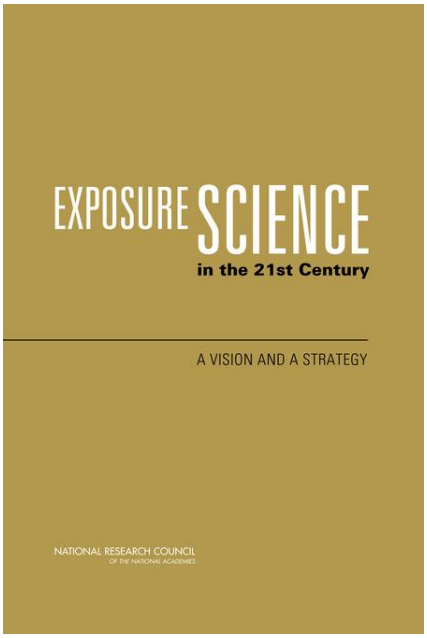
Progress in Meeting ES 21 Goals and Objectives
January, 2015

Background

Recognizing that exposure science is a key component for providing the best public health and ecosystem protection, EPA has undertaken several steps to ensure that the science and research that informs Agency decisions keeps pace with current and emerging environmental issues. In 2010, EPA with support from NIEHS requested the National Academies, as independent advisers on scientific matters, develop a long-range vision for exposure science in the 21st century, and a strategy for implementing this vision over the next twenty years. The report, *Exposure Science in the 21st Century: A Vision and a Strategy*, was released in 2012 by the National Academies.[1]



The report, authored by a scientific panel convened by the National Academies' National Research Council, outlines a framework for advancing exposure science to study how humans and ecosystems interact with chemical, biological, and physical stressors in their environments. The report also describes scientific and technologic advances needed to support the long-range vision for exposure science in the 21st century and concludes with a discussion of the elements needed to realize it. The report identifies a number of recommendations for advancing Exposure Science. These include:

- Use state-of-the-art methods and technologies such as remote sensing and global positioning to gather exposure information.
- Incorporate advances in genomic technologies and informatics to systematically assemble the vast amounts of different exposure data types.
- Engage stakeholders who want to contribute exposure data and studies.
- Coordinate exposure research through a formal collaboration with other Federal agencies (similar to Toxicity Testing in the 21st Century-Tox21) such as USGS, NIEHS, NOAA, CDC, NSF and NASA.
- Train and educate the next generation of exposure scientists.

[1] EPA Website : http://www.epa.gov/nerl/features/nrcreport.html

EPA Role in Implementation of ES 21 Recommendations

The Office of Research and Development (ORD) National Exposure Research Laboratory (NERL) has taken the lead for EPA to begin a dialog on what new partnerships in exposure science can do and how EPA can position itself to achieve maximum benefit from this new science. ORD framed the discussion on what is in the report, what science is being developed now, and what we anticipate in the next 10 years using a two pronged approach in leading this effort:

As a starting point, NERL held an Intra- Agency "*ES21 Summit" on April 21-22, 2014* where regional offices and program partners were brought together to better understand the exposure data needs of EPA and what new areas of exposure science would be most beneficial in meeting those needs. The goal of the summit was to begin a dialog on what new exposure science approaches can do and how EPA can position itself to achieve maximum benefit from this new science. Presentations and panel discussions were used to describe the new vision for the science, the technologies and tools that are being developed, and opportunities for EPA to use this science. Presentations by Paul J. Lioy, Deputy Director and Professor Rutgers, EOHSI and Paul Gilman, Senior Vice President and Chief Sustainability Officer, COVANTA helped to frame the needs and the opportunities in this advancing area of science. In particular, the following was emphasized:

Overarching research needs –

- How to characterize exposures quickly and cost-effectively at multiple levels of integration – including time, space, and biologic scales – and for multiple and cumulative stressors.
- How to develop scaling up methods and techniques to detect exposure in large human and ecologic populations of concern.

Workable strategies to achieve this outcome:

- Identify needs and opportunities through intra-agency collaboration and inter-agency/industry/academia collaboration.
- Develop new tools for today's urgent demands collaboratively creating infrastructure (including educational).

