Advancing Exposure Science
ES 21 Progress Report: 2015

Executive Summary

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 result of that effort was a report, *Exposure Science in the 21st Century: A Vision and a Strategy*, which was released in 2012 by the National Academies.[1]

The report identified a number of recommendations for advancing exposure science. These included:

1. Use state-of-the-art methods and technologies such as remote sensing and global positioning to gather exposure information.
2. Incorporate advances in genomic technologies and informatics to systematically assemble the vast amounts of different exposure data types.
3. Engage stakeholders who want to contribute exposure data and studies.
4. 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.
5. Train and educate the next generation of exposure scientists.

In 2014, in response to recommendations #4 and #5, EPA and NIEHS convened a workshop of federal agency representatives to raise awareness about the report, discuss and understand the key recommendations in the report and identify aspects of exposure science that are ideal for coordination across federal agencies. Since that time, the Federal Working Group on Exposure Science (ES21 Workgroup) has been established to expand federal partnerships, to create a common understanding of exposure science and to drive research across the federal government. The Workgroup is chartered under the Toxics and Risk (T&R) Subcommittee of the Executive Committee on Environment, Natural Resources, and Sustainability. (Appendix A)

In its second year of work, the ES21 Workgroup has made significant progress in furthering the collaboration among and across federal government agencies. Initially five subgroups formed the core of the effort: Biomonitoring; Sensors, Citizen Science, Data Management and Modeling. Recognizing the need for a focus not only on biomonitoring but also environmental monitoring a new subgroup on environmental monitoring has been added to the original five. A communications team has been established to assist the ES21 Federal Working Group in identifying opportunities to share information and to engage additional partners.

The Workgroup has put in place a multipronged approach for advancing exposure science as recommended in the report. This includes: 1) the development of technologies to characterize exposure, 2) the development of data and knowledge management tools to analyze and interpret exposure, and 3) the integration of stakeholders in the research enterprise to enhance the relevance and translation of the research.

As a first step after its initial meeting in early 2014 the ES21 Workgroup developed a matrix of current and projected (near, mid and long-term) activities.[2] Work over the past year has focused on accomplishing many short term efforts identified in that matrix and laying the foundation for the longer term efforts. Some examples of the short term work underway include:

- Educating members on the transformation needed to implement this new exposure science approach
- Implementing opportunities for collaborative actions by each subgroup
- Publishing highlights of the important aspects of the ES21 NAS Report, ES21 Working Group efforts, and broader exposure science implications

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

[2] http://www2.epa.gov/innovation/progress-meeting-es-21-goals-and-objectives

- Translating via the Symposium at International Society for Exposure Sciences (ISES)
- Establishing an inter-agency virtual collaboration space to facilitate communication, document creation and idea sharing across ES21 partners and Subgroups
- Developing a website to provide public access to ES21 products and activities.

A great deal of foundational work has been accomplished by the ES21 Working Group in 2015 including:

- Producing a glossary to harmonize across different exposure terms,
- Establishing an Exposure Dialogue Group
- Identifying and maximizing the impact of a number of ongoing collaborations[3] including:
  - DISCOVER AQ (Deriving Information on Surface conditions from Column and VERtically resolved observations relevant to Air Quality)
  - Federal Coordination of Sensor Technology Small Business Innovative Research (SBIR) Investments
  - DoD Serum Repository data
- Maximizing the use of existing collaboration opportunities and creating new ones
- Developing the framework for a series of case studies to further inform and educate a broader community about ES21
- Developing and presenting a series of webinars designed to further share the concepts behind the ES21 effort.

The ES21 Federal Working Group on Exposure Science Group will continue to build upon current activities by developing a more formal and systematic mechanism for identifying and initiating collaborations and creating an infrastructure across the federal government that will further advance the five recommendations in the NAS report. The group has begun to expand the thinking presented in the NAS report and is exploring areas where there seems to be broad interest across the federal government.

For example, one area of broad interest is science preparedness for disaster response. The value of collecting exposure data post a catastrophic environmental incident is well-recognized. However, the ability to conduct such exposure science research is often hampered by lack of plans, protocols and resources at the time that a disaster occurs. The ES21 Federal Working Group views this "unpreparedness" as a significant challenge to being able to capture exposure data that can be used with potential environmental risk-related outcomes of a disaster. Some federal partners (e.g., HHS, and NIEHS) have recently started or revamped efforts to address this issue. The Work Group expects to leverage these activities to create a Community of Practice in this area.

A very significant benefit of the NAS report is that it has served as an impetus for federal agencies that need and use exposure science for environmental and public health decision-making to do so in a leveraged manner. With the ES21 forum in place, the advantages have become even clearer. Innovative solutions to real world problems now have the benefit of cross-agency expertise and resources. The inclusion of community engagement will make exposure science relevant and perhaps most importantly, practical.

Progress in Meeting ES21 Goals and Objectives: 2015

I. Background

In 2010, EPA, with support from NIEHS, requested that the National Academies, as independent advisers on scientific matters, develop a long-range vision for exposure science in the 21st century

[3] More details are provided in the full report

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.[4]

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:

1. Use state-of-the-art methods and technologies such as remote sensing and global positioning to gather exposure information.
2. Incorporate advances in genomic technologies and informatics to systematically assemble the vast amounts of different exposure data types.
3. Engage stakeholders who want to contribute exposure data and studies.
4. 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.
5. Train and educate the next generation of exposure scientists.

In 2014, in response to recommendations #4 and 5, EPA and NIEHS convened a workshop of federal agency representatives to raise awareness about the report, discuss and understand the key recommendations in the report and identify aspects of exposure science that are ideal for coordination across federal agencies. Since that time, the Federal Working Group on Exposure Science (ES21 Workgroup) has been established to expand federal partnerships, to create a common understanding of exposure science and to drive research across the federal government. The Workgroup is chartered under the Toxics and Risk (T&R) Subcommittee of the Executive Committee on Environment, Natural Resources, and Sustainability.

Exposure science is used across the Federal government to inform many important actions. The broad and complex nature of a multi-scale approach to exposure science will require that the core elements of the systems framework shown in Figure 1 are fully developed and integrated. Figure 1 provides an overview of where various federal partners are currently working within the framework, and illustrates that many of the elements in the framework are being developed across the Federal government. However, it is apparent that these components need to be integrated to realize the full impact of exposure science in addressing key environmental problems. [5]

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

[5] Exposure Science in the 21st Century: A Federal Perspective (Not yet published)

