
THE U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
CENTERS FOR DISEASE CONTROL AND PREVENTION

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND
HEALTH

BOARD OF SCIENTIFIC COUNSELORS (BSC)

EIGHTY-FIRST MEETING

APRIL 21, 2023

Table of Contents

| | |
|---|----|
| Summary Proceedings | 2 |
| Attendees..... | 2 |
| Welcome and Meeting Logistics..... | 3 |
| Agenda | 3 |
| Director’s Opening Remarks | 3 |
| PFAS Overview | 9 |
| PFAS Research Studies and Future Direction..... | 17 |
| Public Comment..... | 31 |
| OSH Economics | 31 |
| Summary and Wrap-Up, Future Agenda, Meeting Dates, Closing Remarks..... | 43 |
| Glossary..... | 45 |
| Certification Statement..... | 47 |

Summary Proceedings

The eighty-first meeting of the National Institute for Occupational Safety and Health Board of Scientific Counselors (BSC) was convened on April 21, 2023 via Zoom. The BSC met in open session in accordance with the Privacy Act and the Federal Advisory Committee Act (FACA).

Attendees

LAUREN BARTON, MD - MEMBER

MIRIAM CALKINS, PhD

LOUIS A. COX, PhD - MEMBER

ENJOLI DEGRASSE - MEMBER

CRISTINA DEMIAN, MD - MEMBER

MICHAEL FOLEY - MEMBER

RUTH FRANCIS - MEMBER

JESSICA GRAHAM, PhD - MEMBER

JOHN HOWARD, MD - DIRECTOR

GRACE LEMASTERS, PhD - MEMBER

SUSAN MOORE, PhD

PATRICK MORRISON - MEMBER

KIMBERLY OLSZEWSKI, DNP - MEMBER

RENE PANA-CRYAN, PhD

KETKI PATEL, PhD - MEMBER

LUIS PIERETTI, PhD - MEMBER

TIINA REPONEN, PhD - CHAIR

ROBERT ROY, PhD - MEMBER

MARIA STRICKLAND - DFO

Welcome and Meeting Logistics

Ms. Strickland called to order the open session of the eightieth meeting of the NIOSH BSC at 10:00 a.m. Eastern Time (ET) on Friday, April 21, 2023. A roll call of all BSC members confirmed that a quorum was present. The roll was also called following the break to ensure that quorum was maintained. Quorum was maintained throughout the day. No conflicts of interest were declared. Members of the public were notified that they would remain in listen only mode until the public comment period.

Agenda

Dr. Reponen welcomed everyone and summarized the agenda of the meeting. She reminded the group there are specific questions to consider for the presentations:

1. Director's Opening Remarks
2. Per- and polyfluoroalkyl substances (PFAS)
3. Public Comments
4. Occupational Safety and Health Economics

Director's Opening Remarks

Dr. Howard thanked the members who extended their service 180 days to attend the Spring meeting. He updated that here in Washington D.C. we have a new location. We moved from Patriots Plaza, we used to have our in-person meetings a long time ago it seems, pre-pandemic, back in 2019. But we're now in a new location called the Constitution Center. For those of you that know Washington well, it's the former home of the Department of Transportation that moved to the Navy Yard next to the Nats' stadium back in 2006. The building was completely redone and now is renamed the Constitution Center. The primary agency that moved in were Treasury Department agencies. The biggest tenant in the building is the Office of the Comptroller of the Currency. OCC is the biggest tenant. But recently, some other Treasury agencies moved out and there was room that the Department of Health and Human Services was offered, and the new administration called ASPR for preparedness and response moved in about 1,000 people and consolidated a lot of their offices across Washington, and CDC was offered some space in the building also. And so we took it, and now the NIOSH Washington D.C. headquarters is in the Constitution Center at 400 7th Street here in Washington, very close to the new area called the Washington D.C. Wharf area. Not too far from Patriots Plaza, only a couple of blocks, our building is actually on top of the L'Enfant Plaza Metro Station.

We have a really nice conference room here that we hope to use regularly. I believe that even one of the subcommittees of the BSC is planning to meet here in person soon. We hope to be able to have our BSC meetings in our headquarters here at the Constitution Center not in the too-distant future.

Dr. Howard noted that we do have a budget; the President did sign the FY 2023 Omnibus Appropriations spending bill. And this was good news for us. Our budget increased to \$362.8 million, which is \$11 million

over FY 2022. So that's always a good year when we have that. Even remaining somewhat flat is a good year even though there are unfunded mandates that we have to fund. But this year, we are very positive.

We received a \$1.5 million increase for the Ag, Forestry and Fishing program, which is entirely extramural, with 11 centers. A \$1 million for the ERCs, which are 18, across the United States. \$2.5 million more for the Firefighter Cancer Registry, and I want to thank Pat Morrison and the entire subcommittee, again, for their strong work in this area. To be able to have that kind of an increase shows the importance that the Congress attaches to firefighter health in general, and cancer specifically. A \$1 million increase in Personal Protective Technologies, which certainly helps our National Personal Protective Technology Laboratory in Pittsburgh. A \$1 million increase in Total Worker Health. We have multiple centers in that area, and it seems to be a very incentivized program for appropriators because they see that many of the issues confronting the American workforce that don't fit into NIOSH's 52-year traditional history of chemical hazards, physical hazards like asbestos, biological hazards, fit very nicely under the Total Worker Health program—issues that are psychosocial in nature, that have to do with the organization of work, that have to do with substance use in the workplace, whether it be opioids, stimulants or cannabis, there are issues related to worker health and safety. And then we received \$4 million for the Mining Program, which we are always happy to support, a very important part. We don't discuss it here in the BSC because there is another FACA—Federal Advisory Committee—that discusses the Mining Program.

I might also add that we don't discuss here in the Board of Scientific Counselors the World Trade Center Health Program, which is a healthcare program that we operate. They have their own FACA. We received an additional \$1 billion for that program for patient care activities.

He continued that the FY '24 budget is coming up and on March 9, the President released his budget and we received some good news in the sense that it was flat—flat given the previous increase in FY '23. Obviously, we would hope, always hope, for a little increase to cover the promotions that we do for our program, and other unfunded mandates. But we can't complain. At least it's not a reduction. No cuts are proposed for the NIOSH intramural/extramural program which the last four or five years we've seen that increase. We have to absorb within our budget the 5.2[%] pay increase for federal civil—this is one of those unfunded mandates that I speak of.

