status

- **Plant 0: Field experiments completed Fall 2004**
  - No adverse effects in any exposure scenario
  - Topical report is now available

- **Plant 1: Field experiments completed Summer 2005**
  - Increased chemiluminescence in heart and lung tissues for POS and PONS scenarios (not P, PO, or PON)
  - Increased arrythmias in MI rats for POS and PONS Scenarios
  - Organics were important: Unclear whether effects resulted from organics alone or from synergistic effects with aerosol mixture
  - Topical report now being finalized

- **Plant 2: Field experiments completed Summer 2006**
  - Health effects data still being analyzed

- **Similar experiments with mobile source emissions planned for 2007**
  - Experiments not DOE-funded, but DOE funding will be used to integrate results with coal plant experiments

"Targeted" Solicitation - FY04

Epidemiology and Toxicology of Primary and Secondary Particulate Matter Emissions from Coal-Fired Power Plants

- **Coordination with EPA via AQRS-PM Working Group**
  - Research Objectives reviewed at pre-solicitation meeting
    - RTP – December 16, 2003
  - EPA scientists participated in proposal reviews

- **Anticipated DOE funding ~ $4.8 - $7.5 Million;**
  - Actual Funding: $2.9 Million DOE + $3.0 Million Cost Share = $5.9 Million
  - Awards made in Fall 2004
    - Project Duration: 2004-08

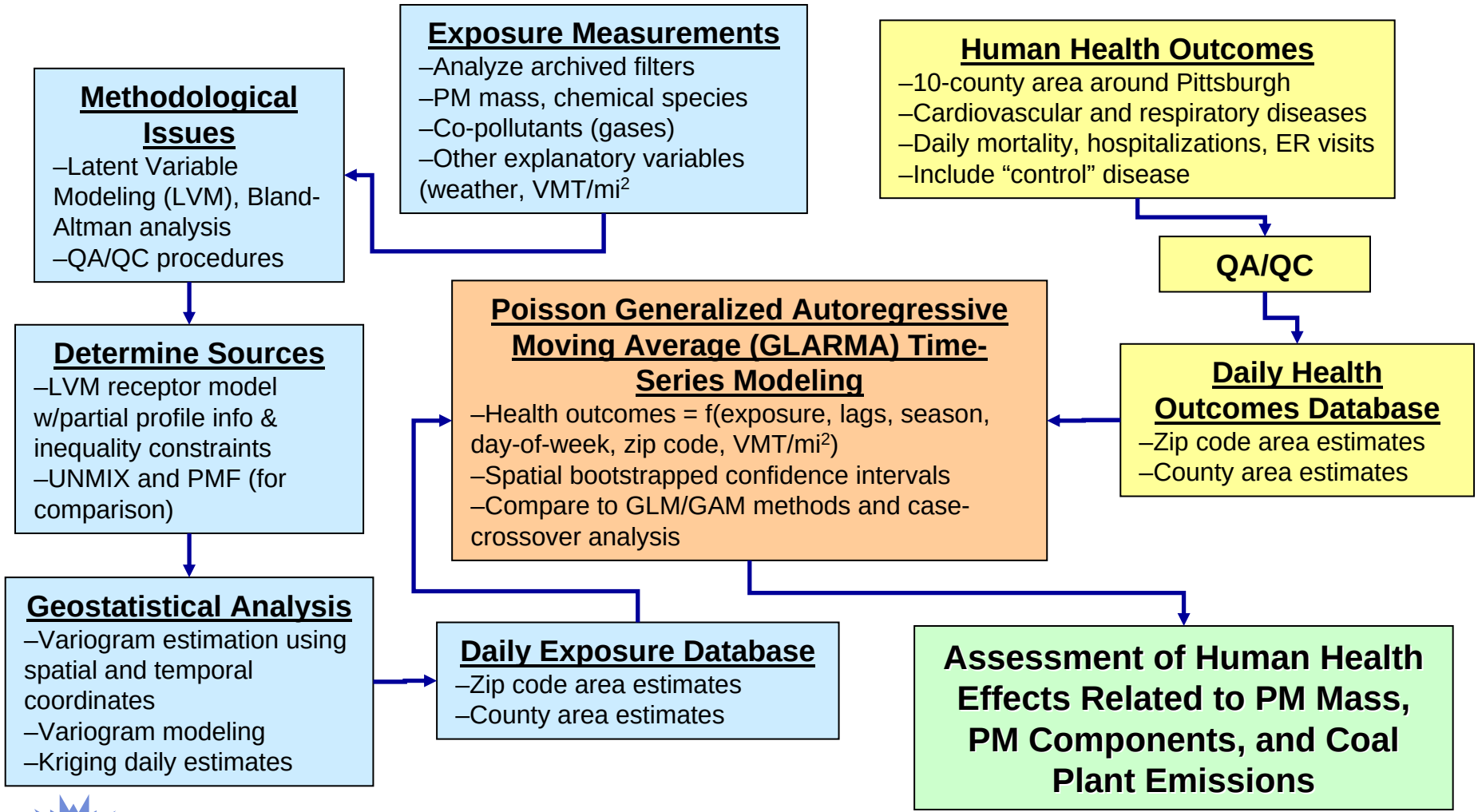
- **Area of Interest 1 - Epidemiology (1 project)**
  - Pittsburgh Epidemiology Study - Design and Feasibility Assessment