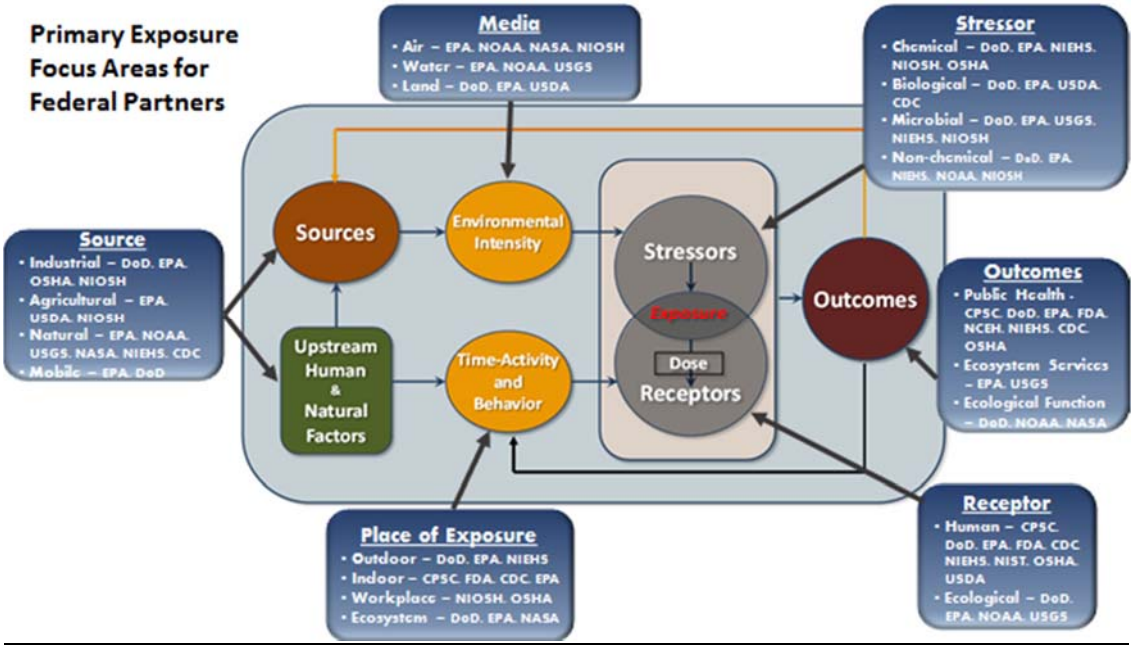


Figure 1

II. Convening the ES21 Federal Working Group on Exposure Science[6]

In 2014, EPA, CDC and other collaborators 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. The purpose of the ES21 Federal Working Group on Exposure Science is to promote Federal participation and collaboration in the development of exposure science. The Working Group will explore how Federal partners can engage in key exposure science areas as articulated in the NAS report. Members 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 effort across agencies.

The ES21 Working Group 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 were 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 and long-term research needs and developing an effective inter-agency forum for

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

collaboration. The biomonitoring subgroup needed to be more focused and so a sixth subgroup for environmental monitoring was formed in the summer of 2015.

Current Structure of the ES21 Federal Working Group on Exposure Science

The current ES21 Federal Working Group on Exposure Science continues to focus on cross-government efforts to identify efficiencies and collaborative opportunities in the area of exposure science. The group now consists of representatives from more than 20 different federal organizations (Appendix B) who share an interest in exposure science research and development. Work has been divided into six subgroups with strong collaboration between the groups.

A. Subgroups

Biomonitoring:
This subgroup assesses ongoing biomonitoring strategies to identify refinements that may be necessary to make them more effective and accurate. The subgroup is charged with reviewing the National Research Council recommendations and develops options for new biomonitoring approaches. Traditional approaches and improvements to biomonitoring can be addressed with a specific focus on greater utilization of biomonitoring techniques to assess exposure and risk.

Environmental Monitoring Subgroup:
This subgroup focuses on developing options for novel environmental monitoring approaches that enable faster identification of chemical, biologic, and physical stressors that are affecting humans and / or ecosystems; exposure-related environmental monitoring that will help identify the largest knowledge gaps and reveal where gathering more exposure information would contribute to reducing uncertainty; and monitoring and collecting data, in a variety of ecological and human settings that contribute to the development of exposure science decision-making tools.

Community Engagement and Citizen Science:
This subgroup focuses on developing strategies to engage communities in furthering the development of exposure science. The National Research Council has made clear that "to maintain public confidence in the integrity of exposure science, innovative forms of public engagement are required." The "public" is both the user and the generator of exposure data.

Data Management:
This subgroup is reviews the current status of policies and procedures associated with exposure data collection, analysis and sharing. They also identify critical needs and opportunities to partner across the government with the goal of establishing a common set of standard operating procedures that can facilitate sharing and utilizing existing and future exposure data.

Modeling:
This subgroup assesses current models to determine what refinements are needed to improve their effectiveness. This group also reviews the recommendations of the National Research Council, and develops options for new, more effective modeling. Exposure models must balance the need for transparency with the need for fidelity and credibility.

Sensors / Dosimeters:
This subgroup reviews the recommendations of the National Research Council; takes inventory of current and emerging tools and gaps, and develops options for new approaches that may enhance or replace older approaches. New challenges and new scientific advances mean an expanded, integrated vision of exposure science is necessary — one that considers exposures from source to dose, over time and space; and accounts for multiple stressors from molecular to ecosystem levels. Advanced sensor and dosimeter technology is an important part of this expanded vision.

Communications Team:
The communications team supports the work of the ES21 Working Group and the six subgroups. The team has developed a communication strategy focused on (1) identifying opportunities to increase participation in the ES21 effort; (2) identifying opportunities to leverage existing work both within and external to the Federal community ;(3) sharing the work undertaken by the ES21 Working Group and (4) advancing the development of this new exposure science paradigm.

ES21 Federal Working Group Accomplishments in 2015

I. Collaborations

ES21 is building on a very rich base of ongoing exposure science collaborations across the Federal government. A number of those collaborations are highlighted below. A more complete listing is contained in Appendix D.

DISCOVER AQ (Deriving Information on Surface conditions from Column and VERtically resolved observations relevant to Air Quality)

The National Aeronautics and Space Administration (NASA) and the US Environmental Protection Agency (EPA) are collaborating on the DISCOVER-AQ project. The overarching objective of the DISCOVER-AQ investigation is to improve the interpretation of satellite observations to diagnose near-surface conditions relating to air quality. NASA deployed two airborne platforms to sample in coordination with re-locatable and fixed surface networks. EPA provided an extensive ground-based instrument network to provide the critical "ground-truth" for the aircraft. By coordinating these efforts, high quality, remotely sensed information was paired with accurate measurement data to generate reliable satellite information on aerosols and ozone precursors for specific, highly-correlated times and locations to be used in air quality models. This partnership will result in more accurate and powerful air quality models which will improve human and ecological health through reduced exposure to pollutants. https://www.nasa.gov/mission_pages/discover-aq/

Federal Coordination of Sensor Technology SBIR Investments

The National Institute of Environmental Health Sciences (NIEHS), the National Institute for Occupational Safety and Health (NIOSH), the National Oceanic and Atmospheric Administration (NOAA), and the US Environmental Protection Agency are collaborating on a coordinated Small Business Innovation Research (SBIR) sensors technology solicitation. The SBIR program is a highly competitive program that encourages domestic small businesses to engage in Federal research and development that has the potential for commercialization. These four federal organizations are working to develop an SBIR solicitation which will focus on development of low cost, easy to use and reliable sensor technology. This partnership will result in the creation of innovative sensor tools that will improve scientific understanding of human – ecosystem pollutant interactions, while stimulating the small business sector of the US economy.

