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RESPONDING TO AGENDA 2020: A TECHNOLOGY VISION AND RESEARCH AGENDA FOR AMERICA'S FOREST, WOOD AND PAPER INDUSTRY

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Handout

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DISCLAIMER

Introduction

Pacific Northwest Laboratory (PNL) conducts more than 1,500 projects a year for government and industry clients. This document presents project summaries that demonstrate specific capabilities of interest to the forest, wood and paper industry in areas where PNL offers significant depth of experience or unique expertise.

Our Focus Though we possess a wide range of capabilities across many of the technology-related issues identified by the industry, we are focusing in this document on capabilities that meet the specific forest, wood and paper industry needs of the following research areas:

- Forest Inventory
- Human and Environmental Effects
- Energy and Environmental Tradeoffs
- Reduction of Impacts of Liquid Effluent
- Solid Wastes
- Removal of Non-Process Elements in Pulp and Paper Operations
- Life Cycle Assessment
- Process Measurement and Controls

In addition, we can provide the forest, wood and paper industry with support in areas such as strategic and program planning, stakeholder communications and outreach, budget defense and quality metrics. These are services we provide directly to several programs within DOE.

A Tradition of Partnering PNL provides access to new technologies, state-of-the-art equipment, unique facilities, and the federal laboratory system. Currently, we maintain 109 active licenses and other intellectual property agreements. Since 1991, we've taken part in 59 Cooperative Research and Development Agreements, and in 1994, 14 staff members participated in staff exchanges with industrial partners.

Contents

Forest Inventory

Fort Lewis/Yakima Training Center Remote Sensing Project

Project Identification
Client: U.S. Army, Environmental and Natural Resources Division, I Corps and Fort Lewis
PNL Project Manager: Joe Stephan
Period of Performance: 1986-Present
Funding Source: U.S. Army
Approximate Funding: About $500K/yr

Remote sensing using satellite data and the modeling techniques developed at PNL for environmental site management can be applied to monitor forest lands, reforestation, landcover degradation and recovery, and impacts from forest fires.

Description The Pacific Northwest Laboratory (PNL) has developed site specific methodologies for analysis of digital satellite and other image and map data using a Geographical Information System (GIS) and analog retrieval and display system.

Spectroradiometric ground and aerial surveys are conducted to confirm analysis results made from the digital satellite imagery. PNL is developing a model for estimating restoration costs of degraded areas.

We are applying this capability in support of the Army at Fort Lewis and the Yakima Training Center (YTC). The overall objective is to support environmental and site management at the YTC. The specific objective is to develop and apply customized remote sensing techniques relevant to the environmental management of Army training sites.

Because the areas involved are relatively large, digital satellite imagery are used to monitor the Army sites for groundcover/vegetation; manmade groundcover degradation; and groundcover restoration, erosion, fires and road development.

By comparing multi-temporal satellite and aircraft imagery, the YTC landcover conditions are monitored site-wide for short-term and long-term changes. The intent is the development of methodologies for quantifying and monitoring environmental change (e.g., landcover degradation and restoration) site-wide.

Forest Inventory

Utilizing Advanced Concepts in Remote Sensing Toward Agricultural Sustainability

Project Identification
Client: DOE-NN20
PNL Project Manager: Eileen Perry
Period of Performance: 10/94-Present
Funding Source: Grant from Washington State University, PNL Agribusiness Commercialization and Development Center
Approximate Total Budget: $28K

Remote sensing methods being developed could be extended to forest production and pulp tree farming, allowing the industry to assess soil condition, monitor crops, and manage lands.

Description The Pacific Northwest Laboratory (PNL) is guiding application of remote sensing (satellite imaging) technology to agricultural lands in three areas: 1) assessment of soil erosion and air pollution potential over dryland wheat, 2) monitoring and management of precision farming, and 3) development of radar remote imaging to enhance crop monitoring. This contribution and collaboration has come from research partners at Washington State University; USDA-Agricultural Research Service; University of Arizona; and Cropix, a private agribusiness company. The research performed uses data collected as part of the DOE Airborne Multisensor Pod System program.

Collaborations We are collaborating with Cropix, Hermiston, Oregon, and are exploring other potential collaborations with local agribusinesses.

Commercialization Activities Potential applications for remote sensing include new sensors and methods using commercial radar data to extend and enhance the crop monitoring capability of commercial services.

Multimedia Environmental Pollutant Assessment System

Project Identification
Client: DOE
PNL Project Managers: James Droppo, John Buck
DOE Technical Contacts: Richard Aiken, Thomas Longo, Paul Beam, Frank Baxter
Period of Performance: 10/83-Present
Funding Source: DOE-HE, DOE-EM
Approximate Total Budget: $4.5M

MEPAS is a versatile risk assessment tool that could be invaluable for the forest, wood and paper industry. MEPAS can provide estimates of the improvement in public health after the industry installs technology required by the maximum achievable control technology regulations. MEPAS was designed for just such multi-dimensional applications.

Description The Multimedia Environmental Pollutant Assessment System (MEPAS) methodology is a fully operational multimedia model that addresses all major environmental transport pathways.