- **Area of Interest 2 - Toxicology (2 projects)**
  - Tri-City Concentrated Ambient Particle Study (Tri-City CAPS)
  - Sub-chronic Inhalation of Simulated Downwind Coal Combustion Emissions

Pittsburgh PM Epidemiology Study - Design and Feasibility Assessment

- **Primary Performer: University of Pittsburgh**
  - Partners: CONSOL Energy, Allegheny County Health Department, Ohio University
- **Objective: Design framework for an epidemiology study to define the public health implications of PM from coal- fired power plants**
  - Retrospective Epidemiological Time Series (1999-2006)
    - Air quality data from DOE-NETL, ACHD, EPA Supersite & STN
  - Exposure Assessed over 35-County Region Surrounding Pittsburgh + Archived Filters
    - Incorporate alternative exposure proxies (VMT/mi^2)
    - All data organized via GIS system
  - Generalized Autoregressive Moving Average (GLARMA) Time Series Model for Each Health Outcome
- **Final Report available ~ March 2007**
- **Full epidemiology study will require 100% non-DOE funding**
  - Analyze archived PM samples (~ $300k required); Collect additional data if needed
  - EPRI has shown interest in co-funding

PITT-PM Retrospective Epidemiological Study Design (1999-2006)



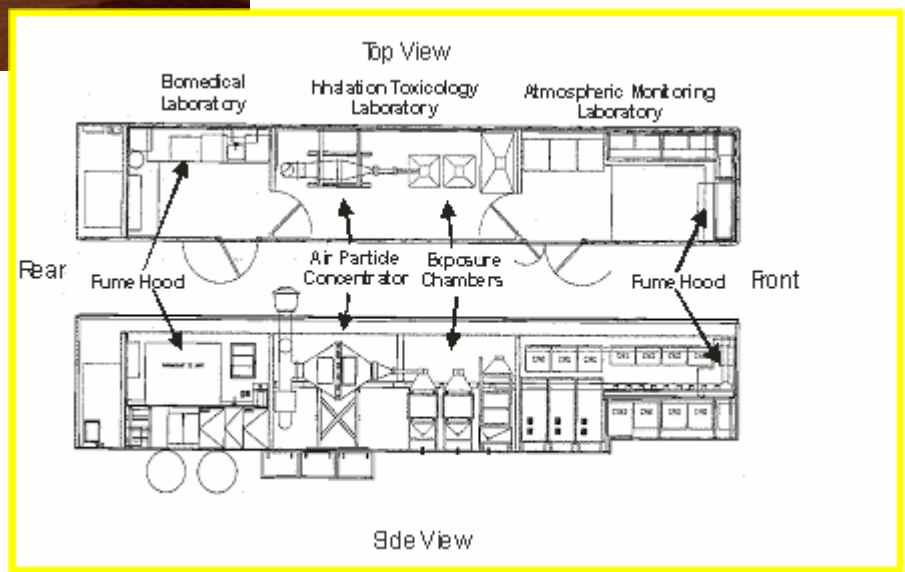
Tri-City CAPS: Overview

- **Primary Performer: EPRI**
  - Subcontractor: Univ. of Michigan (atmospheric measurements)
  - Subcontractor: Michigan State University (toxicology studies)