The DoD Serum Repository

The National Institute of Environmental Health Sciences (NIEHS) and the US Department of Defense (DoD) are working together with a team of universities to utilize the DoD Serum Repository - one of the largest collections of biological samples in the world. The DoD built and maintains the repository for medical surveillance purposes. NIEHS is working with university partners to integrate traditional exposure data with novel assessments of metabolomic signatures of exposure. This partnership will harness the power and utility of an incredibly large and diverse biological repository to examine innovative ways biomarkers can be used to recognize and reconstruct exposures in humans, thus improving human health.

II. Wilson School Data Base of Federal Crowdsourcing and Citizen Science Projects

In an effort to increase awareness of and access to reports, materials and research associated with the ES21 effort, the ES21 Working Group is working with the Wilson School to fully utilize the outreach potential of the Commons Lab Database. The database is designed to characterize the value and diversity of federal crowdsourcing and citizen science to support coordination within and between agencies, and facilitate public analysis and engagement. The data base includes projects funded or supported by federal agencies. These projects may be funded directly, or through grants from

agencies such as EPA, NIH, and USGS. Other projects may receive in-kind support, including equipment lending or support from agency personnel. The Community Engagement/Citizen Science subgroup has begun to populate the database with material from the ES21 group and through this effort will further expand the opportunities for collaboration. https://ccsinventory.wilsoncenter.org/

III. Glossary of Common Terms

In June, 2015 the ES21 Working Group posted the initial version of an ES21 Glossary of Common Terms. This glossary was developed as a cross-Federal effort to identify common exposure science terms. Recognizing that speaking in a common language and using common terminology is fundamental to understanding and addressing exposure science issues, the ES21 Working Group identified this glossary as an important first step in harmonizing exposure terms. The glossary will be updated periodically to include new terms and edit existing language.
http://www2.epa.gov/innovation/exposure-science-21st-century-federal-working-group

IV. Development of a Communications Strategy and Communication Team

Recognizing the need to provide a mechanism(s) to more broadly communicate the work of the ES21 Federal Working Group, a communications team has been formed. The team has produced a communication strategy to begin the process of expanding awareness of the group and its mission. The communications team is focusing on four key messages.

- Innovations in science and technology provide the potential for advances in exposure science.
- 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.
- Achieving this broader vision for exposure science will require an investment of resources and a substantial shift in how exposure science research is conducted and its results implemented.
- Collaboration is the critical key to leverage resources, expertise and innovation in the areas of:
    - Public Health
    - Ecosystem Services
    - Ecological Function
    - Risk Assessment and Risk Management
    - Modeling and Data Science

The group has developed a strategy to:

- Identify opportunities to increase participation in this effort through an internal government communications effort
- Identify opportunities to leverage existing work both within and external to the Federal community
- Advance the development of this new exposure science paradigm
- Share the work that is being undertaken by the ES21 Working Group through public communications

V. Case Studies

A key goal of the ES21 effort is to build upon current activities by developing a more formal and systematic mechanism for identifying and initiating collaborations. A series of case studies is being developed to promote opportunities for leveraged collaborations.

One area of broad interest is science preparedness for disaster response. The value of collecting exposure data following a catastrophic environmental incident is well-recognized. However, the ability to conduct such exposure science research is often hampered by not having plans, protocols and resources in place at the time that a disaster occurs. The ES21 Federal Work Group views this

"unpreparedness" as a significant failing in being able to capture exposure data that can be used to correlate with potential environmental risk-related outcomes of a disaster. Some federal partners (e.g., HHS, NLM, and NIEHS) have recently started or revamped efforts to address this issue. The Working Group expects to leverage these activities to create a "Community of Practice" in this area to create a forum for idea exchange, best practices and to encourage collaboration and cooperation.

In addition, the Working Group expects to define a general mechanism to produce timely and scientifically rigorous information *ahead of a disaster*. To this end, the workgroup has begun to collate the varied resources available from different partners to build on the existing capabilities of these partners and implement a process accessible to all relevant entities. The workgroup will also address specific activities associated with disaster scenarios, such as a major chemical spill, hurricane response and novel disease outbreak. In so doing, we expect to build capacity (e.g., developing a knowledge base of both people and intellectual resources) and systems (e.g., web-accessible and physical tools) that will facilitate agile, rapid response.

VI. Max. Gov

In order to better facilitate communications among the members of the ES21 Working Group a Max.Gov site has been created. The MAX.Gov Federal Community site can facilitate collaborations and information sharing that is far better than the usual work methods of e-mail, attachments, and network file sharing, supporting workgroups and information sharing across office, agency and governmental boundaries. Work from daily activities results in knowledge building to repurpose data into information with lasting value. The Community allows that to happen - it is easy to learn and powerful enough to be used for a broad scope of daily information sharing and collaboration activities.

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, type and 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 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.

The Biomonitoring Challenge

New challenges and 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 associated with knowledge and techniques of:

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

Accomplishments in 2015:

The Biomonitoring Subgroup has focused work on biological monitoring and has recommended creation a separate group to focus on environmental monitoring. Membership in each group was assessed and realigned to focus on either environmental monitoring or biological monitoring. This effort will allow each group to operate more effectively.

Prior to the realignment of the Biomonitoring Subgroup, a case study on microcystis was developed. This case study considered the spectrum from exposure to effects that can result from an algal bloom. It was patterned off of the core elements of the exposure science Framework (see Figure 1) to demonstrate intersections between biomonitoring and other aspects of exposure science. The case study determined gaps and potential improvement that might be made by biomonitoring, such as models to forecast or predict blooms, and anticipate when control measures may be required for public water supplies or recreational waters. The development of this case study prompted the discussion by Subgroup chairs to develop case studies across the Subgroups.

Figure 2

The Subgroup has initiated teleconferences for expanded discussions on biomonitoring at the various government agencies participating in ES21. The focus has been on the following questions:

- Who is doing biomonitoring and why?
- Who uses the biomonitoring data and who generates it?
- How is the biomonitoring data being used?
- What biomonitoring data sources are available?
- What is the quality of the data collected?

The subgroup has developed a list of biomonitoring topics most cited in the current literature to help focus areas of discussion for the subgroup.

The Subgroup also developed a webinar series to focus on biomonitoring activities; webinars are scheduled to continue throughout the fall and into next year. Specific webinars from 2015 include:

- Naphthalene Dosimeter
- Biomonitoring using HL7 Transaction Data and Medical Encounters in the DOD
- Biomonitoring at NIEHS: Applications, Infrastructure and Technology

Environmental Monitoring Subgroup: Co-Chairs: Michael McDonald (EPA), and Kathy Lee (USGS)

[This is a new subgroup under the ES21 Working Group and is in the initial stages of development. Membership is being recruited and a set of planned activities will be developed once the group is operational.]

Charter

Environmental monitoring describes the processes and activities that need to take place to characterize and monitor the quality of the environment. Exposure science examines the complex relationship between the interaction with a stressor and receptor over a period of time. Environmental monitoring enables exposure scientists to characterize and understand stressor fate and transport in a variety of ecosystems.

