Green Zia Tools Assessment for DX-2 Chemistry Lab

Alicia H. Pope & Marla Maltin
Applied Technology (AT)
Bryan Carlson
Applied Chemical Technology (ACT)
Jim Stine, Ken Laintz, Connie Gerth, Greg Sullivan & Kien-yin Lee
Dynamic Experiment Division (DX-2)
Jack Mizner
The IT Corporation (IT)

Background

The Dynamic Experimentation (DX) Division is the Laboratory's primary experimental resource for maintaining a safe and reliable nuclear weapons stockpile in the absence of nuclear testing. DX Division personnel perform research, engineering, and experimentation on high explosives and dynamic processes essential to the success of the nation's Science-Based Stockpile Stewardship program. The division's stockpile management responsibilities include the manufacture of production detonators for the stockpile and surveillance of stockpile detonators and energetic materials. The division operates and maintains a suite of explosives firing sites—both locally and at the Nevada Test Site—with state-of-the-art diagnostics and including world-class radiographic machines.

DX Division encompasses the following principal programs and facilities:
- AGEX I—hydrodynamic testing
- AGEX II—explosively driven pulsed-power physics and high-energy-density physics
- Detonator production
- High-explosives science
- Department of Defense Programs - advanced conventional munitions development
- PHERMEX—Pulsed High-Energy Radiographic Machine Emitting X-Rays
- DARHT—Dual-Axis Radiographic Hydrotest facility (under construction)
- U1a—Nevada Test Site facility for the underground testing of special nuclear materials

DX-2 is a group within the DX division at LANL concerned with all aspects of High Explosives (HE) from cradle to grave. These aspects include chemistry, engineering, materials properties, and physics related to the synthesis, formulation, performance, and safety of explosives; monitoring and surveillance of explosives in the enduring nuclear stockpile; unique applications of explosives; and environmentally conscious destruction/disposal of explosives and explosive devices. DX-2 is currently housed in a 1950’s vintage chemistry lab where current operations have evolved within the space constraints of the building. In general, lab space is used inefficiently due to the challenge of new technology being adapted to an old lab design.

The DX division currently occupies 26 square miles of lab space. The long-term plan is to co-locate people and facilities within a campus environment in TA-22. The envisioned campus environment will consist of 7 buildings. Five of these will be GPP projects consisting of light labs/office buildings, with one medium-heavy lab/office. The two proposed line item projects are a Confined Firing Facility and a HE Chemistry Lab. Most of the discussion to date has focused on the current activities within the existing chemistry lab and the needs for the new, "proposed" chemistry lab (10 years in the future).

A Green Zia analysis was conducted on the operations of the DX-2 group according to the New Mexico Green Zia Environmental Excellence Award program guidance hhtp://www.nmenv.state.nm.us/. This Green Zia assessment focused on a high-level approach. The DX-2 Chemistry Lab consists of a number of discrete, interrelated processes and activities. These processes and activities have similarities and use the same infrastructure, therefore it is possible to identify generic opportunities for process improvement and waste minimization. It is noted, however, that each process may have unique attributes that may result in different approaches to process improvements and waste minimization. These differences are noted and may require separate Green Zia analyses to identify and implement effective improvements. Detailed cost analysis, such as activity based costing and life-cycle analysis, typically conducted as part of a Green Zia analysis, will be performed separately on specific opportunities as indicated in the Action Plan.

The Green Zia Analysis had two distinct goals: 1) to identify operational improvements at the current lab and 2) to identify improvements in operations and sustainable elements that will be included in the design of the new facility. Both are interrelated. The approach was to identify problems and challenges with current operations, then to brainstorm solutions. Solutions may be applicable to current operations only, future operations only, or to both. It is important to begin incorporating processes, procedures and work habits that will be designed into the new facility into current operations so that they can be tested for efficacy, and to prepare researchers for anticipated work conditions.

The approach for the Green Zia assessment is shown graphically below in Figure 1. The goal of this process is to improve the operations at the DX-2 Chemistry lab and to determine the functional and space requirements for the new facility. This high-level green zia assessment will set the course for this approach by defining needs, strategies and potential solutions for both the existing and planned chemistry labs. These solutions will be further defined and evaluated using additional green zia tools for specific applications, site visits to similar facilities, and the consultation with experts in laboratory design and operations.