Dr. Howard transitioned to organizational changes including that he is very happy to announce that our Associate Director for Science, John Piacentino, was appointed to NIOSH Deputy Director for Program, replacing Margaret Kitt, who retired. John assumes his new duties as Deputy on January 1. But, since we do not have a replacement for his job as Associate Director for Science, John is very graciously performing both jobs until a new ADS is selected, and we hope that is not too far in the future, so John doesn't have to do two jobs.

Frank Hearl, our longstanding Chief of Staff at NIOSH, retired the end of the year. Very happy that Maria Strickland has stepped in as our Acting Chief of Staff, and we are recruiting for a new Chief of Staff, and hope to have one appointed soon.

Dr. Howard also noted a couple of retirements. R.J. Matetic, long time in the Mining Program, who headed our manufacturing sector, did a swell job there, also retired at the end of the year; as well as Dori Reissman, who had been at NIOSH for many years and last served as Associate Administrator of the World Trade Center Health Program. She retired on March 1. I'm very happy that Commander Brittany Rizek has stepped in in her role. And also, on very sad news, Dr. Jessica Kogel, who was our NIOSH Associate Director of Mining, retired in December of '22 and she passed away the next month, in January of 2023.

Dr. Howard then covered a few of the issues starting with under the Emergency Response section, really some great information here that's been provided by Captain Lisa Delaney and her team. As you all know, the Public Health Emergency is ending on May 11 of this year, just a couple of weeks away. Our activities have really been dialed back for many months now, and CDC is beginning to dial back their COVID-19. Of course we are still seeing COVID-19, we are still seeing fatalities, primarily in the quite elderly or the unvaccinated. CDC has now recommended that people who are aged 65 or greater, or are immunocompromised due to a medical condition, are eligible for yet another booster of the bivalent vaccine, which came out last fall.

Our major effort at NIOSH is getting our ventilation materials web page up, and we're really happy that we've received lots of support from the White House. When we started in the pandemic era of late '19 and early '20 all the way into 2021, ventilation was really not a major topic, and we're really delighted that attention is now focused on that by a number of federal agencies and the White House, and we're very happy to serve as technical experts in that area. As you know, the federal health emergency changes a lot of things, and I think we're still going to be dealing with that as we go through the months, especially with regard to CMS benefits—the Centers for Medicare and Medicaid Services.

I will point out one emergency response that we were involved in. In East Palestine, Ohio, a train derailment, quite a massive one, with an attendant fire, and unfortunately the tank cars were filled with a known carcinogen, vinyl chloride, which there is an OSHA reg even, even though OSHA does not have jurisdiction over the active train movement and the employees that are on it. Once the train stops though, there is jurisdiction, and OSHA—through their Cleveland office—has been involved.

We also were involved, at NIOSH, joining CDC-ATSDR in a response. ATSDR attention was focused on the population of East Palestine, and our folks were focused on the cleanup workers, the contractors, and others during that particular episode. So I definitely want to thank our folks for their strong work in that area.

Dr. Howard then discussed the Respiratory Health Division (RHD) response in a location in Michigan of a paper mill. Billerud Corporation, which is a Swedish corporation, headquartered in Sweden, has a plant near Midland, Michigan, and there has been a significant outbreak of blastomycosis. It is a fungus, similar to coccidioidomycosis and histoplasma and others that are very common. In the case of blastomycosis, another sort of environmental hazard in vegetative material, along riverbanks and in soil, it's now affected this paper mill, such that about 19 to 20 folks have symptomatic blastomycosis. One contractor of the plant has died attributed to blastomycosis, and we have about 70 or 80, at last count, cases of individuals who—not symptomatic—but who have tested positive. They're confirmed cases in that respect.

Dr. Howard continued that we are at the site now. The employer has idled the plant—not shut it down but idled it—doing a thorough cleaning, changing all the ventilation systems, of which there are many in this plant. This plant is many acres large. It's a very large plant with 850 workers. What we're doing is collecting urine samples on all those 800 folks, looking for a positive antigen test, which will help us decide how many people have been exposed, and filling out questionnaires in terms of symptomatology, etc. It's a big project and I'm sure that we're going to be there for a while. It's kind of a mystery right now as to why folks in this plant have developed blastomycoses. We've checked in the community; there's no community cases. We've even checked among veterinarians who take care of dogs who are used in hunting and their nose is right next to the ground. Veterinarians have reported no cases of blastomycosis in the dogs. We're still trying to figure this out, and very interesting mystery right now.

It's one of the rare opportunities that NIOSH has to actually do disease detection work of the ID nature, the infectious disease nature. We are having folks from the CDC's Mycotics Branch that are experts in fungus join us in this particular investigation. He then turned it back to Dr. Reponen.

Dr. Reponen thanked Dr. Howard for your update and the very thorough written document. Congratulations, first of all, for the new location. We look forward to being there in the fall. And also, great news about the increased budget, and also President's budget—as long as I remember, always the NIOSH budget was cut in President's budget so this is the first time that I remember in fifteen years or so maybe. She opened it to the Board for questions.

Dr. Roy said he is a big fan of the NIOSH ERCs and have been in the Midwest, in Minnesota for a number of years. He asked how is the overall health of the ERC program?

Dr. Howard said he thinks it's good. I'm not an ERC representative so maybe somebody on the Board who works at ERC may want to comment. They do very well on appropriations every year. All I can say is the ERCs are productive. They do excellent training. They're producing lots of great research.

Dr. Reponen said she used to be the Director of the Cincinnati ERC but I've stepped down from that, so I don't know exactly this year how it's doing but I agree with Dr. Howard, said that it's overall, it's very good. I think there is a good amount of trainees and also good research done by faculty and trainees, very well-connected. I think they keep in touch with each other. There is a meeting at least once a month with all the ERCs to talk about the issues that are common issues. Our ERC just had a symposium in Michigan where Michigan, Kentucky, Ohio, and Illinois had a regional symposium.

Dr. Howard mentioned that the federal government has acquired a large tract of land right next door to the University of Cincinnati Medical Centers, and we are in the process of developing an architectural plan for a new building. It's a campus consolidation. Currently, we're in two locations in Cincinnati. So that's something that maybe by the fall meeting, we'll be able to announce that we're on board there. There's one little sliver of property that the City of Cincinnati owns that we need to finalize, but we have architectural drawings and we're just really excited to be that close to the Cincinnati ERC folks and the Med Center there.