MEPAS includes impacts for organic and inorganic chemicals. This IBM PC-compatible software provides an integrated approach for assessing a wide range of exposure routes to people by either deterministic or probabilistic endpoints. The innovative model helps answer such questions as "How risky are potential environmental releases?" and "How do risks change with different activities?" Investigators can quickly study implications of various control strategies.

The MEPAS methodology was originally developed for DOE to assist in assessing environmental concerns at DOE's facilities. Subsequent applications of updated versions have included tank waste characterization studies and groundwater plume prioritization efforts. Currently, MEPAS is being applied in a number of DOE site-wide assessments. As part of one of these efforts, MEPAS recently successfully underwent a national independent technical review.

Collaborations The current user-interface for MEPAS was developed in a collaborative effort with Mesa State College in Grand Junction, Colorado. That collaborative effort received a Federal Laboratory Consortium Technology Transfer Award in 1993.

Commercialization Activities As part of a technology transfer program, commercial versions of MEPAS have been licensed in the United States and five other countries. Foreign language versions are under preparation.

Columbia River Comprehensive Impact Assessment

Project Identification
FWP Number: 21309
Client: DOE-EM
PNL Project Manager: Paul Eslinger
DOE Project Manager: Randy Brich
Period of Performance: 8/93-7/97
Funding Source: DOE-EM
Approximate Total Budget: $3.3M

Description The Pacific Northwest Laboratory (PNL) is conducting the Columbia River Comprehensive Impact Assessment for DOE. We are evaluating the current human and ecological risk from contaminants in the Columbia River that are attributable to past and present activities at the Hanford Site in south-central Washington State. The risks will be evaluated for hazardous and radioactive materials.

The purpose of the project is to determine if enough contamination exists in the Columbia River to warrant cleanup actions under environmental regulations. A significant activity in this project is the determination if whether or not a contaminant is attributable to Hanford activities.

The techniques used to identify contaminants and species of concern in the Columbia River could be the same techniques used to identify specific problems presently facing the forest, wood, and paper industry. The environmental sampling and risk analysis approaches would also be very similar. Some of the contaminants of interest might be the same as those examined in the project. Interactions with the public and environmental activist groups would also be very similar.

A related example might be the bleaching process in producing paper. To determine which bleaching process and chemicals have the least detrimental effect on the environment, the various processes and chemicals would need to be identified and screened for a variety of effects. The study would likely be scrutinized by many special interest groups before its results can be implemented.

Because the Columbia River provides drinking water, crop irrigation, ecological habitat, and recreation opportunities, public involvement activities are important for the project. Activities include the following: individuals can visit PNL and interact with scientists, data and documents are made available to all interested parties, public meetings are being conducted on all project aspects, and technical reports are written for public understanding.

Human and Environmental Effects

Collaborations The project is a joint activity of three government agencies at the Hanford Site: the U.S. Department of Energy, the U.S. Environmental Protection Agency, and Washington State Department of Ecology.

Multimedia-Based Occupational Ergonomics Analysis Tools

Project Identification
Client: DOE-OHER
PNL Project Manager: Frank L. Greitzer
DOE Project Manager: David Weitzman
Period of Performance: 10/94-9/95
Approximate Total Budget: $270K

Description A Pacific Northwest Laboratory (PNL) ergonomics team with formal training and experience in ergonomics, industrial hygiene, biomechanics, safety, training, multimedia, and user/computer interaction is developing an occupational ergonomic analysis tool. The awareness/reporting component of the tool provides ergonomic awareness information to increase the user's knowledge of potentially hazardous postures.

User-friendly tools will permit specialists and nonspecialists in the forest, wood and paper industry to evaluate work places and tasks, identify ergonomics hazards in the workplace, offer suggestions on how to eliminate the hazards, and help to determine compliance with many key provisions of the anticipated OSHA regulations. As the direct and indirect costs of injuries are reduced and controlled, the cost of doing business decreases, the work environment improves, and employee efficiency increases.

Users can respond to this presentation by providing information about their own work environment. A "quick-fix" checklist is integrated with the awareness/reporting component to help users assess general compliance of their work situation, without requiring detailed data entry. Additional analysis, requiring more detailed information, may be recommended based on the user's report. The more detailed analytic components enable users to

- review information that enhances awareness of common ergonomic problems
- input data to describe a specific task
- make adjustments to a task specification and view results
- obtain printed output that points out problems with the work situation and recommends solutions.

Collaborations PNL is working in partnership with the U.S. Occupational Safety and Health Administration (OSHA), to develop computer-based analytic tools for evaluating computer workstations and lifting task design in accordance with good engineering and ergonomic practices as well as with respect to anticipated OSHA ergonomic regulations. Beta testing of

the tools will be performed by industry contacts from the State of Washington Department of Labor and Industries.

Commercialization Activities PNL is currently investigating commercialization options and possible CRADA partnerships to meet the needs of approximately 6,000,000 large and small businesses. The businesses need to perform ergonomic analysis without the resources of an ergonomic professional.