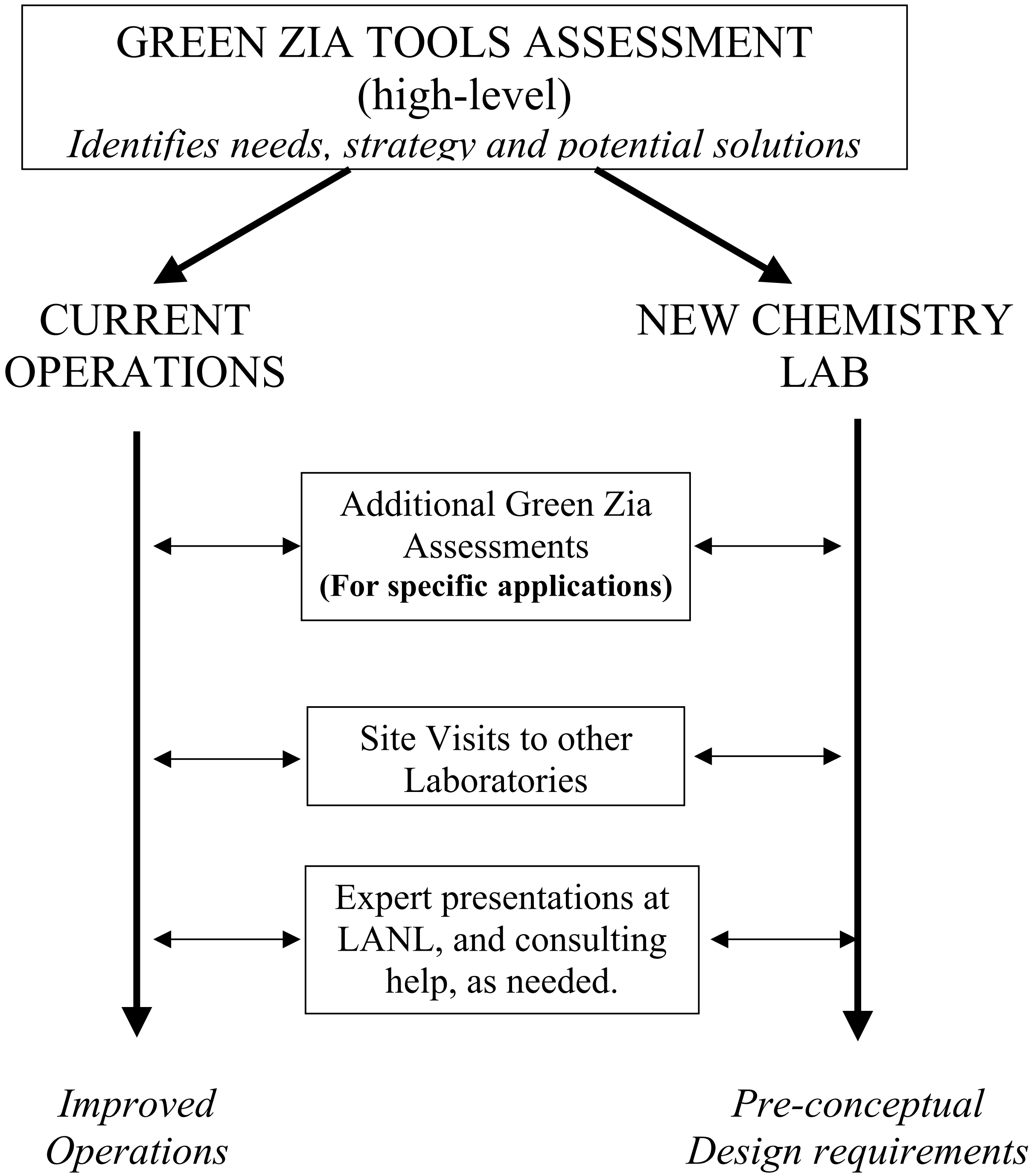

Figure 1. Green Zia Tools Assessment for DX-2 High Explosive Chemistry Lab

The Challenge

The operations at the chemistry lab are conducted in individual laboratories arranged along a central utility corridor with doors opening to a pedestrian corridor (see figure below). Individual labs vary in size and shape. Figure 2 presents a schematic of this arrangement. Underground storage bunkers are provided on either side of the laboratory for HE storage when it is not being used for analysis or experimentation in an individual laboratory.