ORD /NERL used the outcome of the *ES21 Summit* to better define the new vision for the science, the technologies that are being developed and opportunities for EPA to use this science. Based on the outcome of the internal EPA Summit, NERL refined the planned focus for the Inter-Agency *ES21 Federal Partnership.*

Convening the ES21 Federal Working Group on Exposure Science[2]

In early 2014, NERL convened the first meeting of the ES21 Federal Working Group on Exposure Science. The group is co- chaired by Dr. Jennifer Orme- Zavaleta of EPA/ORD and Dr. Gayle DeBord, of CDC/NIOSH/DART. The purpose of the ES21 Federal Working Group on Exposure Science is to promote Federal participation and collaboration in the development of exposure science. This activity will benefit from the framework recommended by the National Academy of Sciences (NAS) in their 2012 report on *Exposure Science in the 21st Century: a Vision and a Strategy*. The working group will explore how Federal partners can engage in key exposure science areas as articulated in the NAS report. Members

[2] EPA, FDA, NIH/NIEHS, USGA, CDC, OSHA, DoD, USDA, NIST, DoE, OSTP, DHS, CPSC, NASA

will advance and share issues related to their specific agency mandates and interests, and the Working Group will serve to share information, promote collaborative activities, and reduce duplication of efforts across agencies.

The ES21 Federal Working Group on Exposure Science is chartered under the Toxics and Risk (T&R) Subcommittee of the Committee on Environment, Natural Resources and Sustainability. This committee falls under the National Science and Technology Council, which is part of the White House Office of Science and Technology Policy. The charter for the group was developed and was signed on June 26, 2014. (Appendix A). The T&R Subcommittee leadership provide guidance and input to the ES21 Working Group efforts.

ES21 has developed into a forum for Federal agencies to collaborate and advance the field of exposure science. The Working Group is addressing the key exposure science areas identified in the NAS report by:

- Examining the current body of knowledge, data, and tools for assessing both human and ecological exposures;
- Identifying and coordinating ongoing exposure-related activities among Federal agencies;
- Prioritizing activities and research collaborations that could substantially modernize and promote the use of exposure science; and,
- Identifying innovations to modernize methods and optimize the use of exposure data to fulfill the objectives and goals of participating agencies.

Based upon early discussions and identification of exposure science activities underway in each of the partner organizations, five subgroups of the Federal Working Group have been formed to address collaborative opportunities and challenges. In the past year, each of these groups has made significant progress in further refining the emerging challenges and needs of exposure science, identifying the short, mid- term and long term research needs and developing an effective inter-agency forum for collaboration. Detailed planning matrices for each sub group that identify these goals can be found in Appendix B. During FY'15, the inter-agency group will continue to move forward on the ES21 effort and will document progress and ensure that the work of this group is shared broadly to inform not only the federal partners but all others with an interest in advancing exposure science.

ES21 Sub –Groups

Biomonitoring: Co-Chairs Mary Mortensen (CDC / NCEH) and Andrea Pfahles-Hutchens (EPA / OCSPP)

Charter: Monitoring of exposure to stressors can play many roles including determination of stressor presence, stressor type and stressor level. With few exceptions, however, monitoring techniques do not provide the quantitative information needed for use in exposure assessment. There is an ever increasing need for development and collection of different types of biological markers and environmental indicators of exposure. The workgroup will assess ongoing strategies to determine what refinements may be necessary to make them more effective and accurate. The workgroup is charged to review the recommendations of the NRC and develop 1) options for new approaches that may be more useful than traditional approaches and 2) improvements to traditional approaches with a specific focus on greater utilization of biomonitoring to assess exposure and risk.