Army Production Base Modernization Activity Waste Minimization Support

Project Identification
FWP Number: 16509
Client: U.S. Army
PNL Project Manager: Tapio Kuusinen
DoD Project Manager: Robert Scola
Period of Performance: 1990-Present
Approximate Total Budget: $725K

Description To meet its waste minimization goals, the U.S. Army will be investing significant financial and manpower resources in hazardous waste minimization (HazMin) activities. To help target these investments, the Office of Production Base Modernization Activity has contracted with Pacific Northwest Laboratory (PNL) to develop PROBE: the "PRoject Opportunities and Benefits Evaluation" model.

PROBE is a decision support tool to help make cost/benefit decisions among competing environmental investments. The wood, forest, and paper industry faces the same factors influencing investment decisions as the Army. PROBE is an example of a leading edge decision support tool that performs functions not currently available on the commercial software market.

PROBE is a user-friendly software package that is designed to help Army personnel—at both the installation level and at the command level—to do two main tasks:

- evaluate and prioritize their hazardous waste streams, and
- evaluate and prioritize proposed HazMin projects to address those waste streams.

PROBE is designed to help improve the Army's ability to make informed decisions regarding the direction of waste minimization investments, so that the resources that are available for HAZMIN activities will have the greatest benefit to the Army and the environment. With the information provided by PROBE, Army personnel at all levels will be better able to make clear choices about which hazardous waste streams to target for waste minimization and what sorts of HAZMIN projects to implement.

Environmental Risk Management Program for the Western Area Power Administration

Project Identification
FWP Number: 21458
Client: DOE Western Area Power Administration
PNL Project Manager: Frank V. DiMassa
Western Area Power Administration Project Manager: A. L. Roybal
Period of Performance: 6/93-9/95
Funding Source: Western Area Power Administration
Approximate Total Budget: $330K

Description Pacific Northwest Laboratory (PNL) is working with DOE's Western Area Power Administration (Western) in developing and implementing environmental risk management programs. Western markets and transmits Federal electric power in 15 central and western states. Environmental protection and compliance activities are important in managing the construction, operation, and maintenance of Western's vast network of transmission lines, substations, and other facilities.

Risk management tools can help the pulp and paper industry effectively prioritize environmental management activities, decrease overall risks, improve internal and external risk communication, and improve risk management. The QuIC and SEQUEL risk management programs provide methods the industry could adapt. QuIC helps gather and structure basic information needed to make decisions about environmental issues. SEQUEL uses the input to evaluate environmental risk based on an issue's potential human health and ecosystem impacts, regulatory impacts, business impacts, and public perception impacts.

The environmental risk management program consists of three main components: risk assessment, risk management/decision making, and risk communication. To assist in risk assessment and risk management, simple tools were developed to generate preliminary evaluations of risk, risk rankings, and risk comparisons. Two assessment methods were developed for use by Western: the "Qualitative Issue Characterization" (QuIC) approach and the "Semi-Quantitative Evaluation" (SEQUEL) approach. The QuIC approach is used to gather and structure the basic information needed to make decisions about environmental issues.

The SEQUEL approach uses this information to evaluate and rank environmental risk issues and to also evaluate Western's ability to manage that risk. SEQUEL evaluates environmental risk based on an issue's potential human health and ecosystem impacts, regulatory impacts, business impacts, and public perception impacts. The ability to manage risk is based on the organization's environmental policies, human and financial resources, and its performance in the area of policy implementation.

By comparing the risk score for an environmental issue with the score gaging Western's ability to manage risk, Western is able to identify imbalances and work toward correcting deficiencies in their risk management program. Similarly, a comparison of different risk issues can be used to more efficiently allocate environmental management resources.

Through a contract extension, Western has authorized PNL to automate the QuIC and SEQUEL processes. Western is working with both public and private electric utilities to cost share the development of the computer software and to participate in the testing of these tools.

When fully implemented, the new Western environmental risk program should help effectively prioritize environmental management activities, decrease overall risks, improve internal and external risk communication, and improve Western's ability to manage risk.

Risk Communication—Project Summaries

Project Identification
Clients: DOE Richland Operations Office, U.S. Air Force at Eielson Air Force Base, DOE Office of Environmental Management, U.S. Centers for Disease Control
PNL Project Managers: Andrea McMakin and Regina Lundgren
Period of Performance: 1992-Present
Funding Source: Varies; projects are typically subtasks within larger programs.

Timely information that addresses the concerns of stakeholders and accurately communicates risks of standard practices or proposed changes can help the forest, wood and paper industry better communicate facts to the public. PNL's risk communication specialists focus on providing products that adequately inform stakeholders so they can make appropriate decisions.

Description The Pacific Northwest Laboratory (PNL) maintains a risk communication capability to serve the needs of clients who must explain complex technical information to their stakeholders or involve the public in their decision-making processes. Some recent projects include:

- **Risk Perception Research Regarding Hanford Site Radiation Workers**—PNL applied the "mental models" methodology to characterize the knowledge and perceptions of DOE contractor radiation workers about ionizing radiation and hazardous chemicals. PNL staff members interviewed workers, coded results, and mapped onto an expert model of risks to identify matches and discrepancies. They recommended improvements in worker training.