The workgroup is charged to review the recommendations of the NAS report Exposure Science in the 21st Century and develop (1) options for novel environmental monitoring approaches that enable faster identification of chemical, biologic, and physical stressors that are affecting humans and / or ecosystems (2) exposure-related environmental monitoring that will help to identify the largest knowledge gaps and reveal where gathering more exposure information would contribute reducing uncertainty and (3) monitoring and collection of data, in a variety of ecological and human settings, which contribute to the development of exposure science decision-making tools.

The Environmental Monitoring Challenge

Consistent with the challenges faced by all of the ES21 Federal Working Group subgroups, effective environmental monitoring is subject to a range of institutional, political, and legal constraints. Cultural and organizational changes over the last few decades have resulted in fewer available resources for environmental monitoring. These constraints require development of a more coordinated, efficient and technological approach to environmental monitoring. Even if effective monitoring data is gathered, it may not be used in decision making. Uncertainty associated with monitoring data allows stakeholders to contest the use of monitoring in decision making. New monitoring systems and partnerships are needed across government, states, regional and local levels to produce high quality data and information for decision makers.

As the Environmental Monitoring Subgroup charter is finalized and the Subgroup populated, a plan for 2016 accomplishments will be developed.

Sensors / Dosimeters: Tim Watkins (EPA / ORD)

Charter:

Sensor technology has emerged as a key innovation in exposure science. Sensor technology 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 Subgroup is charged to review the recommendations of the NRC, inventory current and 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 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 2015:

As a starting point for discussion of potential collaborations, the ES21 Sensors and Dosimeters Subgroup conducted a series of webinars to share information on the activities described above. The webinars identified several possible areas of collaboration including sensor technology development, communication and education, and development of guidance documents. The Subgroup has identified the coordination of Small Business Innovative Research (SBIR) investments as initial area of collaboration that would clearly identify the common interests in and need for sensor technologies across the Federal Government.

The most significant effort during the past year for the Sensors Subgroup was to develop an approach to coordinate Sensor Related Small Business Innovative Research (SBIR) solicitations. Federal partners have ongoing SBIR programs that have included requests for proposals related to monitoring, including sensor technology. However, these requests have not been coordinated in the past and the overall federal investment has not been captured, nor has there been a consistent federal message about the interest in and utility of sensor technology. Key elements of the proposed approach include:

- Developing a website hosted by SBA to provide an overview of sensor-related SBIR funding opportunities across federal agencies, including solicitation dates, award types (grant or contract), and dollar amount.
- Developing common language for the website and that agencies could use in their SBIR solicitations regarding the utility and value of sensor technologies for each federal organization. Each organization can supplement this common language with language specific to their need in their specific solicitation.
- Working with Federal partners at US EPA, NIEHS, NIOSH, NOAA, and DOD (NASA and US DOT/FHWA will be added)

The goals for this effort are focused on:

- Articulate a common need and interest for sensor technology development, evaluation, and application across the federal government.
- Identify the federal commitment to sensor technology research and quantify federal SBIR investment.
- Provide one central web location to make it easier for small business innovators to apply for federal funds related to sensor technology.
- Avoid duplicative investments.

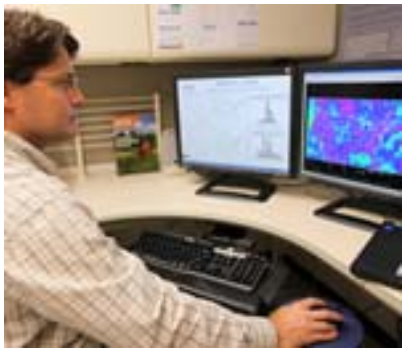
The Sensors Subgroup worked on a number of other efforts to expand the knowledge base regarding the new ES21 effort. These included:

- America Industrial Hygiene Association (AIHA) Webinar **-** Presented information and activities for the ES21 Federal Partners group and the Sensors and Dosimeters subgroup in a webinar hosted by AIHA on sensor technologies. Other participants in NIOSH and the National Nanotechnology Coordination Office (NNCO).
- International Society of Exposure Science (ISES) **-** Contributed to the development of the symposium for the 2015 ISES Conference, which was held in October 2015.
- Case Studies **-** Contributed to the development of two case studies (still in progress) to highlight the potential role of sensor technologies in advancing exposure science. The first case study relates to the Disaster Preparedness and the second address the role of technology in advancing exposure science.

As the ES21 Sensors and Dosimeters Subgroup moves forward, the ultimate goal is to enhance precision of exposure assessment for health and ecosystem risk assessments. In the near term, the focus will likely be on the development and evaluation of real-time monitoring tools to improve the precision of spatial and temporal measurements of exposure and internal dose for variety of environmental contaminants. Furthermore, there is strong consensus that there is a near-term need to develop technical guidance/performance specifications for emerging technologies so potential uses for these approaches may be fully realized. In the longer term, issues of big data will need to be considered, as well as the integration of data from these emerging technologies with data from more established and traditional methods.

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 Subgroup will assess current models to determine what refinements may be necessary to make them more effective. The Subgroup 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 2015:

The Modeling Subgroup has expanded participation to include the DoD, EPA, CDC, NIEHS, NOAA, OSHA and USDA. The Subgroup has been working to identify modeling efforts and to coordinate and collaborate where possible. Some examples of the modeling efforts underway include:

- DoD - ERDC Landscape Contaminant Modeling System (ELCMS) - ELCMS defines locations/regions for safe drinking water that require minimal treatment. ELCMS provides secure water through an ability to identify, predict, and assess with statistical confidence the location of unique chemical contaminants within a landscape. With ELCMS, the Army can characterize the water quality within a landscape where operations are planned to enhance the performance of the filtration systems by minimizing use of the poorest quality water and enhance solder confidence in using portable filtration and thus reducing the reliance on bottled water.
- DoD - Eulerian – Lagrangian-Agent-Method (ELAM) – ELAM is an approach developed by ERDC's Environmental Laboratory for analyzing and forecasting the movement and

distribution patterns of individual animals responding to environmental conditions on land and in the water.

- EPA - National Environmental ATLAS (EnviroAtlas)- Merges data from EPA, USGS, NOAA, etc. to provide wall-to-wall geographically explicit data characterizing ecosystem services across the U.S., plus high-resolution analysis for selected communities. Categories of ecosystem services include: clean water for drinking; clean water for recreation and aquatic habitat; adequate water supply; food, fuel and fiber; recreation, cultural and aesthetic amenities; contributions to climate stability; protection from hazardous weather; habitat and the maintenance of biodiversity; and clean air.

- EPA - Cloud computing base knowledge management system - Ubertool is a prototype cloud computing-base knowledge management system to support ecological risk decisions mandated under FIFRA and the Endangered Species Act. The Ubertool dashboard infrastructure integrates the processing of model results for over a dozen commonly-used EPA aquatic and terrestrial regulatory models and supporting datasets.