Dr. Lemasters said we can't wait till NIOSH gets closer because a lot of us drive back and forth to one of your buildings a lot of the time. It will promote a lot more interactions and intercommunication.

Dr. Reponen had a question about a draft plan for strategy to address respiratory protection for the public, and the Board members might remember that a year ago, last Spring meeting, we reviewed the National Academies' report and there was like several questions about who should take care of the public, the respiratory protection for public, and some discussion was what role NIOSH should or could take on this. So can you give any insights on what's the current thinking of NIOSH on this strategy?

Dr. Howard said we do have a follow-up to the National Academy review and you will hopefully see pretty soon in a Federal Register Notice, where we're going to ask for comments on a white paper that will lay out what we think the strategies should be for developing respiratory protection against inhalational hazards for the general public. And it's no surprise we went through the last three and a half years in a bit of a muddle when it comes to how the public should be protected vis-à-vis workers that are under an OSHA respiratory protection standard or workers in general who are not under a standard but they're workers. Now we're talking about the general public. We've briefed the CDC Director, who is very supportive of this, and we're now working with ASPR, the Administration for Preparedness and Response, to be able to work with them, who we think may be the best to be able to sort of have the umbrella agency with us. We certainly are the technical experts, our NPPTL colleagues are, and we believe that we, with ASPR, would be happy to lead this effort. It's all within HHS because the other player in the respiratory protections, especially for healthcare workers with the surgical N95, is FDA, while all of us are in the same department, and indeed the National Academy recommended that HHS should take the lead in collaboration with DoL. We're putting the finishing touches on the white paper. And then we hope to be able to socialize it through a Federal Register Notice Request for Information and get lots of comments on it. So we're very excited about that.

Dr. Howard read the chat with the question "When will NIOSH Michigan release its findings?" Yes, you know, the Department of Health, there's two counties that have a combined Public Health, local Public Health Department there, and they are the ones that issued the announcement about the contractor at the plant who passed away with blastomycosis. I only mentioned two parties—us and the Mycotics Division at CDC—but the employer has been overwhelmingly supportive. The CEO arrived from Sweden. That afternoon they idled the plant for three weeks. The union, which is a paper workers' union but a subsidiary of the U.S. Steelworkers, United Steelworkers, tremendously active, tremendously supportive and in fact, our folks, with the plant idled, are using the union hall to be able to meet with all of the employees which, of course, you know, when you think about it, is much safer than actually doing it at the plant. We have the local Public Health Departments. We have the State of Michigan Health Department. Michigan is a State Plan state, having safety and industrial hygiene kind of separate. MIOSHA is also involved. So it's a very large, collaborative effort. Dr. Howard confirmed NIOSH is taking urine samples.

Dr. Reponen said I'm assuming there's also source investigation to see where it is coming from. This is a very common fungus in the environment and, incidentally, it likes wood. So in a paper mill, you would think that probably something in the process has a very high contamination.

Dr. Howard said this is an interesting plant because what comes out the other end is paper. But what comes into the plant are actually trees; it's a combined sort of pulp mill and paper mill. The trees come in with bark, vegetation, dirt, you know, you name it. One of the theories is that the blasto is coming into the front end of

the plant by virtue of that material that you just mentioned. That's one theory that's how it's getting into the plant and why it's sort of set at the plant. It's the Billerud plant and it's in Escanaba.

Dr. Reponen suggested we talk about the East Palestine. It hits home here in Ohio and of course Pennsylvania. You mentioned that NIOSH has participated in the first responders. Is there still something going on? Because my understanding is the cleanup is still very much going on there, the environmental cleanup.

Dr. Howard agreed with Dr. Reponen and said the soil is being replaced and there are some riverine issues going on. Our participation was fairly brief. This is another one of those responses in which you've got the Governor of Ohio, the Governor of Pennsylvania, you've got federal OSHA, you have the CDC folks, you have DoT, you have EPA. Our role was fairly minor in being able to provide sort of technical assistance, to making sure that the cleanup workers were well-protected, etc. To my knowledge, at this point in time, we've not been involved in any other type of ongoing issue. There was some discussion about maybe doing that kind of study but we have not been approached. We don't have the resources to do that. But we certainly are happy to provide any technical resource. It's really a DoT/EPA kind of lead. They're the lead agencies, not really HHS.

Dr. Patel asked regarding the East Palestine are there any plans to look at training for folks who would respond to these accidents in the future, like accident investigation type training? What would they need to be protected if they are part of an investigation team?

Dr. Howard said we've done a lot of work—even since 9/11, over the last 21 years—in our program. We've distributed to every state Office of Emergency Services our ERHMS program, which is Emergency Response Monitoring and Surveillance. We have done extensive work in making people more aware that they need to prepare before an event happens, pre-response, than issues during the response itself. And then what do you do in certain situations after in terms of monitoring some of the questions that Dr. Patel asked? We've done that and it's all available on our website in our ERHMS program. But a lot of times, that doesn't necessarily get the follow-through that we hope for.

Mr. Foley asked if you have any updates about things like employment arrangements, H-2A workers, and systemic inequity, so disparities in exposures across race and gender. I'd be very interested in learning about what NIOSH has been doing in these areas.

Dr. Howard said we've just gotten that off the ground in a formal way and Dr. Rashaun Roberts is heading our Health Equity Office, and I think that would be a great presentation to do.

Dr. Reponen read that Dr. Patel commented that based on interactions with colleagues in other states, very few responders deployed ERHMS so it would be interesting to look at how well local states are aware, have the capacity, and actually do implement this framework, and to what extent.

Dr. Howard said it's the struggle that we have of NIOSH creating great guidance, great recommendations, great information, and then the uptake isn't as high. Are the right people getting access? It's always a struggle and our comms team, headed by Christy Spring, they're focused on how do the right people get the resources. We're always happy to receive information about how to do that better.