Description of the Biomonitoring Challenge**:** New challenges and new scientific advances mean that an expanded, integrated vision of exposure science—one that considers exposures from source to dose, over time and space, to multiple stressors, and from the molecular to ecosystem level— is now needed. This vision is defined as the extension of exposure science from the point of contact between stressor and receptor inward, into the organism; and outward, to the general environment including the ecosphere. This group will focus on the challenges presented including lack of knowledge and techniques, including:

- Biomarkers and Biomonitoring Techniques (front and back end of the regulatory process)
- Improved use of Biomonitoring and environmental monitoring to evaluate & reconstruct exposure, and
- Linking exposures to ecological and human health outcomes

Accomplishments in 2014:

- Convened to begin the process to develop) options for new approaches that may be more useful than traditional approaches and 2) improvements to traditional approaches with a specific focus on greater utilization of biomonitoring to assess exposure and risk.
- Reviewed their charter and has made some modifications to better align with the ES21 NAS report
- Identified opportunities for collaboration across the federal partners
- Completed the planning matrix that lays out short, mid- term and long term goals[3]
- Began development of a library of resources – access to publications, newsletters, etc.
- Looking at a potential example project as a model for the group to use

[3] See Appendix B

Sensors / Dosimeters: Tim Watkins (EPA / ORD)

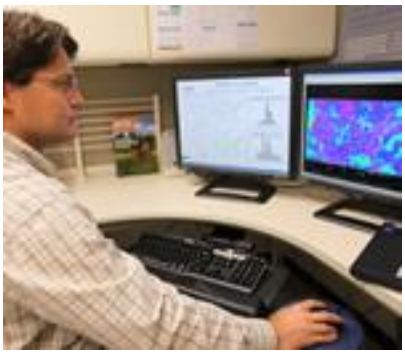
Charter: Remote sensing has emerged as a key innovation in exposure science. Remote sensing has been defined as the "acquisition and measurement of data/information on some properties of a phenomenon, object, or material by a recording device. . . ." New tools are needed to facilitate the collection of real time, reliable exposure information. The workgroup is charged to review the recommendations of the NRC, inventory current/ emerging tools and gaps, and develop options for new approaches that may enhance or replace older approaches.

Description of the Sensor / Dosimeter Challenge: New challenges and new scientific advances mean that an expanded, integrated vision of exposure science—one that considers exposures from source to dose, over time and space, to multiple stressors, and from the molecular to ecosystem level— is now needed. This vision is defined as the extension of exposure science from the point of contact between stressor and receptor inward, into the organism; and outward, to the general environment. To improve data quality for Remote Sensing and increase its utility for exposure studies, technologic improvements are needed.

Accomplishments in 2014:

- The subgroup charge and charter have been finalized
- Completed the planning matrix that lays out short, mid- term and long term goals[4]
- A series of webinars to discuss exposure activities in more depth has been developed These include:
    - Oct 8th EPA: Ron Williams, Kristen Benedict – EPA Sensors, Policy Perspectives (complete)
    - Oct 22nd Corps of Engineers: Overview Brandon Lafferty, Austin Davis
    - Nov 5th NIOSH: Mark Hoover et al. – NIOSH Center for Direct Reading & Sensor Technology
    - Nov 19th NOAA: Greg Doucette et al. – Sensors for Harmful Algae, Toxins & Bacterial Pathogens
    - Dec 3rd Corps of Engineers: Jan Hulla – Napthalene Dosimeter
    - Feb 11th NIEHS: David Balshaw – Sensor Development and Validation Programs
- The group is encouraging participation from the other subgroups to identify opportunities for collaboration and synergies
- The group is developing a terminology reference that will be appropriate for use by the other subgroups and a potentially wider use community
- Citizens Science Sensors Toolbox is being developed

[4] See Appendix B



Models: Billy Johnson (DoD / CoE)

Charter: Exposure models will continue to support diverse efforts such as risk analysis, impacts assessment, life cycle and sustainability assessments, epidemiology and energy analysis. Models for screening, prioritization, and prediction need to be developed and validated. Exposure models must balance the need for transparency with the need for fidelity and credibility. Models need to be backed up by data to be acceptable. The workgroup will assess current models to determine what refinements may be necessary to make them more effective. The workgroup is charged to review the recommendations of the NRC and develop options for new approaches that may be more effective than older approaches.