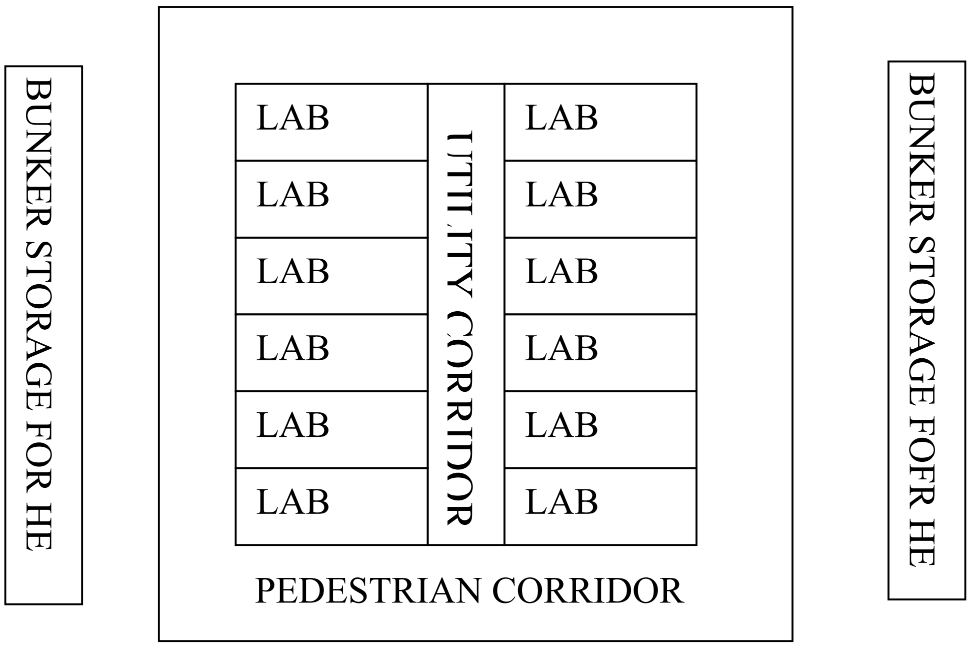

Figure 2. Schematic of Lab Space at DX-2 Chemistry Lab

The laboratory walls are constructed of poured concrete (one foot thick). The door to the pedestrian corridor is intended to be a blow-out structure. The wall to ceiling height is approximately 12 ft. In general all the laboratories contain stainless steel benches, sinks and fume hoods mounted on both sides of the laboratory. The dimensions of the lab benches are: height ~ 40 inches, depth ~ 36 inches with a 4-6 inch back lip. Cabinet storage is located underneath the benches and utilty connections (water, vacuum, gases) are provided through valved connections penetrating the back lip. Cabinets with glass doors are located above the lab benches, extending from the benches to the height of the ceiling. Center islands and computer work stations are located in some of the laboratories. Each of the laboratories has a one lb. limit of HE with the exception of the Synthesis Lab.

One of the following three basic functions may be conducted in each of the laboratories:

1. Synthesis. This function involves the synthesis of new explosive compounds and is the most chemical intensive operation. Most syntheses produce mg quantities of new compounds. However, following testing, large quantities may be synthesized for use in pilot scale experiments.
2. Analysis. This function consists of testing HE compounds. The tests may include: analysis of basic characteristics such as molecular weight, density, chemical structure; and determination of compound properties such as spark, friction and impact limits and vacuum thermal stability. Chemicals used for analysis are primarily involved in sample preparation prior to analysis.
3. Pilot Scale Testing. This function involves experimentation on larger quantities of HE.

Because the current operations at the chemistry lab are conducted in a facility nearly 50 years old, personnel are faced with unique challenges to accomplish their jobs. This is primarily due the challenge of new technology being adapted to an old lab design. In genera, personnel are conducting more analytical and micro-chemistry operations in a facility designed for large-scale wet chemistry processes. The research chemists and engineers, by necessity, must spend part of their time working with the building constraint and addressing peripheral issues (waste management, poor space allocation, lack of an automated sample and chemical management system) to meet compliance requirements and accomplish their job functions. This directly affects their productivity. LANL management recognizes this and is proposing a new DX-2 Chemistry Lab as a line item project. A study conducted by D-4 (Cost Saving for the Dynamic Experimentation Division Strategic Facility Business Plan) compared the cost to upgrade the existing facility to meet current code requirements (i.e., grounding and electrical systems, hoods) and mission needs with the cost of building a new facility, and concluded that the design and construction of a new facility is life-cycle cost effective.