- **Community Relations Support for Eielson Air Force Base Superfund Cleanup**—PNL provided community relations support for cleanup of petroleum-contaminated sites at Eielson Air Force Base, Alaska. PNL staff 1) assisted in researching, writing, and revising a community relations plan; 2) prepared proposed plans for cleanup of operable units that would achieve consensus among the Air Force and state and federal regulators; 3) produced public information and risk communication materials such as fact sheets, newsletters, and slide presentations; and 4) advised the Air Force on communicating risks to members of surrounding communities.

Energy and Environmental Tradeoffs

- **Public Outreach for the Hanford Site Environmental Monitoring Program**—PNL staff prepared a public information booklet summarizing the Hanford Site annual environmental report. They surveyed stakeholders (state and federal regulators, environmental interest groups, scientific community, public) to provide input for content, format, and approach to the booklet.

- **Environmental Assessment of Urgent-Relief Acceptance of Foreign Research Reactor Spent Nuclear Fuel**—Working with a writing team from national laboratories and other government contractors to compile and prepare material, PNL staff wrote a summary for decision-makers and general readers of the environmental assessment to accept spent nuclear fuel. The summary included responses to public comments and provided the basis for DOE to issue a Finding of No Significant Impact for the proposed action.

- **Communication Support for the Hanford Environmental Dose Reconstruction Project**—PNL staff managed communication activities and projects to communicate results of multi-million-dollar dose assessment project to decision makers and various stakeholders. They advised the project's independent Technical Steering Panel on risk communication.

- **Public Information for the Tank Waste Remediation System Project**—PNL staff produced a public information booklet on the Hanford Site underground waste tanks, compiling technical and public information material as sources. They surveyed state and federal regulators, environmental interest groups, scientific community, and the public to obtain input for content, format, and approach.

Industrial Technology and Energy Modeling System

Project Identification
PNL Project Manager: Joe Roop
Period of Performance: 1995
Funding Source: Laboratory Directed Research and Development Funds
Approximate Total Budget: $20K

Description The Pacific Northwest Laboratory (PNL) is using internal development funds to test and enhance the Industrial Technology and Energy Modeling System (ITEMS).

ITEMS allows the industry and specific mills to continually evaluate the economic and environmental impacts for "what if" scenarios, including substituting ozone for chlorine, modifying the pulping process to reduce methane production, or exploring alternatives to de-inking processes.

The economic-engineering modeling system can be used to produce detailed process flow descriptions of an industry, linking its technologies, energy costs, and operating budgets. This model will allow industry to determine the total environmental and economic impact of changing process variables, such as altering bleaching chemicals at a paper mill.

ITEMS includes eleven industry models, including a well-defined wood products, pulp and paper module. Each module is independent of the others, so the system does not solve as a simultaneous system of industries. Features of the economic-engineering model include the following:

- Capacity is represented by a collection of technologies, described in terms of energy use, emissions, capital costs, O&M costs, and life time.
- Capacity for technologies is fixed at the year of calibration and retired with age.
- Costs for capacity are annualized.
- Costs for new capacity are calculated using a capital recovery factor that considers the discount rate, equipment life, investment tax credit, and depreciation schedules at the time of the investment.

Energy and Environmental Tradeoffs

The model is calibrated to energy used in manufacturing as reported in the 1991 Manufacturing Energy Consumption Survey. Major drivers are industry output and fuel prices. The model needs to be calibrated to assure that industry models track historical data over the recent past.

Low-Temperature Catalytic Gasification of Wet Industrial Wastes

Project Identification
FWP Number: 13794
Client: DOE-OIT
PNL Project Manager: Douglas C. Elliott
DOE Project Manager: Charles Russomanno
Period of Performance: 10/89-Present
Approximate Total Budget: $3.3M

Description The Pacific Northwest Laboratory (PNL) is facilitating commercialization of TEES (Thermochemical Environmental Energy System). TEES is an innovative process for treating wet organic waste to produce fuel gas and clean water thereby eliminating waste and recovering energy.

TEES provides an option for disposal of wet organic sludges such as waste fiber slurries or other organically contaminated wastewaters.

TEES may also offer a new alternative to black liquor recovery boilers. Because of its unique non-oxidizing environment, the pulping chemicals could be recovered and reused. Because it operates efficiently on organic solutions it may reduce the need for evaporation of the black liquor.

In TEES, a metal catalyst is used to reform the organics by reaction with water. Methane and carbon dioxide are the major product gases. The net result is a separation of the organics from the water by converting them to gases. The process is operated in the liquid phase at sufficient pressure such that the water does not boil. Liquid phase heat exchange is key to the efficiency of the process. Within the project, the process has been developed through engineering scale testing, and a mobile onsite demonstration unit is now available for testing.

Collaborations The industrial interactions have included direct funding from a major chemical manufacturer and a major food processor. Testing of industrial wastes is currently being undertaken for numerous food processors and chemical manufacturers. In addition, we have secrecy agreements in place with two major catalyst manufacturers.