- CDC - Carbon nanotube (CNT) dosimetry modeling for risk assessment - The purpose of this project is to generate the data needed to develop a human respiratory tract deposition model for CNTs, and to develop the model using these data. This project includes three components: (1) Evaluation of transmission electron microscopy (TEM) methods to determine the airborne size distributions of CNTs in the workplace and laboratory; (2) Measurement of CNT deposition in a human respiratory cast model; and (3) Development of a comprehensive human respiratory tract deposition model for airborne CNTs.

- CDC - Deriving hazard bands to protect emergency responders - The intent of this project is to supplement the Immediately Dangerous to Life and Health (IDLH), Acute Exposure Guideline Values (AEGL), Emergency Response Planning Guidelines (ERPG), and Temporary Emergency Exposure Limits (TEEL) values with a categorical process for identifying the potential toxic effects from a single exposure event, ranging from mild, transient health effects, such as respiratory irritation; to severe and irreversible, such as respiratory corrosivity; to life-threatening effects based on hazard information already published and readily available on safety data sheets, container labels, and REACH (Registration, Evaluation, Authorization and Restriction of Chemical) registration dossiers.

- NIEHS - High Throughput Screening (HTS) Initiative - The goals of the HTS Initiative are to prioritize substances for further in-depth toxicological evaluation, identify mechanisms of action for further investigation (e.g., disease-associated pathways), and develop predictive models for in vivo biological response (predictive toxicology).

- NOAA - HYSPLIT – An atmospheric dispersion model used at NOAA and worldwide for a variety of purposes, from emergency response to long-term ecological assessment. The model is freely available and can be run on the web or downloaded and installed to run locally (via a built-in Graphical User Interface, the command line, and/or scripts).

- NOAA - HAB Forecasting - NOAA's Harmful Algal Bloom Operational Forecast System (HAB-OFS) provides information and operational forecasts regarding the potential development, intensification, transport and associated impacts of Karenia brevis blooms in the Gulf of Mexico.

The Modeling Subgroup has also developed a number of webinars to better explain the current state of modeling work in the federal government.

- Screening Level Modeling of Contaminant Fate/Transport and Exposure – U.S. Army Corps of Engineers – April 16, 2015

Screening level models, or models of reduced form, can provide invaluable information regarding contaminant movement and exposure concentrations within multimedia environmental systems, and such applications can be performed relatively quick with low cost. This webinar provided an overview of screening level models and modeling systems developed through the U.S. Army Engineer Research and Development Center as well as a discussion of their uses, performance, and benefits.

- HYSPLIT Atmospheric Modeling System – NOAA – August 13, 2015

The HYSPLIT atmospheric modeling system (and its precursors) has been under continual development at the NOAA Air Resources Laboratory since the 1940's. It is used at NOAA and worldwide for a variety of purposes, from emergency response to long-term ecological assessment. The model is freely available and can be run on the web or downloaded and installed to run locally (via a built-in Graphical User Interface, the command line, and/or scripts). The model can be run on Windows, Mac, or Linux-based platforms. In this webinar, the capabilities and features of the model were summarized, along with examples of its usage at NOAA and by others.

Data Management: Vasu Kilaru (EPA / ORD)

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 2015:

The Data Management Subgroup has been working collaboratively with the other subgroups to identify best practices for sharing data across the Federal government. Partners in the subgroup include representation from the Department of Defense, Environmental Protection Agency, Center for Disease Control and Prevention, National Institute of Environmental Health Sciences, National Oceanic and Atmospheric Administration, Occupational Safety and Health Administration and the U.S. Department of Agriculture.

Examples of Exposure Data Sources identified for sharing include:

- DoD - Adaptive Risk Assessment Modeling System (ARAMS) - ARAMS incorporates various existing databases and models for exposure, intake/update, and effects (health impacts) into an object-oriented, conceptual site modeling framework.

- EPA - National Environmental ATLAS (EnviroAtlas) - Merges data from EPA, USGS, NOAA, etc. to provide wall-to-wall geographically explicit data characterizing ecosystem services across the U.S. plus high-resolution analysis for selected communities. Categories of ecosystem services include: clean water for drinking; clean water for recreation and aquatic habitat; adequate water supply; food, fuel and fiber; recreation, cultural and aesthetic amenities; contributions to climate stability; protection from hazardous weather; habitat and the maintenance of biodiversity; and clean air.
- CDC - Occupational exposures sampling strategies manual update - This project aims to develop occupational exposure sampling strategy guidance appropriate for the evaluation and control of a variety of occupational exposure agents.
- NIEHS - National Toxicology Program (NTP) - The NTP is a federal interagency program headquartered at NIEHS. Its goal is to develop and apply tools of modern toxicology and molecular biology to identify substances in the environment that may affect human health.
- NOAA - HYSPLIT – Is an atmospheric dispersion model used at NOAA and worldwide for a variety of purposes, from emergency response to long-term ecological assessment. The model is freely available and can be run on the web or downloaded and installed to run locally (via a built-in Graphical User Interface, the command line, and/or scripts).

A complete listing of all identified data sources can be found in Appendix C.

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

Charter

The Community Engagement/Citizen Science Subgroup 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 key for success. The Subgroup will assess ongoing strategies to determine what refinements may be necessary to make them more effective. The Subgroup 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

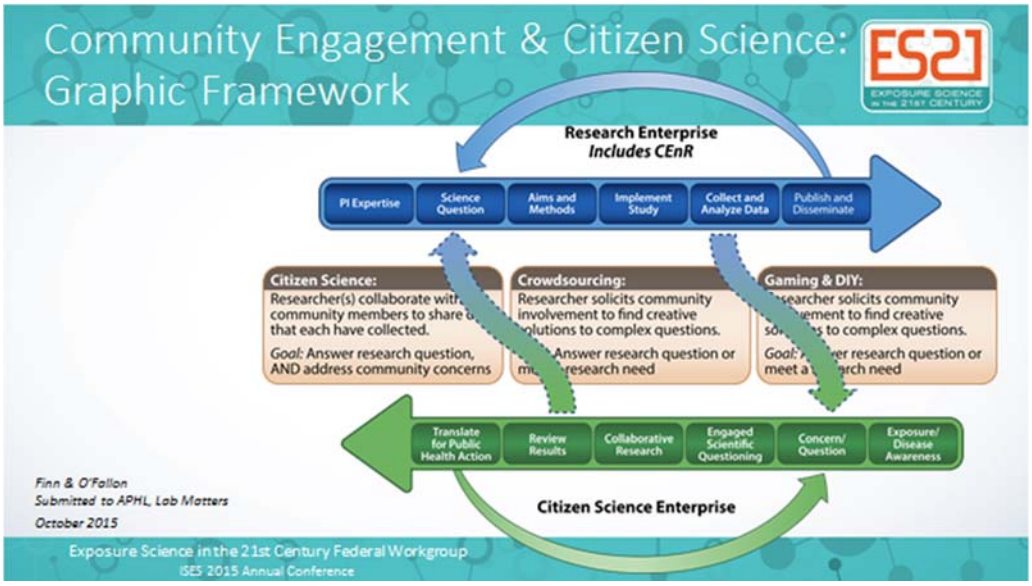
New challenges and new scientific advances mean that an expanded, integrated vision of exposure science—one that considers exposures from source to dose, over time and space, to multiple stressors, and from the molecular to ecosystem level— is now needed. This vision, dubbed "the eco-exposome," is defined 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 for 2015