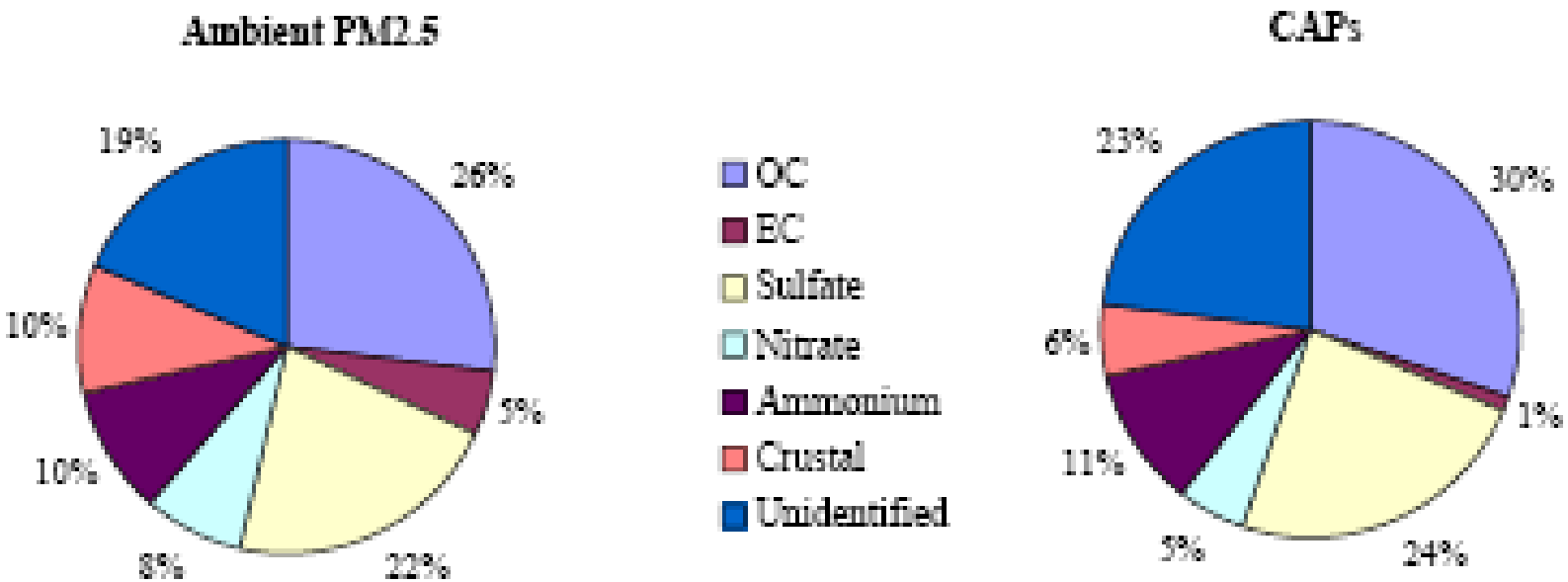
- **Approach: “Take the rats to the field”**
  - Detroit - Ambassador Bridge (traffic and secondary sulfates)
  - Steubenville, OH (industrial sources and secondary sulfates)
  - M.K. Goddard State Park, Northwest PA (secondary sulfates only)

- **Mobile ambient particle concentrator & animal exposure laboratory**
  - Normal and hypersensitive rats exposed to CAPs (8h/day) for 13 days
    - Concentration Factor ~ 30
    - Summer and winter exposures at all 3 sites
  - Source apportionment to confirm sources of CAPs
  - Link responses to PM sources and components

Tri-City CAPS: Mobile Exposure Laboratory "AirCARE 1"