Dr. Patel suggested linking up with NIEHS Clearinghouse and Dr. Howard said we've done that too. In fact, I speak at their conferences, and those folks are pretty plugged in to us already because a lot of them are both NIEHS as well as NIOSH grantees too. So they're a little more connected than others. It's the folks that are in state government and local government that we have the most trouble getting at, because those are normal relationships. They're sort of CDC relationships because CDC funds a lot of money to that direction, but we are in sort of the Labor Department side as opposed to the Health Department side. So a lot of times, you know, we need some more suggestions about that area.

Mr. Morrison said we have been able to be part of the NTSB investigation on the train derailment. The other thing I can't go without saying—thank you to the group here and Dr. Howard—the National Firefighter Registry for Cancer is really being released, and I want to thank Grace. There's one of the largest first responder conferences that's coming up in Indiana, and the NIOSH team and Dr. Fent and others are going to have one of the first formal discussions about where the Registry is. I just appreciate all the work that NIOSH did on this, the last-second work that they had to. Dr. Howard, thank you for assisting us in that and getting that taken care, and Grace, it's actually happening. They're amazing to work with. I appreciate all the work they do especially for the first responders out there and what they're doing for the workers.

Dr. Howard said thank you, Pat, and thank Grace and thank the whole subcommittee because you all deserve credit. And it's been a long time coming, but it's here, and we're just very grateful to IAFF and all of our supporters and partners. It's just been wonderful.

Dr. Reponen thanks Dr. Howard and said we'll move on to the PFAS presentation now.

PFAS Overview

Dr. Calkins said first, I do want to say thank you for the opportunity to present here today to the BSC. This is a real privilege to get to discuss this topic with everyone who's on the call today. I know it's a really important subject and it's a really highly discussed topic right now, and it's one that we have been dedicating more and more time to here at NIOSH. So I'm going to start us off by presenting an overview of what per- and polyfluoroalkyl substances are, to make sure we're all on the same page, and talk about some of the activities and considerations for occupational settings. And then we'll pause for some firefighting questions before moving on to Susan's presentation where she'll go over some of the work that we're doing at NIOSH.

PFAS are a large group of synthetic chemicals, I mean that they're not naturally occurring. And, depending on the definition you use and the source you're looking at, they can include over 12,000 individual substances. That's the number that currently is on the EPA's Computational Toxicology System. Generally speaking, they consist of a fluorinated aliphatic structure, so that's a carbon chain where the hydrogens have been replaced with fluorine molecules, and then they typically have a functional tail end. They're often categorized as or per the family tree you see on the screen here today, by polymers and nonpolymers. Polymers tend to be some of the bigger molecules such as PTFE, also known as Teflon. And then nonpolymers are further categorized as the perfluoroalkyls—excuse me—and polyfluoroalkyls. Generally speaking, polyfluoroalkyls include a lot of the precursor compounds such as the fluorotelomer alcohols; and the perfluoroalkyls are the compounds

that we hear talked about the most. These are typically the terminal compounds, and they're generally further described by either their functional group—so we'll hear sulfonates or carboxylates—as well as by their chain length. So you may hear long-chain and short-chain, typically where the cutoff is either at a C6 or a C8, so a carbon chain of six or eight molecules.

Dr. Calkins continued asking, why are they a concern? Well, they have been integrated quite extensively into consumer and industrial products, as well as used in a number of processes, since about the 1950s and this is largely because they have a number of desirable properties, including their ability to repel both water and oil, being resistant to thermal pressures or stressors, and being chemically stable. They have been given the nickname “forever chemicals,” largely because they are highly persistent in the environment. They do have, some of them, a potentially long half-life in humans as well. And there is growing toxicological and epidemiological evidence of health effects that affect multiple systems.

So a few of these are listed in the upper right corner of your screen, a few of the specific outcomes or indicators, but generally speaking, these health effects can be grouped into effects to the cardiovascular, reproductive, endocrine or immune systems, effects to specific organs such as the liver and kidneys, as well as potentially increased risk of certain cancers.

Dr. Calkins said our understanding of exposure for the general public has been growing quite rapidly. There's a lot of data that's been produced as part of the CDC National Center for Environmental Health or NCEH, National Health and Nutrition Examination or NHANES Survey. This is a nationally representative population that includes a number of different exposure and health measures and is administrated by that part of the CDC. Now, as part of that work, a few select PFAS have been included for approximately the last 20 years, and we do detect some of these PFAS still in the population. However, some of them have been declining, most notably PFOS, which is one of the long-chain PFAS that have actually been quite intentionally and somewhat effectively phased out of production in the U.S. However, they are still present in products. They're still used internationally so they are still a part of the conversation and we do still see them in the population that is sampled as part of NHANES.

There's also been a lot of work to understand some of the environmental sources of PFAS, most notably PFAS in drinking water and where some of the point sources may be coming from. So PFAS have been included in the UCMR-3, which is the Unregulated Contaminant Monitoring Rule. It happens every five or so years, and that last one, the UCMR-3 where PFAS was included was about ten years ago. It's also currently being included in the UCMR-5 that I believe is either just getting underway or is currently underway. And so, from that data, we do understand that PFAS is in some drinking water in the United States. There's also growing information about it, about the presence of PFAS in certain soil or other environmental media including fish or game, for example. There has been a number of different efforts, including the map that you see from the Environmental Working Group. There are other, similar maps out there including some from, other from federal agencies that are underway to try to map out where these sources are, and include not only drinking water levels that have been detected but also other potential point sources such as military sites or industrial sites.

Dr. Calkins mentioned that all of this information has fed into some really nicely characterized exposure pathway work. However, most of this work has really focused on the general population. So we see figures like this one, where we have a source such as an industry source that then contributes to PFAS in consumer products or potentially the environment, and then people interact with either those products or the environment and that's where their exposure is primarily coming from.

However, we are NIOSH and we focus on worker exposures and so it's really important to understand, right off the bat, and emphasize that workers interact with chemicals and potential hazards in different ways. And so the pathways that are relevant for workers may be different, particularly because they are interacting in a different timing in the lifecycle of that chemical or that hazard, and so the ways in which they interact and even the specific forms of that chemical that they're interacting with may be different than what we would see in the general population.

So, from a big-picture perspective, PFAS has emerged as a high-priority topic, and this is not only true of federal, state, and local government but it's also true of standards organizations, unions, and impacted parties, and the academic and research world. And I do want to just point out that the examples that are included on this slide are just that. They're just examples. They're not the only ones that are working on this.