Commercialization Activities The process is licensed to a small engineering and construction management firm. We have a CRADA in place with the licensee allowing them to operate the onsite demonstration unit.

Reduction of Impacts of Liquid Effluent

Recovery of Colorants and Auxiliaries - Membrane Technologies

Project Identification
Client: AMTEX, The American Textile Initiative and DOE-ER
PNL Project Manager: Richard Hallen
Period of Performance: 10/94-9/95
Approximate Total Budget: $75K

Description The AMTEX Textile Resource Recovery (TReC) project is funding research at the Pacific Northwest Laboratory (PNL) to develop membrane separation technologies for the recovery and reuse of water, dyes, and auxiliary chemical used in textile processing. Typical textile finishing plants use 2 million gallons of water per day. The resulting wastewater contains highly colored dyes and residual salt from the dyeing process. The industry is interested in recovering the water, salt, and dyes for reuse. The water and salt are recovered by ultra and/or nanofiltration technology. Salt concentration is increased to concentration high enough for reuse by reverse osmosis. The dyes are concentrated in the retentate and must be further separated for reuse.

The pulp and paper industry has problems with both color and heavy metals in wastewater effluents much like the textile industry. Some of the dyes contain toxic metal as a complex which can not be easily removed by conventional treatment technologies. Textile effluents have been found to be toxic because of high salt (sodium chloride and sulfate) and need to recover and reuse salt. The textile plants are large water users and need to recover and reuse water. Many similarities between the paper and textile industry exist. Paper plants that produce colored paper have the same dye/toxic metals problem as the textile industry. Natural metals exist in cotton such as zinc and cause problems with wastewater discharge. Cotton is a cellulosic fiber much like wood pulp.

Electrokinetic separation technologies are being examined for dye separation. In fabric dyeing, mixtures of dyes are used to obtain the desired hue/shades. For reuse, the mixtures must be separated back to the original single component dyes. Electrokinetic separation is one of the few technologies with high enough resolution to separate the complex mixture of dyes. Electrophoresis of the mixtures was used to demonstrate the feasibility of the separations. Electro-ultrafiltration was examined as for potential large scale separations. The technical feasibility of dye separation has been demonstrated.

Collaborations The TReC project currently has 40 industrial partners. They vary from fiber producer to dye house.

Destruction of Recalcitrant and Low Concentration Organics Using Low-Temperature Plasma

Project Identification
Client: DOE-EM
PNL Project Managers: Bill Heath, Theresa Bergsman
Period of Performance: 1988-Present
Funding Sources: PNL Advanced Process Technologies Initiative, Battelle-Internal Research and Development, Private Clients (confidential)
Approximate Total Budget: $3M

Description Low-temperature plasmas create a reactive environment without heating up an entire process stream. The technology allows low concentrations of contaminants (10-1000 ppm) to be oxidized with lower energy demands. Plasma development has addressed organic contaminant destruction for solid bound contaminants in soils, liquids, and gases.

The forest, wood and paper industry could use low temperature plasmas to achieve volatile organic compound (VOC) destruction of organics and hazardous organic materials including methanol, chloroform, reduced sulfurs, formaldehyde, pinenes and terpenes from vents without cooling or heating the process stream. Low temperature plasmas have been shown to destroy color and AO_x from bleach plant effluent and to create an oxidizing environment to bleach pulp. Pulp bleaching shows Kappa# reduction, I.V. reduction, and brightness similar to combined O_2-extended delignification followed by ozonation.

A gas phase plasma technology, sometimes called a corona reactor, uses a patented packed dielectric bed. It is at the initial stages of commercialization. The Pacific Northwest Laboratory is developing technologies that will use plasma and catalysts to improve the economics and control of NO_x and SO_x.

Collaborations Bionomics, major forest products company (confidential)

Combining Organics Combustion and Joule-Heated Vitrification for Economical Waste Management

Project Identification
Client: DOE
PNL Project Manager: Chris Chapman
Period of Performance: 1981-Present
Funding Source: DOE-EM, PNL Laboratory Directed Research and Development, Internal Research and Development, Private Contracts (confidential)
Approximate Total Budget: $1.3M

Description The Pacific Northwest Laboratory (PNL) had developed vitrification technologies to immobilize radioactive nuclides. Joule-heated melters pass electric current through a molten fluid to generate heat. Feeding of slurries directly onto the molten fluid was developed to simplify the processing of liquid wastes. Directly related to this processing was the fate and handling of slurries, which contained combustible materials. PNL also developed low-energy use technologies to control the volatization, pyrolysis, and combustion of these organics and to control the oxidation state and quality of the glass products.

PNL is targeting an economically viable alternative to new generation municipal landfills with this application. Technologies developed to handle organics in radioactive feeds were extended to accept feeds that were mainly organic and contained substantial heat value.

Using vitrification technology, the forest, wood, and paper industry could make useful products from solid wastes or enhance performance of a recovery boiler.