The challenge is to identify opportunities for improved operations and efficiency under current conditions and to use this as a basis for designing a new facility that exceeds minimum requirements and will be a healthful, resource efficient, and productive working environment. DX-2 management is committed to using sustainable design principles (energy efficiency, water efficiency, resource efficiency, improved indoor environmental quality, reduced waste generation) to design a facility with a minimum environmental footprint that has an inherent flexibility that can accommodate and addresses changing requirements and work scope.

DX-2 personnel decided to meet this challenge by applying the Green Zia systems approach to address these issues. A DX-2, multi-disciplinary, Green Zia team was formed to address the improvement of the Chemistry Lab operations. Participants on this team included people familiar with Chemistry Lab operations. The team consists of the following members:

- Jim Stine, DX-2 Group Leader
- Tom Starke, Pollution Prevention (P2) Program Office, Pollution Prevention Specialist
- Alicia Pope, AT, Team Facilitator
- Bill Jones, Project Management Division (PMD)
- Keith R. Barras, PMD, Architect
- James Covey, PMD, Architect
- José Archuleta, DX-2, Bench-top and Synthesis Chemist
- Bryan Carlson, ACT, Process Engineer
- Ken Laintz, DX-2, Analytical Chemist
- Greg Sullivan, DX-2, Lab Bench Chemical Engineer
- Kien-yin Lee DX-2, Bench-Top and Synthesis Chemist
- Connie Gerth, DX-2, Waste Coordinator
- Jack Mizner, IT Corporation, Pollution Prevention Specialist
- Marla Maltin, AT, Research Intern
- Allan Anderson, DX-DO, Strategic Planner
- Karl Jonietz, P2 Program Office, Marketing and Communication Specialist
- Mike Hiskey, DX-2 Bench-Top and Synthesis Chemist

This report describes the results of this approach and how the team applied the following Green Zia tools to address process improvements at the Dx-2 Chemistry Lab.

- Development of a process map to determine opportunities for improvement
- Determining root causes of selected opportunities (cause and effect diagram)
- A consensus problem statement for generating process alternatives
- Generating process alternatives using brainwriting
- Prioritizing alternatives
- Developing a formal action plan

The results from each of these Green Zia tools is described below.

Process Mapping

The first step in conducting a Green Zia assessment is to develop a process map of existing operations. Figure 3 represents the high-level process flow diagram. The central hatched box represents the entire DX-2 Chemistry lab operations, while the six boxes contained within represent the major activities conducted within the Lab. The flow from left to right represents the work flow at the Lab that results in the products that it produces. The flow from top to bottom represents material flows.

Common to all activities is the need for an HE inventory database and sample management system, and a chemical inventory database and management system. Each of the six activities that comprise the DX-2 Chemistry operations is described below, with a summary their specific requirements.

- Synthesis of High Explosives - This function involves the synthesis of new explosive compounds and is the most chemical intensive operation. An unlimited number of small amounts of inorganic and organic chemicals may be used in the process. Most syntheses produce mg quantities of new compounds. However, following testing large quantities may be synthesized for use in pilot scale experiments. Larger quantities of chemicals and glassware are often needed for the preparation of presursors and intermediates in the synthesis process. Lab space requirements for this activity are:
  - Large hoods with the potential for remote operations to protect against detonation
  - Extensive bench space
  - Extensive, easily accessible storage space for chemicals and lab ware
- Analytical Chemistry - This function consists of testing HE compounds using instrumental methods. The tests may include: analysis of basic characteristics such as molecular weight, density, chemical structure; and determination of compound properties. Instruments that are used in this analysis include mass spectrometry, gas chromatography and UV/VIS light spectrometry . Samples quantities are small and chemicals used for analysis are primarily involved in sample preparation prior to analysis. Lab space requirements for this activity are:
  - Small hoods, portable hoods, or no hoods for sample preparation
  - Minimum bench space for sample preparation
  - Dedicated space for analytical instruments and associated computers