Dr. Calkins said PFAS does have some challenges though, resulting from the fact that it's a large class, and so the approach to managing a class of chemicals is, I think, as many of us know, not easy. And so there's differing opinions and differing approaches that are being included in—depending on the entity that's discussing it and approaching it.

There's also slightly different definitions, and so that can create some challenges in terms of making sure everything is aligned, and looking at similarities, and comparing the exact same, you know, apples-for-apples comparison.

And then the availability of methods, while certainly becoming better and increasing, has been somewhat limited in the past. And so not only the data that's available but also our understanding of what we are able to detect, and where we're able to detect it, is still certainly evolving.

Now there have been, as I mentioned, some voluntary phase-outs for select PFAS, also PFAS in select settings. So there's been some work to really remove PFAS, whether it's a specific species or a specific application. Some of those have been very effective in the U.S. and abroad. However, PFAS is highly litigious, so it's a challenging topic to approach in some settings, and legislation is also increasing quite rapidly.

Dr. Calkins commented that of course we see it in the media, right? There's news that we see popping up probably on everybody's phone and computer all the time, and a lot of this is talking not only about this legislation that's happening and coming about at state or local jurisdictions, or identification of potential new sources of exposure. It's talking about work that's being done within industry to try to address the challenge, work that's being done at the federal level to either characterize exposure or, in this case, there's a national standard that protects communities by setting a drinking water standard. And then also internationally, so ECHA is the European Chemical Agency. There is similar work being done over in Europe as well as other countries around the world, either around restricting or implementing other types of activities.

Before I go into some of the considerations that are really important to consider when we're talking about occupational exposures and the research that we do, I want to touch on just a few of the agencies, the overarching activities that are really relevant for our work, first outside of the federal government and then within the federal government.

Dr. Calkins listed that one is the International Agency for Research on Cancer, which is part of the WHO. Now, IARC, they basically set recommendations or groups, categorization if you will, for hazards in terms of how carcinogenic the weight of the evidence is for them. So they have set PFOA, in a Monograph that was published in 2014, as a Group 2b carcinogen. This means it's a possible human carcinogen based on the weight of evidence. But they have scheduled Monograph 135 to include both PFOA and PFOS. So this will be scheduled for later this year and they'll be reviewing it, and we may see changes in terms of their categorization at that time.

Additionally, the National Academies of Sciences, Engineering, and Medicine or NASEM produced guidance last summer on PFAS exposure, testing, and clinical follow-up. Now, this guidance is specifically tailored for physicians in a clinical setting, but it does provide one of the first pieces of guidance, in the U.S. at least, where there are threshold-based recommendations for when to work on reducing exposure, and when to also include some additional clinical testing and monitoring of individuals. So the thresholds that are set were, there was a number of different criteria that were included, but they are—just to put that up there—they are a sum of, I believe, seven different PFAS. So this is not just any specific one; it's a certain seven that are typically measured as part of NHANES.

Now, within the federal government, there is a lot of work and a lot of activity, and I can't go into everything that's being done here so I've highlighted a few that are really relevant for us. This is not an end-all, be-all list. Please don't think that this is it that's up there. But there is certainly coordination that's going on as well. So there is coordination out of the Office of Science and Technology Policy. That's really helping to make sure that there is transparency between agencies, and communication, and that we are working together to address the problem, and that we are leveraging activities across the government.

Dr. Calkins said to name a few things that are going on here, the EPA is certainly very active in terms of PFAS, not only regulation and collection of information, but also understanding background sources, health assessments, and then even methods development. They've done quite a bit of work to understand how to measure PFAS in water as well as in ambient air. There's work within CDC and ATSDR to understand some of those exposures for the general population. I already mentioned NHANES. ATSDR also has a number of studies, that are either currently underway or have just wrapped up, to characterize exposure in communities that may have point sources of exposure, so some of these more exposed communities within the U.S. The DoD has been providing serum testing for DoD firefighters and is also working to identify PFAS-free alternatives to Class B foam that traditionally has PFAS in it, namely AFFF or aqueous film-forming foam. NIST has also been working on some of that similar research, understanding some of the exposures for firefighters specifically in terms of PFAS in firefighter gear, so turnout gear or personal protective equipment, firefighting foams, and also fire response. They are also working on methods development. NTP, the National Toxicology Program, has been producing quite a solid volume of literature on *in vivo* and *in vitro* toxicology

studies. And then there has been a number of legislative activities that have been relevant to the work that we do including, most recently, the PFAS Bill, which charges FEMA with developing recommendations for firefighters. But PFAS have also been present through the National Defense Authorization Act or the NDAA, and there has been other activity that's been going on.

Dr. Calkins said this is all really important for the work that we do at NIOSH because we really leverage the information that we can get from these other agencies and entities to inform our study design, prioritize exposure pathways and the need for new methods and technologies when we try to understand some of these developing hazards and the landscape of exposure and health in occupational settings.

And this is critical for PFAS because, with it being present in such a diverse range of different products and processes, that also means it's present in a lot of different work environments. So this is a very busy slide, and I know and I apologize, but just to orient you to a few of those settings where there's either release data that suggests that there's high quantities being used, or where there is a lot of applications, different types of uses in those settings. We know that PFAS are present in a lot of different manufacturing settings, so for example, plastics and rubber, metal production, electronics, chemical manufacturing of course, and then paper and textiles, things like that. It's present in building and construction materials. It's also present in lubricants and greases. It's present in coatings and paints, and the list really goes on. So I'm not going to go into that too much more. But it's present in a lot of different settings.

However, the occupational exposure literature is relatively limited to a few different industries. So this figure here is another busy slide. I will not have as many busy slides when we move forward after this. But this is a figure where we've pulled together biomonitoring data from a number of different studies that are published in peer-reviewed literature, and it's for PFOA specifically, which is one of the long-chain carboxylate PFAS that's relatively well-studied. And then just to point out, the x-axis is on a log scale so it's not linear, but what we're seeing here is that a lot of the literature is either in the firefighting and first response worker population, or fluorochemical manufacturing workers, and there's not a lot outside of that. There's a few, certainly, but there's not a ton outside of that.