Description of the Modeling Challenge**:** New challenges and new scientific advances mean that an expanded, integrated vision of exposure science—one that considers exposures from source to dose, over time and space, to multiple stressors, and from the molecular to ecosystem level— is now needed. The NRC Committee identified the need for the further development of existing and emerging methods and approaches, validation of methods and their enhancement for application on different scales and in broader circumstances and improved linkages to research in other areas of environmental health. Models of the processes, dynamics and distribution of exposures to chemical, physical, and biologic agents in association with other stressors are an essential element of exposure science. The challenge for this group is to consider the role that exposure models need to play in supporting exposure science in the 21st century and identifying the gaps that need to be filled. Specific considerations within the charter of this group include:

- Need data to validate models
- Screening Models for Prioritization
- Model development for specific sensitive populations such as children and the elderly
- Integration Between Human Health and Ecological Exposures
- Disaster Science
- Multi Scale Exposure Modeling
- Statistical methods and Tools for Predictive Modeling
- Individual Longitudinal Exposures (DOD)
- Occupational Exposures
- Systems models for sustainability
- Spatially-explicit Models

Accomplishments in 2014:

- Subgroup charter has been finalized, though it may evolve over time
- Organizing exposure activities into categories and grouping them into themes that include:
    - Policy/Regulations/Decision Support
    - Data/Databases/Frameworks
    - Statistical Models – Frequency Distributions based on Exposures, assessing variability, determining proper distribution, parameters derived from empirical data
    - Empirical / Physically Based Models
    - Exposure Pathways
- Completed the planning matrix that lays out short, mid- term and long term goals[5]

[5] See Appendix B

Data Management: Zachary Collier (DoD/CoE)

Charter: There is a compelling need for the development of Policies and Standard Operating Procedures for the collection and management of exposure and exposure-related data. In the near term, exposure science needs to develop strategies to expand exposure information rapidly to improve understanding of where, when, and how exposures occur and their health significance. Data generated and collected would be used to evaluate and improve models of exposure for use in generating hypotheses and developing policies. This data collection and management group is tasked to review the current status of policies and procedures associated with exposure data, and to identify critical needs and opportunities to partner across the government to establish a common set of standard operating procedures to facilitate the sharing and utilization of existing and future exposure data.

- Description of the Data Management Challenge**:** New challenges and new scientific advances mean that an expanded, integrated vision of exposure science—one that considers exposures from source to dose, over time and space, to multiple stressors, and from the molecular to ecosystem level— is now needed. This vision is defined as the extension of exposure science from the point of contact between stressor and receptor inward, into the organism; and outward, to the general environment including the ecosphere. Numerous challenges in the area of data management have been identified and will serve as the starting point for this group. These include:
  - Management Across Heterogeneous Sources
  - QA/QC
  - Linkages
  - Availability of Existing data
  - Ethics of using data
  - Accessibility of Data
  - Current Data
    -how to access, use and integrate
  - Methods for collecting, handling and analyzing "big data" from multiple sources
  - Consistency Across the federal Government
    - Terminologies
    - Platforms

Accomplishments in 2014:

- Identification of current challenges associated with data management. These include:
  - What data are out there? How are people using it?
  - How can we encourage the use of existing data sets, and prioritize what needs to be further collected?
  - Data on nanomaterials; Data on food ingestion (suburban home gardening, farmers markets) and uptake and translocation in plants (e.g., leaves vs. fruit)
  - Big data – use large datasets and high frequency monitoring in conjunction with algorithms to discover patterns and identify problems (similar to credit card buying patterns)
- Issues to be addressed
  - Data Sensitivity; Data Quality; Need to learn what the other Subgroups have identified as gaps, because some have to do with data as well
- Updated project inventory and edited the charter

- Completed the planning matrix that lays out short, mid- term and long term goals[6]

Community Engagement/Citizen Science: Liam O'Fallon (NIEHS)

Charter: The Community Engagement/Citizen Science workgroup will focus on developing strategies to engage communities in furthering the development of exposure science. The NRC has made clear that "to maintain public confidence in the integrity of exposure science, innovative forms of public engagement are required". The public can be the user and generator of exposure data. The new approaches must be embraced by the public if they are to become key players. The group should identify new opportunities and approaches for encouraging the public to identify and address relevant health concerns at the local level. Assessing ongoing strategies and identifying new approaches to engage citizens before, during and after exposure studies is of critical importance for success. The workgroup will assess ongoing strategies to determine what refinements may be necessary to make them more effective. The workgroup is charged to review the recommendations of the NRC and develop options for new approaches that may be more effective than older approaches.