- Wet Chemistry - This function consists of testing HE compounds using traditional chemical methods, such as acid-base titrations, and methods to concentrate or dilute samples prior to analysis. Lab space requirements for this activity are:
  - Bench space for sample preparation and analyses
  - Moderate hood space
  - Storage space for chemicals and lab ware
- Engineering Formulations – This function involves conducting pilot scale experimentation (batch or continuous flow) to investigate synthesis of larger amounts of HE compounds. This activity requires larger quantities of reagents and produces greater quantities of HE and associated waste products. Pumps, containers (1-2 gal), piping and tubing, mixers and other equipment are used to construct the pilot scale tests. Lab space requirements for this activity are:
  - Large hoods. Walk-in hoods and hoods within a separate thermal room are needed.
  - Separate or remote space for operations incompatible with HE, such as vacuum drying.
  - Bench space for sample and reagent preparation
  - Dedicated floor and/or hood space
  - Storage space for chemicals, lab ware and equipment
  - High bay space
- Physical and Mechanical Testing – This function consists of testing HE compounds using physical methods. Tests include spark, friction and impact limits and vacuum thermal stability. These tests are conducted in a lab dedicated to that purpose on specific instruments. Lab space requirements for this activity are:
  - No hood requirements, but the space must meet ventilation and humidity requirements.
  - High bay space
- Quality Assurance - This is an administrative activity applicable to all of the activities listed above. The purpose of a good quality assurance program is to ensure that all materials, spaces and testing procedures meet rigid requirements to ensure that anicpated results used are consistent and meet the highest level of scientific scrutiny and ensure the highest level of employee and environmental safety. Functions within this category include: hood and instrument calibration and testing, verification of chemical purity and analytical standards, statistical methods and testing to ensure environmental conditions within lab spaces.

  The process map considered only those activities conducted in the existing DX-2 Chemistry Lab. It is noted, however, that additional activities are being considered for inclusion in the new facility. These activities include grinding and pressing and laser operations, which will have specific space requirements, and must be considered in developing the design specifications for the new facility.

Root Cause Analysis

The team used a cause and effect (fishbone) diagram (Fig. 4) to examine the methods, equipment , facility design aspects and people-related issues associated with the DX-2 Chemistry Lab operations to the root causes of identify potential contributing causes inefficient laboratory operations. Some of the more significant causes include:

- ✓ Sample and Chemical Management System

- ✓ Specific Environmental Controls (i.e., temperature, humidity) for each of the lab spaces and personnel.
- ✓ Old, poorly functioning hoods that are not matched with needs for each activity.
- ✓ Lab spaces are inadequate for activities conducted in them. Modularity is a critical need for the new lab design.
- ✓ Disposal of HE waste water, waste management, and utilities.