Dr. Calkins continued that within those populations, we see that there is quite a range of potential exposure, as well as between the populations, with some of the lower exposures overlapping a little bit with communities. To point out on this figure, some of those communities, those blue dots or blue squares, those are actually communities with potential point sources. So they're not a background, like an NHANES background. They would be a community that maybe lives near a point source and has potentially an elevated source. So we do know that there is variability within these populations, there's differences between them, and that we're lacking information about others. And this is kind of critical because in order for us to develop and help inform occupational exposure guidance and potentially inform limits on exposure, we really need that information available to us. So, currently, this information is kind of limited.

There are three ACGIH or American Conference of Governmental Industrial Hygienists threshold limit values or TLVs, all of which are for air, that are relevant for the U.S. So this includes perfluoroisobutylene, perfluorobutyl ethylene and ammonium perfluorooctanoate, which is a salt of PFOA. There's additional guidance that's available and relevant for countries outside of the U.S. that certainly could be utilized by

companies in the United States but, typically, we go to the ACGIH information in the U.S. These, some of these I'll also point out, the first two I listed are typically PFAS that we would not—that have not been measured in human serum. So they're not necessarily the PFAS that we would see. So connecting that air information to what's in the body is not necessarily a one-for-one.

There's limited information and research noting protective practices and settings where interventions have actually reduced exposure. There's a little bit out there but not much. And then we're, generally speaking, lacking recommendations for what types of personal protective equipment or PPE would be relevant. So right now, the hierarchy of controls is typically the approach that many are taking in order to just reduce exposure and implement best practices in worksites.

There's also some differences in terms of the availability of methods. So, majority of the analytical chemistry that's available for PFAS has really focused on targeted analyses, largely of these semi-volatile PFAS. So a lot of those terminal compounds would fall into that category—PFOA, PFOS and so on—and they're analyzed on an LC/MS machinery of some sort. It varies depending on the setting.

Dr. Calkins said there is growing capabilities for analysis of some of the volatile PFAS. Typically, these are done on more of a GC/MS setting. It's just a better equipment tailored for that. But that's a newer technology; it's not done quite as often, and so the methods are a little bit harder to acquire or to identify. There are some semi-targeted analyses and then there's also growing non-targeted analyses including Total Organic Fluorine. Total Organic Fluorine can be used, as well as the PIGE method, can be used as a good screening method to identify if PFAS are present in the medium that you're interested in, but it is not appropriate or able to identify different species of PFAS. So you can't necessarily say that all of what's there is attributable to a single PFAS. You would have to do a targeted analysis to understand that.

In terms of the matrices that we can use, those that are readily available are really for water—the EPA has done a fantastic job developing methods that are available and reproducible for PFAS in water—as well as biological, and this is mostly for blood and serum. So those two are accessible and available and reproducible. The ones that are less available or newer, and are harder to maybe find a lab that's able to do them or do an expanded panel on, are air, block materials, dust, and other biological material including urine or milk, for example, and then also just other material. You never know what you might want to test for.

So this is really critical when we talk about occupational exposures because we need to be able to measure it in the media that we're interested in, and understand how that relates from one to the other. It's also critical not only from a research perspective but also when we make a recommendation for a company to maybe do some monitoring, they need to know that they can actually go out and access that, right.

Dr. Calkins highlighted that it's critical when we talk about the routes of exposure. So, for the general public, there's been a lot of focus on this oral route of exposure because of that focus on drinking water as a major pathway contributing to exposure. So that's not relevant—not only relevant—for our understanding of exposure, but it also has really translated into the toxicological world. So when researchers are designing toxicological studies, they'll typically try to use the routes that are relevant for the human population in those studies, for example in mouse models or other animal models.

There's a little bit of a mismatch in what might be relevant for workers from an exposure and health perspective because typically, in a worker population, we focus more on inhalation and dermal as routes of exposure. And this research is certainly being developed and looked at more but, generally speaking, has this really strong focus on the oral route.

Dr. Calkins mentioned that there's been some phasing out. That is actually an area that I think we'll probably get into a little more of a discussion later today as well, but PFAS are used in a number of different settings, some of which may be more available for phasing out than others. So there's some discussion around applying the essential use principle to tailoring how we approach this and which areas are, for example, low-hanging fruit that you can then kind of remove more readily and more easily, and just eliminate PFAS in that setting. And others may take more time, or we may not even have an alternative for it at that time. So, for example, some of the categories that would be considered nonessential would include PFAS in dental floss or ski waxes, things that are enhancing the performance of a product but aren't actually serving to protect health and safety. Whereas on the other end of it, some of those essential uses where we really need to have something developed to substitute and replace PFAS at some point include its use in certain medical devices, or in occupationally protective clothing or applications. So PFAS are used in certain settings to reduce the exposure to other hazards. So if you simply remove it without having a substitute available—and currently there are no substitutes for some of these that are performing at the way that they need to perform—if you simply remove it, you are then potentially increasing the risk of exposure to another hazard. So there's some risk tradeoffs that are being considered as part of these discussions.

Dr. Calkins said understanding exposure in different settings, understanding those routes of exposure, and the health, essential health outcomes that are relevant for not only the exposure but also the route, are major areas of focus within the research at NIOSH, as well as some of the work with methods and understanding what's out there for methods, and then also trying to tailor our work for research going forward, and making sure that we are having the most impact that we can. Acknowledging that there is change happening within the world of PFAS and the application, and so we are really taking that to heart.

Dr. Demian stated what we will see in the future will be a need for education, health information, health education materials both toward the public, workers, and healthcare providers. So, at this time, where could we look toward to see if there's any messaging that has been developed, or is NIOSH involved in planning and doing anything similar?

Dr. Calkins said I am going to ask that we put a little bit of a pin in this great question and return to it after Susan presents, because she will touch on some of those topics, and then it's part of some of the discussion questions we have at the end.

But right now, in terms of where you can look outside of NIOSH, there are, as I mentioned, the ACGIH TLVs. That is one source for some more information about some of those exposures. There's some information that's being developed as part of other PFAS efforts. The clinical guidance is certainly something that ATSDR is taking on and running with. They have some guidance for clinicians for when somebody talks to that clinician about their concerns about their exposure, and so they are actually working to expand some of that as part of the recommendations from that NASEM report that I mentioned. And that NASEM report does

specifically call out occupational exposure so that that will likely be part of some of the development, although I think they're still in the early stages of addressing and revising their existing guidance.