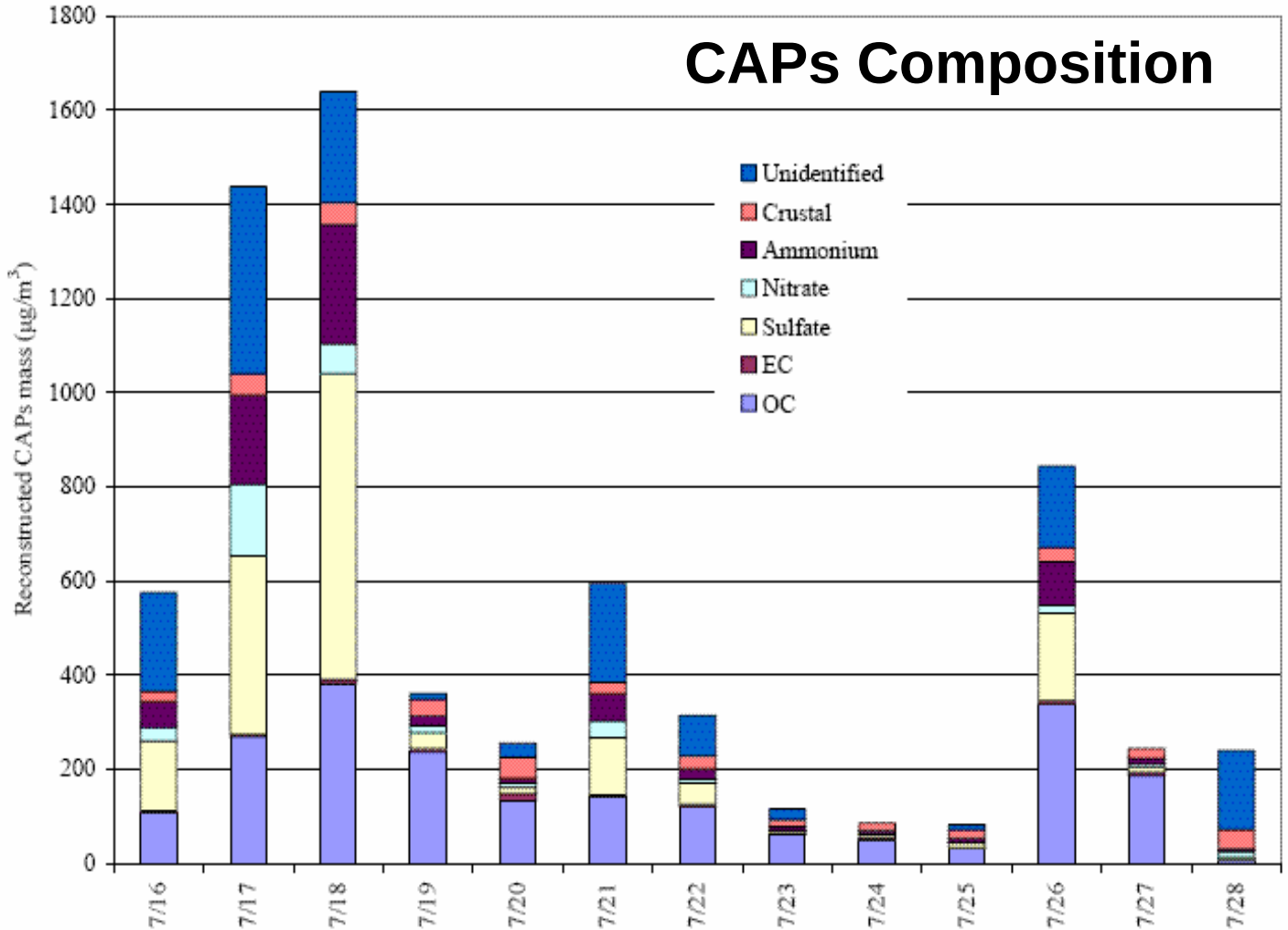


PM Composition, Detroit, Summer 2005



Average July 16-28, 2005

PM Composition, Detroit, Summer 2005



Tri-City CAPS: Results and Status

- **Detroit fieldwork is complete (summer 2005, winter 2006)**
  - CAPs appear to have both cardiac and pulmonary effects
  - Analyses underway to explore associations of PM components and sources with biological responses
    - Day-to-day variations in local source contributions
- **Steubenville summer fieldwork completed (2006)**
  - Preliminary data analysis underway
  - Winter fieldwork scheduled for early 2007
- **Field work at M.K Goddard Park scheduled for summer 2007 & winter 2008**