Description of Challenge: New challenges and new scientific advances mean that an expanded, integrated vision of exposure science—one that considers exposures from source to dose, over time and space, to multiple stressors, and from the molecular to ecosystem level— is now needed. This vision, dubbed "the eco-exposome," is defined as the extension of exposure science from the point of contact between stressor and receptor inward, into the organism; and outward, to the general environment including the ecosphere. Effective implementation of the committee's vision will depend on the development and cultivation of scientists, engineers, and technical experts with experience in multiple fields, in order to educate the next generation of exposure scientists and to provide opportunities for members of other fields to cross-train in the techniques and models used to analyze and collect exposure data. This includes the need for the development of programs to improve public understanding and engagement in exposure-assessment research, including ethical considerations involved in the research.

Accomplishments in 2014:

- Developing a simple tool for a pulse check to collect basic information of Citizen Science and Community-Engagement efforts related to the ES21 report. Plan to finalize it in October and use it shortly thereafter. Envision it being used to help to:
    - understand the distribution of exposure science citizen science activities; understand & communicate what it is about Citizen Science that has a greater impact on health.
    - identify opportunities for developing or growing tools or programs.
- From this pulse check, plan to write a descriptive document that outlines the various uses of citizen science, its impact on health, and future opportunities
- Planning on participating in the Citizens Science Conference in 2015

[6] See Appendix B

Planned Outputs for FY'15 –

- Begin the education necessary to start the transformation necessary to implement this new exposure science approach
- Implementing opportunities for collaborative actions by each subgroup
- Established a virtual collaboration space via the OMB governed MAX.gov tool, which will facilitate communication, document creation and idea sharing across ES21 partners and Subgroups
- Draft a publication that highlights important aspects of the ES21 NAS Report, ES21 Working Group efforts, and broader exposure science implications
- There will be a session at ISES this year on ES21. Focus on planning a coinciding meeting with 2015 ISES meeting. Consider having break-out sessions for Subgroups.
- Will be developing a website to give a public presence to ES21. Could include goals, ES21 charter, how to get involved, etc.

CHARTER
of the
WORKING GROUP ON EXPOSURE SCIENCE FOR THE 21sT CENTURY
TOXICS AND RISK SUBCOMMITTEE
COMMITTEE ON ENVIRONMENT, NATURAL RESOURCES, AND SUSTAINABILITY
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

A. Official Designation

The Working Group on Exposure Science for the 21st Century (ES21) is hereby established by action of the National Science and Technology Council (NSTC); Committee on Environment, Natural Resources, and Sustainability (CENRS); Taxies and Risk Subcommittee (T&R).

B. Purpose and Scope

Exposure science investigates the contact of humans or other organisms with chemical, physical, and biologic stressors, and their fate in living systems. Understanding exposure provides the real-world context for describing risk, along with information on the most effective ways to reduce exposure and improve health. Exposure science has become more important with the emergence of today's complex problems including climate change, security threats, population pressure, urbanization, depletion of natural resources, and increased understanding of environmentally related illness. This complexity, combined with advances in measurement and computational technologies, provides new opportunities for advancing and using exposure science to address today's wide range of health challenges.

The purpose of the ES21 Working Group is to build on the framework recommended by the National Academy of Sciences in its 2012 report on *Exposure Science in the 21st Century: a Vision and a Strategy,* and promote Federal collaboration in the development of exposure science. The ES21 Working Group will serve to share information, integrate activities, and reduce duplication of efforts across agencies in the development of new exposure science.