As a Landfill Alternative: Solid wastes such as wood waste, sludges, dregs, heavy metals, and ash could be immobilized in a glass matrix with a 20-50:1 volume reduction to land fill. The glass product could also be used to manufacture building blocks, bricks, or tile. Dewatered organic materials can provide the major heat source.

As a Processing Addition: A proprietary application of combustion-assisted joule-heated melting is to partially oxidize Kraft black liquor on top of a joule-heated smelt bed. The partially combusted pyrolyzed organics can be fed to the oxidizing zone of a recovery boiler for further combustion and steam generation. The inorganic process chemicals are maintained molten with a joule-heat assist in a reducing environment.

Solid Wastes

Important in the holistic system is to develop forming and handling technologies and markets for glass-ceramic products to use/reuse in society.

Collaborations A joint venture is underway to build and operate a demonstration commercial unit (50MT/day) to accept municipal waste and wood residues as the major energy sources of a joule-heated glass melter. The inorganics from the wood and municipal wastes will combine with silica to form a glass-ceramic initially for use as aggregate.

Solid Waste Projection Modeling/Macro Material Flow Modeling

Project Identification
Client: DOE
PNL Project Manager: Gregory M. Holter
Westinghouse Project Manager: Ken L. Hladek
Period of Performance: 1989-Present
Funding Source: Westinghouse Hanford Company, Funded from Site Operating Pool for Solid Waste Services, Laboratory Directed Research and Development Funds
Approximate Total Budget: $2.7M

Description Researchers at the Pacific Northwest Laboratory (PNL) have been developing and applying logistics simulation modeling techniques to analyze the flow of various types of wastes. Initially developed to analyze transportation, treatment, storage, and disposal options for solid wastes at the DOE Hanford Site, these techniques have broad application to other types of wastes.

The forest, wood, and paper industries face a number of waste management logistics considerations, including the need to more easily compare solid waste disposal options. The logistics simulation modeling could aid the industry in projecting waste quantities and developing and understanding alternative approaches to collecting, transporting, treating, storing and disposing wastes. Logistics simulation modeling provides an open-ended, flexible framework for analyzing system design and operational alternatives. It can be applied to both planned and operating systems.

In addition to the Hanford solid waste modeling, researchers have developed a prototype model to demonstrate how these concepts would be applied to a municipal solid waste/ industrial solid waste system. The prototype illustrates how performance of a waste management system can be characterized in terms of:

- waste generation—total and by waste category
- throughput—total system and by system element
- cost—total system and by system element
- disposal site life/capacity,
- waste diversion ability
- transportation requirements.

Solid Wastes

Logistics simulation modeling aids in the projection of waste quantities over the planning period and in the development and understanding of alternative approaches to collecting, transporting, treating, storing, and disposing wastes. It provides an open-ended, flexible framework for analyzing system design and operational alternatives, and can be applied to both planned and operating systems.

The use of modeling to analyze solid waste systems:

- helps to ensure waste management capabilities will be available in appropriate capacities and types, and on a schedule to match quantities, characteristics, and timing of the wastes to be handled

- helps avoid expensive over-capacity or under-capacity conditions, and ensure completeness of the planned system

- becomes increasingly useful as the complexity of the wastes and their management requirements increase.

Life-Cycle Computer Aided Data Model

Project Identification
FWP Number: 19233
Client: DOE-EE (OIT)
PNL Project Manager: Ken Humphreys
DOE or other client project manager: Tom Foust
Period of Performance: 10/94-Present
Approximate Budget: $1.05M for FY 1995

Description The Pacific Northwest Laboratory (PNL) provides technical support to DOE, Office of Industrial Technologies (OIT) to develop a portfolio of life-cycle assessment tools, methods, and data for industrial application through the Life-Cycle Computer Aided Data (L-CAD) model.

Effective business planning requires frameworks that enable decision-makers to evaluate the cradle-to-grave energy, environmental and economic impacts of a technology.

The forest, wood, and paper industry can use L-CAD to support technology development, design environmentally responsible products, and help policy-makers and regulators understand the impacts of potential decisions. The industry, through the National Council on Air and Stream Improvement (NCASI), is conducting life-cycle assessment studies to improve its use of energy and environmental resources. Many industry firms serve as advisors or reviewers of L-CAD through work on the American Forest and Paper Association and other industry group task forces.

Within industry and government, life-cycle assessment is increasingly recognized as a key approach for these business evaluations. The life-cycle assessment approach relates directly to U.S. economic productivity. The influence of the life-cycle approach will be felt in the global marketplace through life-cycle assessment standards now being developed by the International Standards Organization to support ISO 14,000.

As a prime advocate of the life-cycle concept, the federal government has joined with industry in support of the L-CAD project. The project's overall objective is to develop tools and data that will facilitate the cost-effective use of life-cycle assessments within industry and government as part of routine business decision making.

Life Cycle Assessment

Collaborations Currently, trade associations or research organizations representing nine industries are participating in the project: aluminum, cement, chemicals, electric utilities, forest products, paper products, petroleum, plastics, and steel. This participation includes data collection, analysis, and review activities; serving on the formal advisory group to help define the software system requirements from the industrial user's perspective; and/or direct co-funding to augment the federal funds.