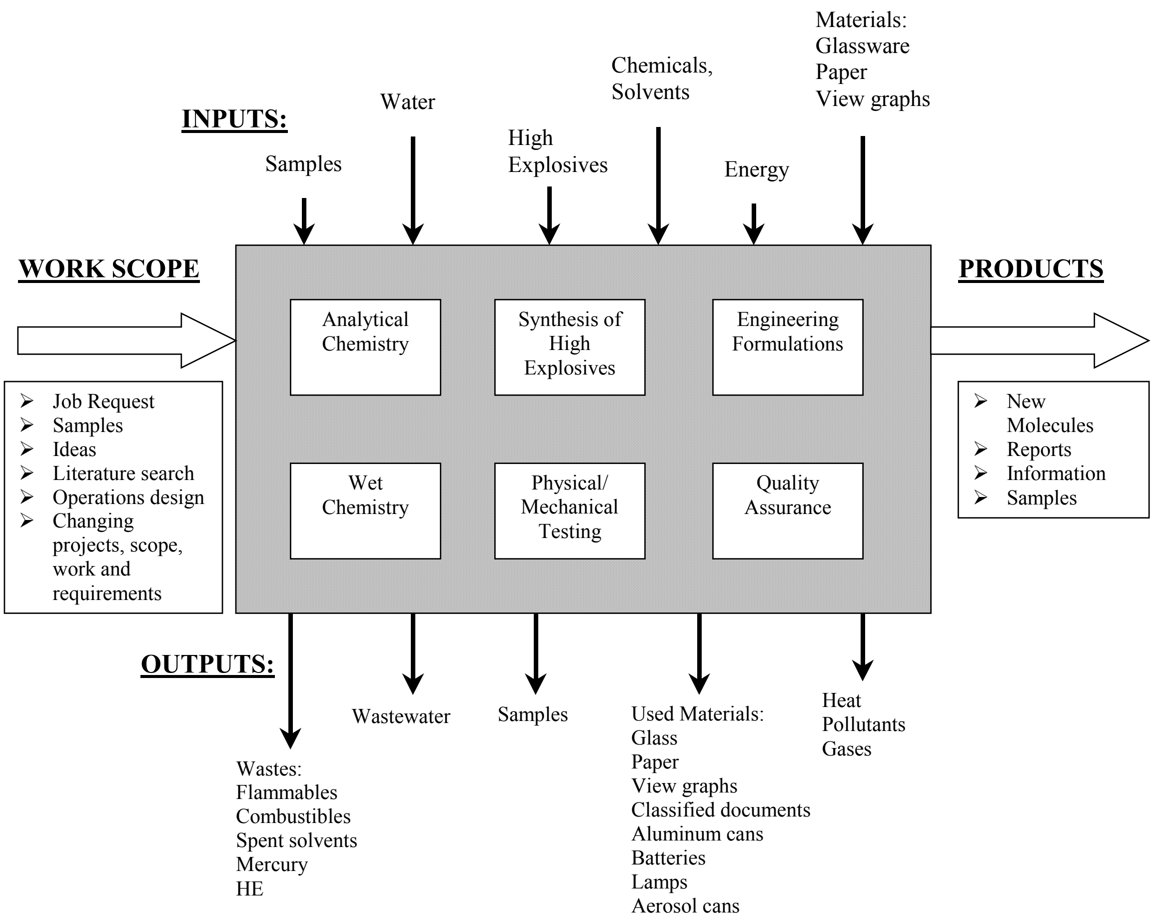

Figure 3. PROCESS FLOW DIAGRM FOR DX-2 OPERATIONS

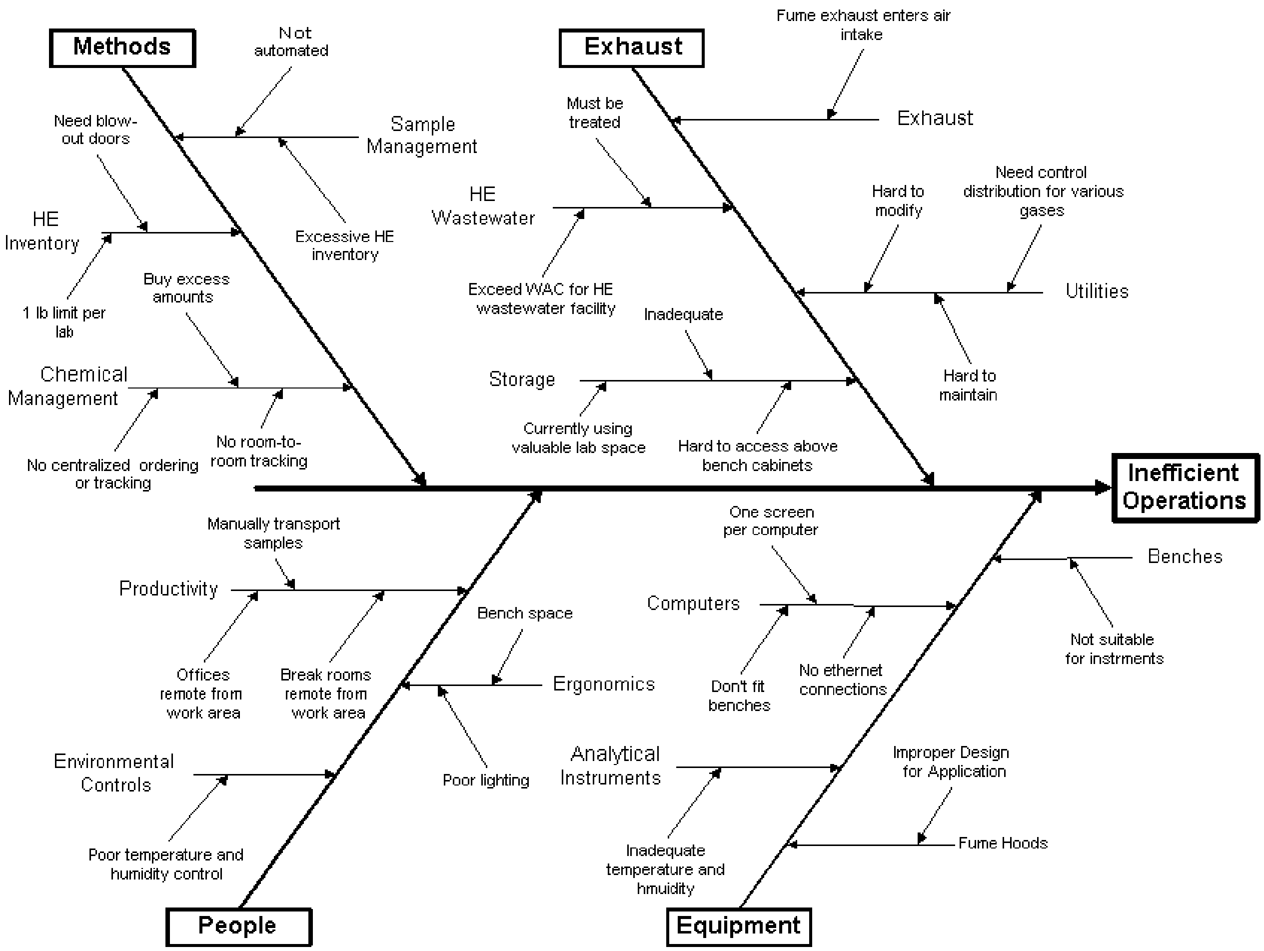

Figure 4. CAUSE & EFFECT DIAGRAM

The operations at the DX-2 Chemistry Lab have evolved within the space and infrastructure constraints of the building to reflect the changes in methods, instrumentation, environmental and safety regulations, and mission needs. DX-2 is currently meeting all regulatory and mission requirements, however, the productivity of the DX-2 researchers is limited by these inherent inefficiencies. By addressing these inefficiencies in a systematic way (i.e., use of Green Zia tools), operational efficiency can be improved for the current operations and designed into the proposed new laboratory.

Figure 5. PROBLEM STATEMENT

Generating Process Improvement Opportunities

The team conducted a brainstorming exercise to develop the following list of alternatives to address improving efficiency and minimizing waste for both the existing operations and at the new Chemistry Lab. Items unique to existing operation and future operations are noted.

- Treat and re-use waste water (consider ozone and hydrogen peroxide as alternatives)
- Use waste water for Cooling Tower make-up
- Break space down into that required for specific activities
- Develop a more efficient storage system
- Use movable ladders to access above bench storage
- Removable shelves (library)
- Stub down utilities for flexibility
- Storage cages outside of the lab
- Modular furniture and movable walls
- Install a centralized chilled water and liquid nitrogen system and a piped in vacuum system
- Install centralized control over lab space to monitor air flow in hoods and environmental conditions in each lab space
- Tour labs with recognized, superior design professionals to gain ideas for the new Chemistry Lab
- Bar code supplies with a local inventory system
- Rethink how HE work is done, i.e., storage
- Automated sample storage and retrieval system
- Employ robotics for high-hazard work
- Use glove boxes for high hazard work
- Set aside part of the facility for un-cleared personnel. This will provide easier access for students
- Use rack mounted computers
- Use flat screen monitors
- Use switch boxes for computer interconnectability
- Use etherlink connections
- Improve Lighting
- Centralized HVAC system with humidity and temperature control
- Relocate exhaust ventilation away from intake vents

Prioritizing Process Improvements

The team identified five areas that should be given the highest priority for implementation. These are listed below.

1. Space (storage, hoods, benches, offices and meeting)
2. Utilities
3. Environmental Controls

4. Chemical/Materials Management
5. Wastewater and Waste Management

Each of these areas was mapped to specific process improvement opportunities and identified as applicable to the existing facility, the new facility, or both. Table 1, below presents this summary. The anticipated impact of the opportunity and additional information needed for a full evaluation are also presented in Table 1. Impacts may include: initial costs, cost savings, productivity improvement, ES&H elements.