C. Functions

ES21 will be a forum for Federal agencies to collaborate and advance the field of exposure science and optimize agency resources by:

1) Identifying and coordinating ongoing and planned exposure science research and development activities among Federal agencies in the near-, mid- and long-term in a

planning matrix. This matrix will focus on the topics areas of modeling, biomonitoring, sensor technologies, managing data, and community engagement/citizen science.

2) Identifying innovations to modernize methods and optimize the use of exposure data to advance research and development, and applications in science and technology;

3) Developing a prioritized list of activities and research collaborations that could substantially modernize and promote the use of exposure science.

ES21 will coordinate with, and address the needs of, other relevant CENRS Committees and working groups. ES21 will report their findings to the Committee prior to the termination date.

D. Membership and Structure

The following NSTC departments and agencies are represented on the ES21 Working Group:

Department of Agriculture,
Department of Commerce,
Department of Defense,
Department of Energy,
Department of Health and Human Services,
Department of Homeland Security,
Department of the Interior,
Department of Labor
Department of Transportation,
Environmental Protection Agency,
National Aeronautics and Space Administration; and
National Science Foundation.

The following organizations of the Executive Office of the President are also represented on ES21:

Office of Management and Budget, and
Office of Science and Technology Policy.

Cooperating departments and agencies shall include other such Executive organizations, departments, and agencies as the T&R Co-chairs may, from time to time, designate. ES21 Co-chairs and an Executive Secretary shall be appointed by the T&R Co-chairs. The Executive Secretary shall maintain and distribute agendas, minutes, records of action, and products, consistent with NSTC procedures.

E. Private-Sector Interface

ES21, in consultation with T&R, may seek advice from members of the President's Council of Advisors on Science and Technology to secure appropriate private-sector' advice, and will recommend to T&R, CENRS and/or the President's Science Advisor the nature of any additional non-Federal advice needed to accomplish its mission. ES21 may also interact with and receive *ad hoc* advice from various private-sector groups consistent with the Federal Advisory Committee Act.

[1] The Federal Advisory Committee Act, 5 U.S.C. App., as amended, does not explicitly define "private sector," but the phrase is generally understood to include individuals or entities outside the Federal government such as, but not limited to, the following: non-Federal sources, academia, State, local or Tribal governments, individual citizens, the public, non-governmental organizations, industry associations, international bodies, etc.

F. Termination

Unless renewed by the Co-chairs of the T&R Subcommittee prior to its expiration, ES21 shall terminate no later than April 16, 2015.

G. Determination

I hereby determine that establishment of the Working Group on Exposure Science for the 21st Century (ES21) is in the public interest in connection with the performance of duties imposed on the Executive Branch by law and those duties can best be performed through the advice and counsel of such a group.

Approved:

H. Zenick — 6/26/14

Harold Zenick, Environmental Protection Agency
(Co-chair, CENR Toxics and Risk Subcommittee)

Date

Patrick a. Mason — 6/26/2014

Patrick Mason, Department of Defense
(Co-chair, CENR Toxics and Risk Subcommittee)

Date

6/26/2014

Christopher Weis, Department of Health and Human Services
(Co-chair, CENR Toxics and Risk Subcommittee)

Date

		Short Term (next two - three years)	Mid Term (next three - six years)	Long Term (beyond six years)
Level of Difficulty	Most	• Establish interagency collaborations and put in place the requisite MOA/MOUs. • Propose the Small Business Innovation Research (SBIR) and Small Business Technology Transfer Research (STTR) concepts and shepherd them through internal review to be advertised as RFPs. • Determine how the workgroup should best proceed with delineating between health or biological and environmental monitoring (eg. develop Subgroups? Stay intact?, etc)		• Transfer the Grantees technologies into NTP and other tox testing agencies. • For priority chemicals generate real-time dose-response data using the real-time chemical monitors while concurrently measuring response using real-time medical imaging. • Generate risk assessment with increased precision.