Beyond that, this is a topic that we actually get questions about a lot, is what respirator do I use, or what I do to reduce exposure, and it's something that we're really actively working on. It's a little bit difficult to address. Yes, there isn't like a single source that I can point you to right now.

Mr. Morrison thanked Dr. Calkins and asked do you know, the EPA and the TSCA, Toxic Substances Control Act, do you know where they are with PFAS itself, either making that if there is a substitute or we are using PFAS chemicals into the future, if somebody is requiring that, there'll be a risk determination before that would be really astute. My basic question is EPA looking at this underneath the Toxic Substances Control Act?

Dr. Calkins said that PFAS are included as part of TSCA. They've actually had a few Significant New Use Rules that have come out in the last few years that have included more PFAS or have adjusted some of the levels. I'm sure some of our industry colleagues that are on the call today are more familiar with some of the TSCA regulations than I am. But they have been working on this, and that is actually a source of some of the information where we pull from. It's one of the huge benefits of the EPA for our occupational exposure work is we're able to actually pull from some of that data, to figure out maybe where we need to go and try to— which industries, which companies we should try to work with.

In terms of evaluating what it sounds like you're getting at is regrettable substitutions and risk tradeoffs, I don't know if that's actually part of the TSCA approach and the mandate.

Dr. Reponen said it was interesting, the map that you showed early on in the presentation that had several big clusters where there seems to be more PFAS exposure. So is that that this is truly some more exposure, or is it that the other areas are not measuring the water?

Dr. Calkins said this is an environmental working group map, it's the cleanest, easiest one to grab. I know that ATSDR is working on maps, as well as EPA, that are similar to this. This is data from a couple of years ago, at least that's when it was last updated. The blue is drinking water. You can't really see because it's overlaid, but there are industry sites that are on here, and then also the purple are military sites. Some of the clustering does have to do with where PFAS are used and where potential releases may have occurred, but there's also, some really clear boundaries, for example around some of the states like Iowa or Michigan. And these are also states that have done a lot of work to try to understand the exposure. So there's just more information. It's entirely possible that some of this is just a reporting bias, where we're seeing more blue dots because there's more data available, and not entirely just because there's more PFAS present. That is a really good point with this map, that there could be some reporting bias in that. However, I think a lot of the blue is from UCMR-3 data. That data is, or that survey, is only applicable to municipal water sources of a certain size. So in rural areas, where people are using well water, they would not qualify necessarily for UCMR-3. So we're missing potentially sources like well water testing, which is something that actually may be more common in some of those areas, some of those states where they've really been focusing on it, and where resources are available to individuals to get their wells tested. So it's a combination of different sources of data and the reporting bias is likely a part of that map.

Dr. Reponen said from EPA there is going to be coming in the future, regulations that all municipal water sources have to be tested for PFAS. So then maybe we'll get a better picture of the contamination.

Dr. Calkins agreed that it's also part of the UCMR-5. There's a larger panel of PFAS, I think it has twenty-something PFAS as part of the UCMR-5 that's happening right now.

Dr. Reponen then turned it over to Dr. Susan Moore for the next presentation.

PFAS Research Studies and Future Direction

Dr. Moore thanked Miriam for starting us off with such a great presentation. I want to start off with saying I'm going to cover some specific NIOSH studies, some different technical support aspects we've done, and talk about where we're going and what we're trying to do towards strategy in this space. But what I want to say first and foremost is I'm not presenting just my work; I'm presenting the work of many different people in the Institute. You can see all their names at the bottom of this slide. Many of them are in attendance today to answer any specific questions you might have about their studies. I just want to thank them for working with me to pull these slides together.

The first thing I want to do is start off with this timeline. Don't worry, I'm not going to go through every little piece of this here. It's more for visual communication. For someone who's looking at these slides after the fact, we've embedded a lot of great hyperlinks to help direct you to some key content. But what I really wanted to point out here is, just like Miriam said, if you go back to the 1999—so there's been a lot of work in this PFAS area that's been going on for a long time. I mean, that's when NCEH first started looking for PFAS in the blood levels for NHANES. But if you start walking down this timeline, you see more and more engagement in those timelines. We just talked about UCMR-3 and how they had 6 PFAS. Now, UCMR-5 has 29. If you start going down this list of different things, and anything that has a star here, this is where you're going to see more and more NIOSH activity beginning. And what I want to highlight here is 2012.

2012 is when NIOSH—although involved in many of these other activities, it's when we published a study, or findings from a study, where we have conceived of, funded, and executed in full a study completely as NIOSH. It was about dermal absorption. It was published in 2012, and that study, that work really served as the foundation for what we decided to do moving forward with our interdisciplinary studies. And as you can see, the stars on these years—2015, '16, '19, '20 and so on—we've had a lot of activity. And I'm going to give you just brief highlights of each of these projects because we don't have time to get into all the details. But I hope you can appreciate the interdisciplinary nature of what we're doing and the diverse approach that we're taking to try to solve this. And also notice just the increased activity in this space in the occupational safety and health space.

Dr. Moore explained that the way these slides are set up, I'm going to first describe generally a study, and then a second study. And then on the next slide I'm going to give you a little more information about this study, and on the slide after that a little more information about this study. And the reason we're doing it that way is first, I want to say, what we're talking about here with these two studies are exposure

assessments and epidemiology. And Dr. Miriam Calkins, who just presented, is actually the project lead for these two studies here I'm going to talk about.

So the first one, at the top here, is "Occupational Exposure and Health Indicator Assessment of PFAS." This is a feasibility study, right. But what we're looking at is going to industries that have either a moderate or high potential for worker exposure—and she presented that data earlier in this presentation so you have an idea of what industry sectors that might be—and then specifically looking to do biomonitoring, looking at industrial hygiene measures, and survey materials, to look at exposure and try to understand the association between those exposures and also any indicators for health. So cholesterol, for example, would be a health indicator. Can we find any association between that exposure and those indicators? And I want to highlight our partner, National Toxicology Program. We partner with them a ton, and we often share our exposure assessment data with them to help inform their *in vivo* work.