Sub-chronic Inhalation of Simulated Downwind Coal Combustion Emissions

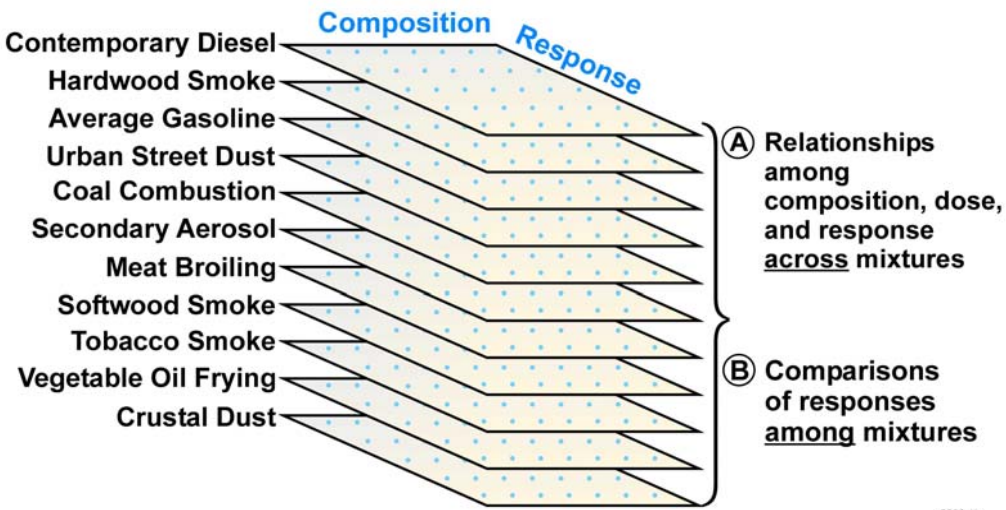
- **Primary Performer: Lovelace Biomedical and Environmental Research Institute**

- **Laboratory simulation of coal combustion atmospheres (4 dilution ratios)**
  - Drop-tube furnace, PRB coal; gases and ammonium sulfate/nitrate particles added downstream