	Medium	• Target for SBIR and STTR funding (to help reduce the uncertainty in animal to human extrapolation)
		  • To increase precision in the "dose" of the dose-response assessment: develop and validate portable real-time chemical sensors that link the chemical measurements to:
		  • GPS coordinates or
		  • Anatomical coordinates
		  • Adapt the imaging technologies used in medicine to be applied to the measurement of "response" in the dose-response used in chemical risk assessments
		• Develop case reports/examples to demonstrate applications of biomonitoring data and use these to identify data gaps, areas of uncertainty, etc. These examples can be formatted according to the Core Elements of Exposure Science Framework to demonstrate intersections between biomonitoring and other aspects of exposure science.
			• Evaluate the proof of concepts generated by the SBIR and STTR Phase I grantees
			• Fund SBIR/STTR Phase II and Phase III for laboratory and field validation of the prototype real-time personal chemical monitors and prototype medical imagers	

	Least	• Explore the feasibility of a group meeting to discuss current and future biomonitoring activities and collaborations within the Federal government
		• Determine best mechanism to report on how biomonitoring data is perceived and used at each agency
		• Identify research needs/data gaps in Biomonitoring (the lack of precision in chemical health risk assessments)
		• Develop collaboration activities within the ES21 Workgroup (eg. working with the Sensors subgroup to identify opportunities to:
		• Increase the precision in measuring the **time** of exposure and internal dose by developing:
		  • Real-time chemical monitoring
		  • Real-time medical imaging or collection of biomarkers
		• Increase the precision of measuring the **place** of exposure and dose by adding place coordinates to chemical monitoring measurements.
		  • GPS for environmental exposures
		  • Anatomical location for dosimetrics		

Level of Difficulty		Short Term (next two to three years)	Mid Term (next three to six years)	Long Term (beyond six years)
	Most		• Work with the **sensors subgroup** to promote the development and use of tools for communities and workers	
	Medium	• Establish Web-based repository of resources including: ○ Successful models ○ Publications ○ Evaluation tools • Develop communication strategies and materials to promote and strengthen community-engagement in exposure science, such as: ○ Podcasts ○ Webinars ○ Journal articles • Engage and coordinate with Federal Community of Practice to identify and promote models of community engagement, citizen science, and crowdsourcing • Identify models to support community engagement used by foundations and other organizations: ○ RWJF ○ Kresge ○ HEFN ○ WK Kellogg	• Coordinated exposure science funding opportunities that engage community partners with a focus on: ○ Research, including community-driven ○ Training to build the pipeline ○ Capacity building to strengthen institutional infrastructure ○ Risk Communication • Establish funding opportunities for gaming & crowd-sourcing of large exposure data sets • Work with the **data management subgroup** on opportunities to: ○ Train/Build Capacity for all research partners ○ Develop shared databases • Support exposure science that focuses on healthful exposures – what are positive exposures in our environment and why do they work?	• Deployment and evaluation of cost-effective sensor tools that can be used by diverse community partners.
	Least	• Organize coordinated sessions at professional conferences: ○ APHA ○ ISES ○ ISEE ○ Citizen Science Association • Identify and consider existing recommendations related to community engagement in exposure science. We do not want to be duplicative. ○ National Conversation ○ Environmental Justice Strategic Plan	• Establish a coordinated webinar series of exposure science grantee projects	

		Short Term (next two to three years)	Mid Term (next three to six years)	Long Term (beyond six years)
Level of Difficulty	Most			• Unified data standard
	Medium		• Dermal data standard • Advanced big data analytics and algorithm development • Metadata standard – including user feedback options for data quality and ease of use	• Ingestion data standard
	Least	• Centralized data website to link to relevant exposure databases and ongoing research efforts • Periodically updated report listing current databases and gaps • Initiation of a Community of Practice	• Inhalation data standard	• Outreach efforts including education, newsletters, and other dissemination efforts