The Community Engagement / Citizen Science Subgroup has been working to create a more coordinated approach to sharing best practices and to expand opportunities to leverage ongoing efforts. In 2015 work focused on:

- Sharing of programmatic efforts
- Informing new and existing efforts
    - EPA Citizen Science Training
    - NIEHS PEPH webinars & podcasts
    - Glossary of terms
- Outlining plan for future
    - Identifying areas for coordination with other groups
    - Developing coordinated sessions at professional conferences
- Planning 2016 meeting focused on interface of citizen science & community-engaged Research
- Inventory of Federal Programs
- Federal Crowdsourcing and Citizen Science Community of Practice (CCS)
- Developed database of projects and a practitioner's toolkit. https://crowdsourcing-toolkit.sites.usa.gov

- Developed a framework for Community Engagement



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); Toxics 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:

a. 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.

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

c. 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. ES2l 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;
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. ES2l 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

ES2l, 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[1] 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. ES2l 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.

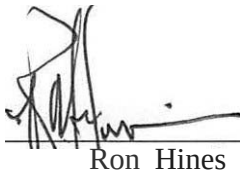
F. Termination

Unless renewed by the Co-chairs of the T&R Subcommittee prior to its expiration, ES2l shall terminate no later than May 21, 2016.

G. Determination

I hereby determine that establishment of the Working Group on Exposure Science for the 21st Century (ES2l) 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:



Ron Hines Environmental Protection Agency
(Co-chair, CENRS Toxics and Risk Subcommittee)

Date

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

21 MAY 2015

Date

Chris Weiss Department of Health and Human Services
(Co-chair, CENRS Toxics and Risk Subcommittee)

21 May 2015

Date

Appendix B

Member Organizations

Centers for Disease Control and Prevention
- -- Agency for Toxic Substances and Disease Registry
- -- National Center for Environmental Health
- -- National Institute for Occupational Safety and Health

Consumer Product Safety Commission

Department of Agriculture
- -- Agricultural Research Service
- -- Food Safety and Inspection Service
- -- National Institute of Food and Agriculture

Department of Defense
- -- Air Force Civil Engineer Center
- -- Army Sustainment Command
- -- U.S. Army Corp of Engineers
- -- Force Health Protection & Readiness
- -- Navy Marine Corps Public Health Center

Department of Energy

Department of Homeland Security

Environmental Protection Agency
- -- Office of Air and Radiation
- -- Office of Chemical Safety and Pollution Prevention
- -- Office of Research and Development

Food and Drug Administration

National Aeronautics and Space Administration

National Institutes of Health
- -- National Cancer Institute
- -- National Institute of Environmental Health Sciences

National Institute of Standards and Technology

National Oceanic and Atmospheric Administration

Occupational Safety and Health Administration

Office of Management and Budget

U.S. Geological Survey

White House Office of Science and Technology Policy

Department of Defense:

Adaptive Risk Assessment Modeling System (ARAMS) - ARAMS incorporates various existing databases and models for exposure, intake/update, and effects (health impacts) into an object-oriented, conceptual site modeling framework. The user has the flexibility to visually specify, through objects, multimedia pathways and risk scenarios. Also, the user can choose which particular module (i.e., model, database) to use for each object.

Training Range Environmental Evaluation and Characterization System (TREECS) - The objective was to develop a client-based, modeling, data delivery, and analysis system that integrates range munitions usage with multimedia and multi-pathway fate/transport modeling to forecast range soil MC concentrations and MC mass export to off-range surface water and groundwater, as well as MC concentrations in surface water, sediment, and groundwater at potential receptor locations.

ERDC Landscape Contaminant Modeling System (**ELCMS) -** ELCMS defines locations/regions for safe drinking water that require minimal treatment. ELCMS provides secure water through an ability to identify, predict, and assess with statistical confidence the location of unique chemical contaminants within a landscape. With ELCMS, the Army can characterize the water quality within a landscape where operations are planned; this would serve to enhance the performance of the filtration systems by minimizing use of the poorest quality water and enhance solder confidence in using portable filtration and thus reducing the reliance on bottled water.

Computational Chemistry - The purpose is to predict environmental fate and transport of Munitions Constituents (MCs) and Emerging Contaminants (ECs) on simple surfaces in terms of adsorption properties, partition coefficients, diffusion coefficients, and surface reactivity.

Toxicology and Physiology

- Environmental Genomics & Systems Biology: The goal is to improve our understanding of exposure and toxicity of Army compound all stages of the technology life-cycle to minimize impacts on operations and the soldier. The approach is to use genomics, systems toxicology and Adverse Outcome Pathways (AOPs) to evaluate effects that result from Munitions exposure. This information is critical for establishing the hazard and risk of these and emerging chemicals to soldiers and the environment.
- Computational Biology: The goal is to develop dynamic mechanistic mathematical models to understand and predict behaviors of animals exposed to chemical stressors and predict adverse outcomes and effects (e.g. toxicity, death, reproductive problems)

Eulerian – Lagrangian-Agent-Method (ELAM) – ELAM is an approach developed by ERDC's Environmental Laboratory for analyzing and forecasting the movement and distribution

patterns of individual animals responding to environmental conditions on land and in the water.

Environmental Protection Agency

National Environmental ATLAS - Merges data from EPA, USGS, NOAA, etc. to provide wall-to-wall geographically explicit data characterizing ecosystem services across the U.S. plus high-resolution analysis for selected communities. Categories of ecosystem services include: clean water for drinking; clean water for recreation and aquatic habitat; adequate water supply; food, fuel and fiber; recreation, cultural and aesthetic amenities; contributions to climate stability; protection from hazardous weather; habitat and the maintenance of biodiversity; and clean air.

Remote Sensing Information Gateway (RSIG) – RSIG provides multi-terabyte, environmental datasets (i.e., NASA's MODIS, EPA CMAQ, NEDIS biomass burning measurement, EPA AirNow and AQS) via an interactive, Web browser and overlays them on a map of the selected region, automatically aligning information from various spatial and temporal scales into a unified visualization.

DownScaler Model – Uses Bayesian fusion to calculate daily ozone (8-hr max) and fine particulate air (24-hr average) concentration surfaces across the US starting in 2001. Data are available as part of CDC's National Environmental Public Health Tracking Network — a web portal for public and professionals to track how the environment affects public health and how people affect the health of the environment (ephtracking.cdc.gov).

IGEMS/CSM model - Includes capabilities to upload and geographically display monitoring data, and can be coupled with modeled estimates.