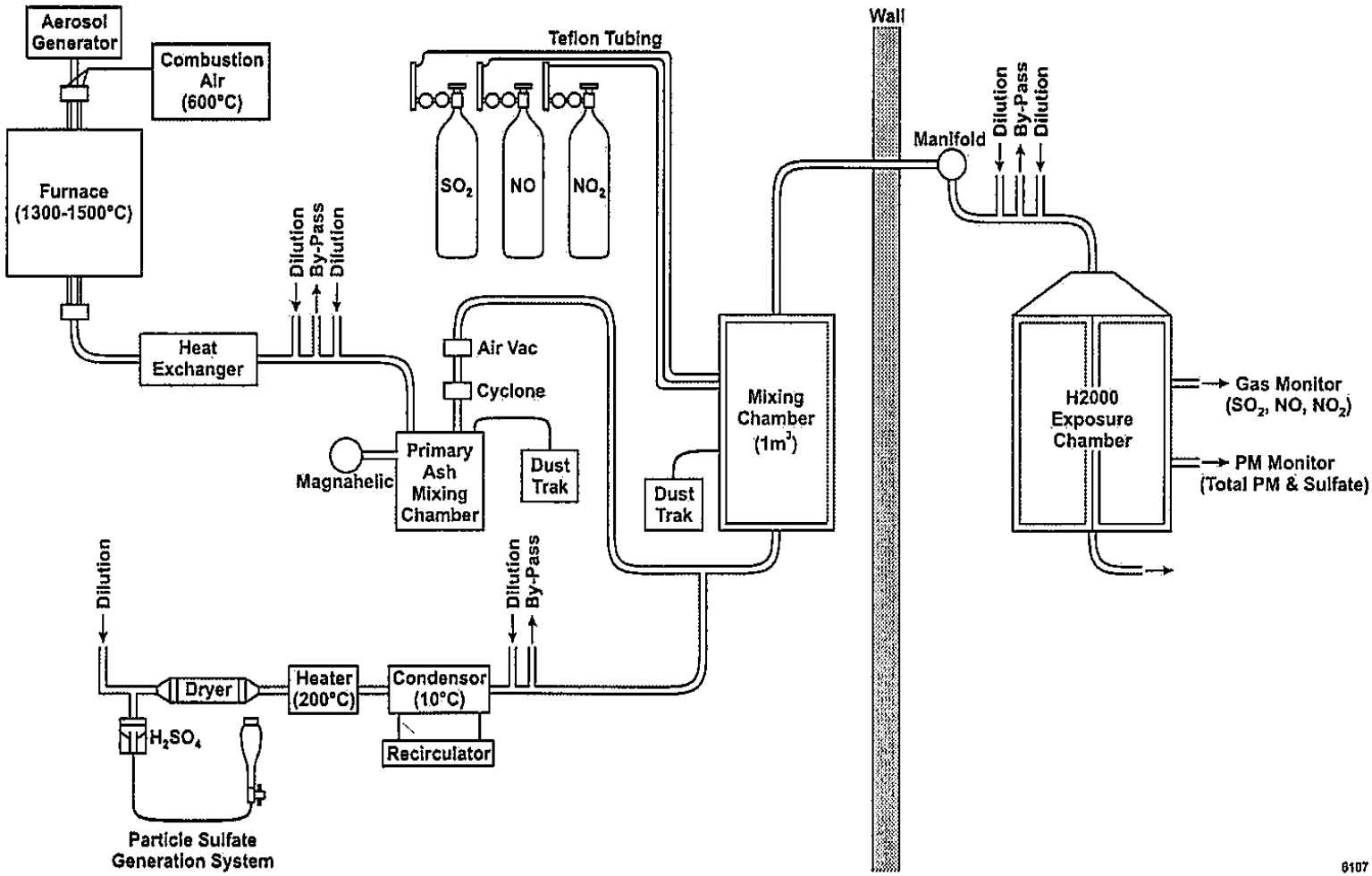
- **Integrated with National Environmental Respiratory Center protocol**
  - Diesels, gasoline engines, wood smoke, road dust also studied in NERC framework