		Short Term (next two to three years)	Mid Term (next three to six years)	Long Term (beyond six years)
Level of Difficulty	Most	• Loosely develop cross agency collaborative R&D efforts (ERDC) • Obtain occupational exposure measurement databases *that are suitable* for the evaluation of exposure models (NIOSH)	• Engage Senior Leadership within each agency to better incorporate Exposure Science into agency decision making (ERDC) • Develop models to estimate occupational exposures (either point estimate of exposure or exposure range) and calibrate the models (NIOSH) • Utilize exposure models in the OSHA rulemaking process to demonstrate the technological feasibility of achieving compliance with more protective occupational exposure limits. (OSHA)	• Incorporate Exposure Science into Management Decisions at the Operational Level (ERDC)
	Medium	• Develop screening level tools that are linked with existing databases and data sources (ERDC) • Evaluate the existing exposure models to determine strengths/weaknesses with independent data sets (NIOSH) • Publish RFI to solicit information from stakeholders on the potential use of exposure modelling when updating OSHA PELs (OSHA) • Identify occupational exposure measurement databases for development of exposure models (OSHA)	• Develop a mechanism (framework, standards, etc) for multi-agency integration of databases, parameter estimation tools, statistical, empirical, and physically based models (ERDC) • Develop a framework of exposure mechanism (e.g., empirical, statistical, and/or physically based models) (NIOSH) • Obtain occupational exposure measurement databases *that are suitable* for the calibration of potential exposure models (NIOSH) • Develop collaboration work with other agencies for sharing databases (NIOSH) • Develop statistical models to characterize the underlying distribution of occupational exposures and make inferences regarding the “probability” of exposure above the PELs (OSHA)	• Select a common suite of tools/models/systems/etc that multiple agencies will maintain and support (ERDC) • Continue maintenance of the developed models (NIOSH)
	Least	• Investigate current on-going efforts within other agencies (ERDC) • Identify occupational exposure models, pre-existing or currently under development (NIOSH) • Conduct literature review to identify existing publications on the development and use of occupational exposure models (OSHA)	• Formalize longer term collaboration across multiple agencies (ERDC)	• Develop and support multi-agency funding programs to facilitate joint collaboration (ERDC) • Introduce the models to users for utilization by offering professional development courses or workshops (NIOSH)

		Short Term (next two to three years)	Mid Term (next three to six years)	Long Term (beyond six years)
Level of Difficulty	Most	• Establish interagency collaborations and put in place the requisite MOAs. • Propose the SBIR and STTR concepts and get them through internal review so that they are advertised as RFPs. • Development of technical guidance/performance specifications for emerging technologies. Development of a program to provide "recognition" of sensor technologies - not the same as "approval" of new technology for use in regulatory monitoring network	• BIG DATA: Developing data standards/Defining data collection needs to evaluate quality/consistency of data from emerging technologies	• Transfer the Grantees technologies into NTP and other tox testing agencies. • For priority chemicals generate real-time dose-response data using the real-time chemical monitors while concurrently measuring response using real-time medical imaging. • Generate risk assessment with increase precision. • Short term health effects studies • Review and potential revision of regulatory monitoring requirements – requires rulemaking(s)

	Medium	• Target for SBIR and STTR funding;
		  • To increase precision in the "dose" of the dose-response assessment: develop and validate portable real-time chemical sensors that link the chemical measurements to:
		  • GPS coordinates or
		  • Anatomical coordinates
		  • Adapt the imaging technologies used in medicine to be applied to the measurement of "response" in the dose-response used in chemical risk assessments
		  • This will reduce the uncertainty in animal to human extrapolation
		  • Messaging short-term concentration data
			• Evaluate the proof of concepts generated by the SBIR and STTR Phase I grantees
			• Fund SBIR/STTR Phase II and Phase III for laboratory and field validation of the prototype real-time personal chemical monitors and prototype medical imagers	

	Least	• Identify Gaps- The lack of precision in chemical health risk assessments
		• Identify Opportunities
		  • Increase the precision in measuring the **time** of exposure and internal dose by developing:
		  • Real-time chemical monitoring
		  • Real-time medical imaging of biomarkers
		  • Increase the precision of measuring the **place** of exposure and dose by adding place coordinates to chemical monitoring measurements.
		  • GPS for environmental exposures
		  • anatomical location for dosimeters
		  • Definition of sensor (include innovative technology and advanced monitoring too?)
		  • Performance evaluations of new technologies
		• Develop a glossary of sensor / dosimeter terminology		

ES21 Partners

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