Microtrac Personal Activity Model - Uses GPS data on location and speed to estimate the time people spend in various "microenvironments" such as inside and outside their home, school, workplace, and motor vehicle. Using MicroTrac with personal GPS devices, accelerometers, and health monitors in exposure and health effects studies will allow scientists to link the location and activities of study participants with air pollution measurements and measures of health effects during a study.

Climate Multi-scale Air Quality Model - Multiscale system used for air quality management that is capable of addressing complex air pollution issues including photochemical ozone, particulate matter, air toxics, acid deposition and nutrient deposition. Develops concentrations at a 4 to 12 km grid resolution across the US every hour. Provides visualization of air quality surfaces. Currently is running continuously.

SHEDS and SHEDS-Lite – Both models integrated source-exposure-dose modeling components to provide low-to-high tier predictions of chemical exposure. Models have the ability to develop time course exposure from minutes to days for multiple chemicals by multiple pathways. Models also provide variability and sensitivity analysis of outputs.

Physiological and Anatomical Visual Analytics (PAVA) - PAVA is a web-based visual analytics tool to support the development, validation, and communication of physiologically

annotated data (PAD) that lets users import and combine results from multiple physiologically-based pharmacokinetic (PBPK) models to visualize tissue dosimetry levels.

Physiologically Relevant Parameter Estimation (PReParE) - PReParE estimates physicochemical and biochemical parameter values used in dosimetry models

Cloud computing base knowledge management system - Ubertool is a prototype cloud computing-base knowledge management system to support ecological risk decisions mandated under FIFRA and the Endangered Species Act. The "Ubertool" dashboard infrastructure integrates the processing of model results for over a dozen commonly-used EPA aquatic and terrestrial regulatory models and supporting datasets.

Community- (Tribal-) Focused Exposure and Risk Screening Tool (C-FERST/T-FERST)- Community mapping, information access, and assessment tool. C-FERST and T-FERST are expected to increase the availability and accessibility of science for risk ranking and understanding the environmental health consequences of community based decisions. It incorporates the latest research estimating human exposures to toxic substances in the environment. Designed to assist communities and Tribes with the challenge of identifying and prioritizing environmental health issues and potential actions.

BenMAP - A computer program that uses a Geographic Information System (GIS)-based database to estimate the health impacts and economic benefits occurring when populations experience changes in air quality, can be used to identify more effective approaches for implementation of National Ambient Air Quality Standards (NAAQS).

Center for Disease Control and Prevention

Occupational exposures sampling strategies manual update - This project aims to develop occupational exposure sampling strategy guidance appropriate for the evaluation and control of a variety of occupational exposure agents.

Supplementing Recommended Exposure Levels (RELs) with health hazard bands - A hazard banding approach may be the most appropriate way to define RELs for families of materials where the data or resources are too limited to allow for a comprehensive and conclusive assessment of risk.

Carbon nanotube (CNT) dosimetry modeling for risk assessment - The purpose of this project is to generate the data needed to develop a human respiratory tract deposition model for CNTs, and to develop the model using these data. This project includes three components: (1) Evaluation of transmission electron microscopy (TEM) methods to determine the airborne size distributions of CNTs in the workplace and laboratory; (2) Measurement of CNT deposition in a human respiratory cast model; and (3) Development of a comprehensive human respiratory tract deposition model for airborne CNTs.

Deriving hazard bands to protect emergency responders - The intent of this project is to supplement the Immediately Dangerous to Life and Health (IDLH), Acute Exposure Guideline Values (AEGL), Emergency Response Planning Guidelines (ERPG), and Temporary Emergency Exposure Limits (TEEL) values with a categorical process for identifying the potential toxic effects from a single exposure event, ranging from mild, transient health effects, such as respiratory irritation; to severe and irreversible, such as respiratory

corrosivity; to life-threatening effects based on hazard information already published and readily available on safety data sheets, container labels, and REACH (Registration, Evaluation, Authorization and Restriction of Chemical) registration dossiers.

Methods to develop OELs for nanomaterials - The purpose of this project is to develop and implement an evidence-based strategy to develop recommended occupational exposure limits (OELs) or occupational exposure bands (OEBs) for nanomaterials.

National Institute of Environmental Health Sciences

National Toxicology Program (NTP) - The NTP is a federal interagency program headquartered at NIEHS. Its goal is to develop and apply tools of modern toxicology and molecular biology to identify substances in the environment that may affect human health.

Interagency Coordinating Committee on the Validation of Alternative Methods (ICCVAM) - ICCVAM's mission is to facilitate development, validation, and regulatory acceptance of new and revised regulatory test methods that reduce, refine, and replace the use of animals in testing while maintaining and promoting scientific quality and the protection of human health, animal health, and the environment.

High Throughput Screening (HTS) Initiative - The goals of the HTS Initiative are to prioritize substances for further in-depth toxicological evaluation, identify mechanisms of action for further investigation (e.g., disease-associated pathways), and develop predictive models for *in vivo* biological response (predictive toxicology).

National Oceanic and Atmospheric Administration

HYSPLIT – Is an atmospheric dispersion model used at NOAA and worldwide for a variety of purposes, from emergency response to long-term ecological assessment. The model is freely available and can be run on the web or downloaded and installed to run locally (via a built-in Graphical User Interface, the command line, and/or scripts).

Real-time Environmental Applications and Display sYstem (READY) - READY is a world-wide-web based system that has been developed for accessing and displaying meteorological data and running trajectory and dispersion model products on ARL's web server. This system brings together dispersion models, graphical display programs and textual forecast programs generated over many years at ARL into a form that is easy to use by anyone.

Atmospheric Mercury Modeling - HYSPLIT-Hg model tracks mercury emission sources and links these emissions to atmospheric transport, transformation, and deposition.

Atmospheric Dioxin Modeling - HYSPLIT-SV (Semi-Volatile) is a special version of the HYSPLIT model that simulates the atmospheric fate and transport of semi-volatile air pollutants.

HAB Forecasting - NOAA's Harmful Algal Bloom Operational Forecast System (HAB-OFS) provides information and operational forecasts regarding the potential development, intensification, transport and associated impacts of Karenia brevis blooms in the Gulf of Mexico.