Table 1. Summary of Improvement Opportunities for Current & New Lab

PRIORITY AREA	OPPORTUNITY	APPLICABILITY	IMPACT/NEEDS
Space	Break space down into that required for specific activities	New Facility	Overall cost reduction by matching facility size to needs
	Efficient materials storage system	Both	More value in new facility
	Movable ladders to access above bench storage	Existing Facility	Potential safety conflict
	Removable library shelves	New facility	
	Storage cages outside of labs	Both	More value as designed in feature of new facility. Limited space and options in existing facility
	Modular furniture and movable walls	New Facility	Important feature to address changing requirements and mission needs
	Set aside part of facility for un-cleared personnel	New Facility	Permits students and employees and contractors awaiting clearance to still accomplish relevant work
	Use rack mounted computers	Both	Save valuable bench space
	Use flat screen monitors	Both	Save valuable bench space
	Use switch boxes for computer interconnectibility	Both	Save valuable bench space
	Increase use of etherlink connections	Both	Reduces need for computer hardware
Utilities	Stub down electric utility connections for flexibility	New Facility	Important feature to address changing requirements and mission needs
	Centralized chilled water, gas supply and piped in vacuum system	New Facility	Important feature to address changing requirements and mission needs
Environmental Controls	Centralized control over lab space to monitor air flow in hoods and environmental conditions in each lab	New Facility	Important feature to address changing requirements and mission needs
	Employ robotics for high hazard work	New Facility	Important safety and productivity feature
	Use glove boxes for high hazard work	Both	Important safety and productivity feature
	Improve lighting	Both	Improves productivity
Chemical and Materials	Bar code supplies with local	Both	Reduces material and

PRIORITY AREA	OPPORTUNITY	APPLICABILITY	IMPACT/NEEDS
Management	inventory system		waste management costs
	Rethink how HE work is done (i.e., storage)	Both	
	Automated sample storage and retrieval system	New Facility	Important safety and productivity feature
Wastewater and Waste Management	Treat wastewater to meet WAC	Both	Reduces waste water disposal costs
	Treat and re-use wastewater	New Facility	Reduces waste water disposal costs, and reduces water usage
	Use wastewater for cooling tower make-up	New Facility	Reduces waste water disposal costs, and reduces water usage

Table 2. Action Plan for Prioritized Options Paper

ACTION	ORGANIZATION	DEADLINE	COMMENTS
1. Work with DX-2 personnel to identify the desired features of the Laboratory.	AT, P2 Office, DX-2, Sandia, IT, PMD, FWO, DX, PM-DS	January 15, 2003	- Attend Tradeline Conference, LEED Workshop, and Lab 21 (Complete) - Conduct web searches (May 2002-April, 2003) - Develop & Revise design principal list (May 2002-February, 2003) - Tour Sandia Model Laboratories (June, 2002). - Use Green Zia Tools on key DX-2 activities to ID P2 opportunities for future building including Activity Based Costing (May 2002-September, 2002).
2. Develop marketing materials	AT, P2 Office, & DX-2	May 1, 2003`	- Develop brochures (May2002-April, 2003) - Develop presentations (May 2002-May, 2003) - ID other marketing options (May 2002-October, 2002)
3. Perform Cost/Benefit analysis for all identified options.	AT, P2 Office, DX-2, Sandia, IT, PMD, FWO, DX,	March 15, 2003	- Productivity analysis for the options (July 2002-December, 2002) - Assess the first cost, recurring cost, and ROI. Include impacts of Options (in dollars) (July 2002-December, 2002)
4. Prioritize option for F & OR	AT, P2 Office, DX-2, Sandia, IT, PMD, FWO, DX, Technology, IT, FWO, and Pollution Prevention Office	April 15, 2003	- Develop method for prioritizing options (February, 2003). - Develop draft options paper written in F & OR language (April 15, 2003).
5. Final options recommendations & reference document	AT, DX-2, PMD, IT, FWO, P2 Office	May 1, 2003 (however, living document till final F & OR's is complete.	- DX-2 review document (April 16-23, 2003) - Incorporate DX-2 feedback (April 23- 26, 2003). - Document published (May 1, 2003).

Figure 6. ACTION PLAN