NERC Study: General Framework

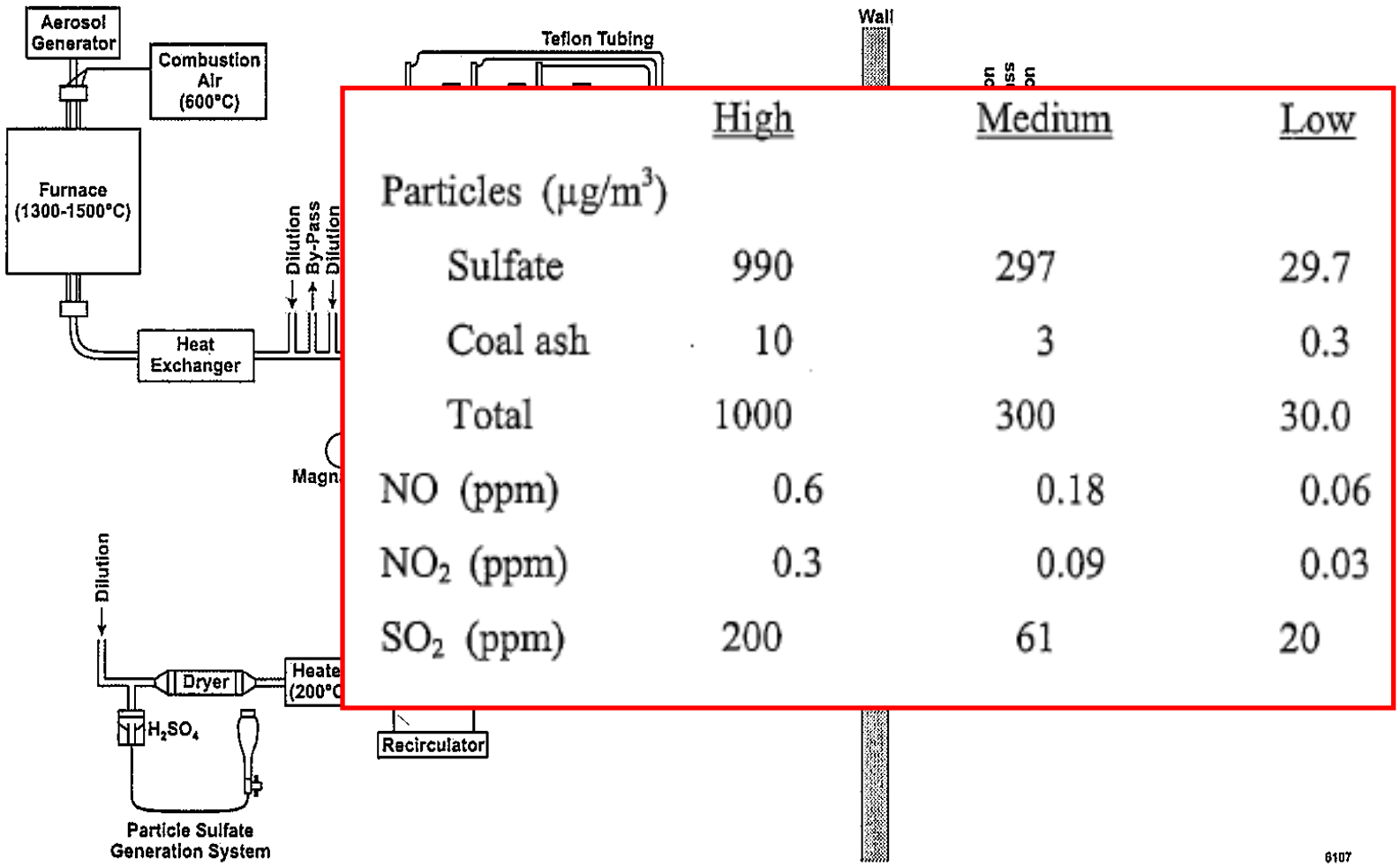
- Dose-response studies (4 treatment groups + control)
- Expose 7 days/wk for up to 6 months
- Characterize exposure at highest practical level of detail (>500 analytes)
- Measure health outcomes in 5 general categories (>200 parameters)



Laboratory Generation of "Downwind" Coal Combustion Emissions



Exposure Chamber Target Concentrations



	High	Medium	Low
Particles ($\mu g/m^3$)			
Sulfate	990	297	29.7
Coal ash	10	3	0.3
Total	1000	300	30.0
NO (ppm)	0.6	0.18	0.06
NO_2 (ppm)	0.3	0.09	0.03
SO_2 (ppm)	200	61	20

NERC Coal Emissions Study: Project Status

- **Coal emissions generation and processing system completed and verified**
  - Phase I Report available
- **Animal exposures began November 2006**

Project Web Sites

- **Pittsburgh Epidemiology Study - Design and Feasibility Assessment**
  - http://www.netl.doe.gov/technologies/coalpower/ewr/air_quality_research/health_effects/**pitt_coal.html**
- **TERESA**
  - http://www.netl.doe.gov/technologies/coalpower/ewr/air_quality_research/health_effects/**teresa.html**
- **Tri-City CAPS**
  - http://www.netl.doe.gov/technologies/coalpower/ewr/air_quality_research/health_effects/**cardiopulmonary.html**
- **Sub-chronic Inhalation of Simulated Downwind Coal Combustion Emissions**
  - http://www.netl.doe.gov/technologies/coalpower/ewr/air_quality_research/health_effects/**coal_emissions.html**

NETL Contacts

- **Tom Feeley**
  - Technology Manager, Innovations for Existing Plants
  - Phone: (412) 386-6134
  - Email: thomas.feeley@netl.doe.gov
- **Sara Pletcher**
  - Project manager for TERESA, Tri-City CAPS, and Lovelace (NERC) projects
  - Phone: 304-285-4236
  - Email: sara.pletcher@netl.doe.gov
- **Bill Aljoe**
  - Project manager for Pittsburgh PM Epidemiology Feasibility Study
  - Phone: 412-386-5659
  - Email: aljoe@netl.doe.gov

Questions?