Commercialization Activities PNL has held commercialization discussions with a number of firms. We are incorporating their suggestions into a commercialization plan that will be finished in FY 1995. We have secured private sector funding to support part of the commercialization effort.

Process Measurement and Controls

Sensors, Sensor Systems, and Control Systems

Project Identification
Client: Multiple
PNL Project Managers: Kevin Widener, Jeff Griffin, John Hartman
DOE or Other Client Project Managers: Multiple
Period of Performance: 1965-Present
Funding Sources: Multiple
Approximate Total Budget: >$20M

The number and amount of chemicals used in the paper industry is staggering. Each chemical is monitored and tracked for environmental compliance or for optimizing system performance. As processes and monitoring requirements are changed, the industry must keep pace using reliable, sensitive and accurate sensor technology.

Description For federal, state, and industrial clients, the Pacific Northwest Laboratory (PNL) has designed, fabricated, evaluated, demonstrated, and delivered specialized sensors, sensor systems, and instruments to meet unique client requirements.

In addition, PNL has provided integrated systems for equipment control and data acquisition and analysis. Delivered systems have included PC-based and embedded control hardware. Development includes both hardware and software. PNL has developed sensors based on electrochemical, electromagnetic, optical (including fiber optic sensors), piezoelectric, electromechanical and radiation effects and mechanisms. Our activities have ranged from demonstrating sensing principles and prototype sensors to the delivering field-deployed sensors and sensor systems. Sensor structures have included micro-sensors fabricated with integrated circuit methods common to industry, sensors with integrated optics structures, fiber optics, and other sensors assembled from discrete parts. PNL has internal glass shop and fiber optic fabrication facilities to prepare specialty fiber optics and fiber optic sensors. PNL-developed sensors and technology applicable to the pulp and paper industry include:

- Suspended gate, field effect transistor micro-sensors for detection of chemical analytes.
- Low-light measurement systems for characterization of chemical reactions at levels below the visual threshold.
- Optical-based sensor systems for measurement of chlorinated hydrocarbon concentration in atmosphere and in aqueous solutions. The instrument-operating principle is readily adaptable for measurement of other elemental analytes.

Process Measurement and Controls

- Optical systems to support laser ablation-based chemical characterization of solid samples.
- Optical fluorescence methods and equipment to support detection of fluorescence emissions from constituents in samples or on solid surfaces.
- Optical sensing systems to provide characterization of sample surface characteristics including metal surface quality and fiber/particle characteristics.
- Optical diffraction and image analysis methods and instruments for characterizing synthetic fibers and for use in process control.
- Optical holography methods and instrumentation for characterizing droplets and aerosols in particles ranging in size from one to hundreds of microns.
- Electromagnetic sensors (eddy current) to detect moisture in dielectric materials and conductivity and flaws in metallic parts.
- Bulk and surface acoustic wave sensors with chemically selective coatings for the detection of molecular analytes.
- Integrated optics planar waveguide structure to provide enhanced spectroscopic analysis sensitivity for non-invasive evaluation of liquid samples.
- Acoustic waveguide technology capability to rapidly determine fluid viscosity and density with an in situ measurement.
- Miniaturized X-ray fluorescence system for detection of heavy metals in restricted space applications.

PNL offers a laboratory facility with suitable equipment to evaluate the serviceability and survivability of equipment and instrumentation under environmental, mechanical, and electromagnetic stresses.

A key element of our approach to sensor development and measurement is to produce statistical designs; chemometric, univariate, and multivariate analyses; and data visualizations for sensor-derived chemical data sets. We fuse chemical information from multiple sources to uncover important relationships, confirm knowledge of a process, quantify system uncertainties and make reliable predictions.

Instrumentation Development for the Atmospheric Radiation Measurement Program

Project Identification
Client: DOE-OHER
PNL Project Manager: Jeff Griffin
Period of Performance: 1990-Present
Funding Source: DOE-OHER
Approximate Total Budget: $10M

Description The Atmospheric Radiation Measurement (ARM) Instrument Development Program has developed a variety of prototype instruments suitable for unmanned field-monitoring of atmospheric constituents such as water vapor, aerosols, clouds, and atmospheric state parameters such as temperature and humidity.

Remote sensing/measurement techniques and instrumentation developed under the ARM program would be useful for monitoring fugitive emissions from plants to maintain compliance, real-time remote monitoring of paper pulp/paper processing operations parameters; and operator-friendly turn-key computer-based control and data acquisition systems for pulp/paper plant processes.

The technologies implemented in these instruments include laser radar, Lidar millimeter-wave radar, infrared radiometry, and atmospheric transmissometry.

Collaborations The program is a collaborative effort between several DOE national laboratories; other federal agencies such as NASA, NOAA, NCAR; and universities.

Commercialization Activities The Pacific Northwest Laboratory is pursuing commercialization of the Micro-Pulse Lidar through a collaboration with Technical Services Corporation. Commercialization of the Multi-Filter Shadowband Radiometer is being pursued by Yankee Environmental Systems.