ES21 Collaboration Efforts

Title	Partners	Time Frame	Description
DISCOVER AQ (Deriving Information on Surface conditions from Column and VERtically resolved observations relevant to Air Quality)	EPA, NASA, NOAA, and state organizations	2011 - 2015	NASA developed a series of four field campaigns to collect 3-D air quality data that could be used to better understand emission, chemistry and meteorological processes governing near-surface pollution levels in a variety of different urban airsheds. The collaborations resulted in deployment of successful observational systems for all four field campaigns. EPA provided an extensive ground-based instrument network to provide the critical "ground-truth" for the aircraft, sondes, and satellite-based measurements. The DISCOVER AQ campaigns also provided the opportunity to evaluate Federal Regulatory Methods (FRM) and Federal Equivalency Methods (FEM) used to ascertain compliance for the National Ambient Air Quality Standards (NAAQS) under real-world conditions. New innovative new technologies were also evaluated, such as small sensors, remote sensing spectrometers and satellites for monitoring ambient air pollution. Citizen science activities engaged school children in the collection of air pollutant data using handheld sensor devices.
U.S. GeoPlatform	Federal Agencies, State & local & Tribal governments, non-profit organizations, academic institutions, industry, citizens	Current	The U.S. GeoPlatform (http://www.geoplatform.gov/overview-page) effort provides shared and trusted geospatial data, services, and applications for use by the public and by government agencies and partners to meet their mission needs. Through the GeoPlatform, users have access to a one-stop shop to deliver trusted, nationally consistent data and services. The GeoPlatform also provides authoritative data to support informed decision making, problem-solving applications / services, shared infrastructure to host data and applications, and a national focal point where governmental, academic, private, and public data and applications can be visualized together to inform and address national and regional issues.
Pilot Study of Exposure to Chemicals in	NIEHS, EPA	Ongoing	The study will help researchers develop and evaluate tools and techniques for assessing the multitude of chemicals people are exposed to every day. Personal

Consumer Products: An NIEHS/EPA Collaborative Methods Demonstration and Evaluation			care products are of interest because of the efficiency of their delivery. Phthalates, parabens and triclosan have endocrine disrupting potential and are common ingredients in PCPs. The primary objectives of the study are to evaluate predictive models of chemical exposure as well as demonstrate and evaluate novel methods for chemical exposure measurements. EPA scientists will focus on how well the high-throughput chemical exposure models, parameters and components predict chemical environmental concentrations and exposures. NIEHS will investigate how effectively exposure to chemicals in consumer products and food packaging can be classified by comparing questionnaires and daily diaries with body-burden measurements. http://ntp.niehs.nih.gov/ntp/about_ntp/bsc/2014/june/ohat_epa_collaborative_508.pdf
Regional Hubs for Risk Adaptation and Mitigation to Climate Change	USDA, NOAA, DOI	Ongoing	The Climate Hubs were established in February of 2014 to deliver science-based knowledge, practical information and program support to farmers, ranchers, forest landowners, and resource managers to support climate-informed decision-making in light of the increased risks and vulnerabilities associated with a changing climate. These activities further the mission of maintaining and strengthening agricultural production, natural resource management, and rural economic development under increasing climate variability. Key partners in this effort include the public and land grant universities, Cooperative Extension, USDA researchers, the private sector, state, local and regional governments, the National Oceanic and Atmospheric Administration (NOAA), Department of Interior (DOI) regional climate change experts, and non-profits engaged in providing assistance to landowners. http://climatehubs.oce.usda.gov/
CyAN (Cyanobacteria Assessment Network)	EPA, NASA, NOAA, USGS	Ongoing	This collaborative effort integrates the efforts of the U.S. Environmental Protection Agency (EPA), *National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration* (NOAA), and U.S. Geological Survey (USGS) to provide an approach for mainstreaming satellite ocean color capabilities into U.S. fresh and brackish water quality management decisions. The overarching project goal is to support the environmental management and public use of U.S. lakes, reservoirs, and estuaries by providing the capability to detect and quantify cyanobacteria blooms using satellite data records.

			The four Federal agencies are participating in the project to (1) develop a uniform and systematic approach for identifying cyanobacteria blooms using ocean color satellites across the contiguous United States; (2) create a strategy for evaluation and refinement of algorithms across satellite platforms; (3) identify landscape linkage postulated causes of chlorophyll-a and cyanobacteria blooms in freshwater systems; (4) characterize exposure and human health effects using ocean color satellites in drinking water sources and recreational waters; (5) characterize behavioral responses and economic value of the early warning system using ocean color satellites and mobile dissemination platform; and (6) disseminate satellite data through an Android mobile application and EnviroAtlas. We anticipate that the use of uniform satellite data products will improve the decision-making ability of managers. In addition, satellite data products may augment federal, state, tribal, and municipal monitoring and research efforts. At the conclusion of this project, there should be an increase in the applied use of remotely sensed water quality data for water quality management. The use of this technology has tremendous potential owing to the temporal and spatial coverage of the imagery and the current lack of data available for many systems. Using satellite data to monitor and report blooms throughout a region or state would provide a novel robust tool and assist in holistic management of events that may involve significant risk to the public. Ultimately this project will reduce resource needs and potential exposures of the public.
The DoD Serum Repository	DoD, NIEHS	Ongoing	The DoD Serum Repository is among the largest collections of biological samples in the world. It contains more than 55 million frozen, archived serum specimens collected primarily from applicants to and members of the United States Uniformed Services with additional samples collected on individuals before, after, and occasionally during deployment experiences. The Armed Forces Health Surveillance Center maintains the repository for medical surveillance purposes. The specimens are carefully linked to demographic, occupational, deployment history, medical visits, and immunizations information via the Defense Medical Surveillance System. DoD, with additional support from NIEHS, has partnered with researchers at Emory University and the University of Rochester to integrate traditional exposure data (ambient monitoring, occupational and industrial hygiene assessments) with novel

			assessments of metabolomics signatures of exposure and response as well as inflammatory and allergic response biomarkers resulting from a series of well-defined exposure situations. Pre-, during, and post-deployment serum specimens are being examined for 1) biomarkers of oxidative stress and inflammatory disease processes, cardiovascular risk, and pollutant inhalation using multiplex cytokine analysis; 2) MicroRNA biomarkers of inflammatory disease processes; and 3) Immunoglobulin E (IgE) antibodies as a sentinel signal of allergy and asthma. These tests will allow analysis of effects associated with deployment specific exposure events, the theater of deployment, as well as independent effects on serum biomarkers of disease risk. This collaboration allowed DoD and NIEHS to obtain valuable data on exposures and health outcomes using the same resources.
Collaborative Strategy on Bed Bugs	CDC, EPA, USDA, DoD	2015	The Collaborative Strategy on Bed Bugs was developed to clarify the federal role in bed bug control and highlight ways that all levels of government, community, academia and private industry can work together to reduce bed bugs across the United States. Controlling bed bugs can be very costly and nearly all communities and states are currently facing resource limitations. Collaborating and sharing training programs, communication materials or treatment plans will conserve resources and may also lead to higher quality outputs by providing new opportunities for improvement. The strategy outlines four priority areas for bed bug control (Prevention, Surveillance and Integrated Pest Management [IPM], Education and Communication, and Research). Each of these areas is critical to national efforts. http://www2.epa.gov/sites/production/files/2015-02/documents/fed-strategy-bedbug-2015.pdf
Federal Coordination of Sensor Technology SBIR Investments	DOD, DOE, EPA, NASA, NIEHS,NIOSH, NOAA, USACE, USDA	FY 2016 and on-going	**Background:** Federal partners have ongoing SBIR programs that have included requests for proposals related to monitoring, including sensor technology. However, these requests have not been coordinated in the past and the overall federal investment has not been captured, nor has there been a consistent federal wide message about the interest in and utility of sensor technology. **Coordination Goals** • Articulate a common need and interest for sensor technology development, evaluation, and application across the federal government. • Identify the federal commitment to sensor technology research and quantify federal SBIR investment. • Avoid duplicative investments & Identify complementary investments.