Decision Support for Operations and Maintenance

Project Identification
Client: U.S. Marine Corps (USMC); U.S. Army Forces Command (FORSCOM)
PNL Project Manager: Don Jarrell
Client Project Manager: Dick Walsh, HQ U.S. Marine Corps; Adrian Gillespie, FORSCOM
Period of Performance: 1989-Present
Funding Source: USMC; FORSCOM
Approximate Total Budget: $4.5M

DSOM can help reduce long-term costs for any industrial process where life-cycle operation and maintenance (O&M) is maintained through reliability-centered and on-condition maintenance techniques. DSOM employs a holistic approach that considers all aspects of the supporting infrastructure, including operator training. It establishes a plant infrastructure capable of a self-supporting improvement that has both immediate and long-term results, providing a permanent solution to O&M issues.

Description The Decision Support for Operations and Maintenance (DSOM) program has developed a novel Artificial Intelligence (AI) decision support system for plant operations that supplies an on-line source of engineering expertise to operators and maintenance personnel. DSOM helps operations staff increase the efficiency, reliability, and safety of plant operations and maintenance.

The project has specified, procured, installed, tested and verified the operability of an associated data acquisition system for decision support, a knowledge-based AI reasoner, and a display/interface that allows plant personnel to easily interact with the decision support system.

In the future, the project will develop an implementation plan that ports AI decision support systems to other plants and utility operations. Engineers will extend the DSOM system to allow monitoring and control of the thermal energy distribution system.

Collaborations Naval Facilities Engineering Systems Command, Port Hueneme, CA

Electric Pump/Motor Diagnostician

Project Identification
Client: DOE
PNL Project Manager: Dick Meador
Period of Performance: 10/93-Present
Funding Source: PNL Laboratory Directed Research and Development
Approximate Total Budget: $250K

Description The electric pump/motor diagnostician project has developed and demonstrated a method for reducing both the risks and the cost of operations and maintenance of a centrifugal pump/motor unit. The Diagnostician can be coupled to other component models to provide automated, real-time, integrated degradation and fault diagnoses.

The pump/motor diagnostician project developed and demonstrated a low-cost automated diagnostic method for use on pumps and motors. The diagnostician allows a plant operator to detect degradation or fault conditions long before catastrophic failure and subsequent process shutdown. The project has created a generic diagnostic methodology that applies to any industrial process component, reducing the risks and cost of operations and maintenance.

The Diagnostician uses neural nets and fundamentals of fuzzy logic to predict, identify, and diagnose degradation and fault conditions in electric pumps or motors and advise personnel of the pump/motor condition through a user interface.

The electric pump/motor diagnostician project has demonstrated proof-of-concept for automating the analytical process in diagnoses of selected faults in electric motor/pump equipment.

Cartridge Case Measurement and Eject System

Project Identification
Client: U.S. Army
PNL Project Manager: Les Kirihara
Client Project Manager: Bo Hajduczok
Period of Performance: 1971-Present
Funding Source: U.S. Army Material Command
Approximate Total Budget: >$20M

The paper industry is faced with a critical need to inspect paper surface defects, fiber orientation, strength, stiffness, curl, and individual ply characteristics while the paper product is moving. PNL has demonstrated ability to deliver and support complex high-speed inspection systems needed for high-quality paper production.

Description In the Cartridge Case Measurement and Eject System (CCMES) program, the Pacific Northwest laboratory (PNL) developed, demonstrated, delivered, installed, and supported an automated high-speed, on-line inspection system.

CCMES was a first-of-a-kind technology. It allowed 100 percent inspection of brass cartridge cases using a variety of non-destructive testing methods.

System development included inspection concepts; practical inspection modules; mechanical handling equipment for direct coupling to production equipment; electronics for signal processing, data analysis, and decision making; and a computer system to track inspection process results with a focus on production line performance.

Remote Handling Equipment and Robotics

Project Identification
Clients: Multiple
PNL Project Manager: Mark Evans
Project Managers: Multiple
Period of Performance: 1992-Present
Funding Sources: Multiple
Approximate Total Budget: $10M

Description The Pacific Northwest Laboratory (PNL) has worked in concert with several industrial and federal clients to identify needs for robotics. We have designed, developed, integrated, and delivered specialized remote handling and robotic equipment to meet specialized application requirements.

Like the automobile industry, the forest, wood and paper industry is striving to remain a strong competitor in worldwide markets. To achieve economic productivity, the industry will likely move toward reliance on remote handling and control of raw materials, processes, wastes, and finished product to remain cost-competitive with a high quality product.

The range of our activities has included:

- Computer modeling to provide evaluation of remote handling mechanism and robotic system design and functionality before equipment purchase, assembly, and delivery
- Development of remote handling robots to support assay evaluation without direct operator handling of materials
- Development of remote vehicles for in situ examination of hazardous areas without requiring operator exposure to hazards
- Development and integration of robotic end-effectors for remote removal of wastes from storage tanks