Dr. Moore then introduced the Board to our Fire Fighter Cancer Cohort Study, specifically the part of that study that's looking at the exposure and epigenetic markers. Now, once again, we're partnering with a lot of different organizations here. This is a 30-year multicenter prospective study specifically looking at carcinogenic effects and cancer prevention. You can see our partners here: University of Miami, Rutgers, Michigan, University of Arizona. They're all partners with us, but we are also partnering within the CDC, and you can see we've partnered with NCEH to look at the actual—help us with some of the analyses specifically. Within this study, we have multiple firefighter subgroups, and we're also conducting assessments of fire department practices to explore that as well. Specifically, the study is looking at exposure routes and epigenetic changes. So let me go to the next slide and again, I'm going to talk about that health indicator study.

This study is ongoing. Again, it's a feasibility study. And a key thing to understand about this study is we've got really two types of measurements. We have personal measurements, and we've got worksite measurements. For the personal measurements, we've got two biological matrices—so we've got serum and urine, we've got breathing zone samples, and we also have employment history. For the worksite measurements, we're looking at drinking water and area air. Now, this is a cross-sectional study, and we are focusing on the manufacturing and services sector. Remember I said we were focusing on those from moderate to high exposure.

What we're targeting for this study is 150 participants spread across 10 different worksites. We are currently in our recruitment phase, and I know Miriam would love it, if you're interested in learning more about how you can get involved, if you would reach out directly to her. At the end of my presentation, you'll see her contact information. Definitely would be interested in support and help getting folks to participate in this. Again, what we're doing here is we're measuring these various things about exposure, and then we're trying to see if there's any associations with health indicators. An example again is cholesterol, to see what that informed. And this is at the feasibility stage.

Dr. Moore then explained the second study she mentioned, which is the Fire Fighter Cancer Cohort Study. Now, we have had a lot of activity on this study. There's no way I could give you everything that's been going on in this short presentation. I have a few snapshots of the publications here. But one of the things I want to

give you as an example of the type of data that's coming out of this study is right here in this figure. So it's just example information. So what we've found through that study is that the serum levels from various fire departments are similar to what we're seeing in NHANES. However, some of the departments were having higher levels than others. So we have to be cautious interpreting this information, right? NHANES is nationwide, it's generalized across the whole U.S. population, right, which is not necessarily what we'd be seeing when we're looking at specific fire departments. So we have to recognize that. We can't draw too much of a conclusion just yet with where we are. But recognize, we do see similar levels in fire departments as NHANES, with some fire departments showing notably higher levels than others. So, more to explore there.

Dr. Moore then shifted gears. I just did the exposure assessment studies. Now I want to reframe your brain to thinking about personal protective equipment, and specifically, dermal exposures and how PPE is related to that, and materials testing of that PPE.

The first study I'm going to go over here on top, again being led by Dr. Calkins. This is part of that Fire Fighter Cancer Cohort Study but this part of the study focuses on dermal exposure to PFAS. So what we're doing in this study is we're taking firefighters at their departments. They're wearing new gear, it's never been exposed to any kind of live burn exercise, and they're wearing this gear while they're doing their physical training activities, right, their regular physical training as part of their employers' requirements. New garments are being worn by them during this. And also, we're working with fire departments who have new recruits coming on and they have to do their physical training as well. So that's what the garments are.

Specifically, what we're measuring though is we're looking at serum pre and post. We're looking at their urine levels daily, and we're also looking at silicon wristbands which, during the activity itself, to see if we can detect any PFAS on the skin. And we'll go into more details about this in just a second, but we're partnering with Duke and Carnegie Mellon to do this work. And I really hope everyone sees that we're listing our partners, so I'm hoping you recognize that NIOSH has worked very, very hard to diversify the partners that we work with, and to really seek out the people and organizations who are pushing the research and the developments in all the areas so that we have the broadest impact we possibly can, and we're leveraging the nation's resources as best we can.

Dr. Moore then moved on to the second study she's going to go over when it comes to PPE is one that's about looking at the firefighter textiles, specifically looking at the effect of laundering. So you can imagine there's PFAS that are embedded in some of the layers of the turnout gear or the garments, and we're wondering if, during the washing process, the laundering process, if some of those PFAS are getting liberated and then perhaps migrating through the different layers of the textile and making, potentially could be making, contact with the skin, therefore opening up a dermal route of exposure. So that's, so these two studies are looking at those two things. For the second study on the bottom here, we're partnering with NIST, who's playing a major role in the methods development for us, and this project is led by Crystal Forester.

The first study I want to talk about, this acute PFAS toxicity. I want to credit this photo. This photo is from Peaslee et al. (2020), which is not a NIOSH publication so I want to recognize this photo credit. But this really shows you what we're looking at. Remember, these folks are wearing new turnout gear, never exposed to

any kind of live burns or anything, and they are doing their physical training activities, and we're looking to see the PFAS that we see in the various layers of the garment, how it might be absorbed in by the sweat, wicking it away from the textile, bringing it back to the skin, and could potentially be entering the body that way. That's what this study is about.

The second study I mentioned about the laundering, we're actually looking at structural firefighter turnout gear and wildland gear. I'm going to look at the structural gear first here on the left. And if you're not as familiar with turnout gear, I've talked about there being multiple layers. This is a beautiful picture to give you an idea. You can see this layer here, the thermal liner closest to the skin, moisture barrier, and the outer shell here. So what we're doing in this study is we're taking multiple textiles that are used to construct these garments. We're looking at seven different outer shells, we're looking at two scoured outer shells, five moisture barriers, and seven thermal liners as part of this study, and again, looking at, as we launder these, how do we see the concentration of PFAS degrading or moving to the different layers of the garment.

Dr. Moore said this figure on the right here, I want to be very clear, this is illustrative. This is not real data yet. We don't have real data yet. We're early in the study. Illustrative to conceptually help you understand what we're going to be looking at is the concentration of the PFAS as a function of the number of washings over time. So this curve, again illustrative, just assumes that there might be a degradation from one of the layers as those PFAS may be migrating to other layers of the textile.

We're also looking at some wildland garments. They are single-layer. Unlike the structural firefighters, they are single-layer garments, and we're looking at five different textiles for that part of the study.

Dr. Moore continued that we've talked about exposure assessments, we've talked about PPE; we're going to talk about toxicology now. This work is ongoing. Again, there's going to be two studies on the slide I'll first introduce. The project leads for this one, we have Lisa Weatherly and Stacey Anderson. We're specifically looking at toxicology following dermal exposure to PFAS. This is an animal study, right. It's looking at four carboxylate and four sulfate PFAS. They're specifically looking at serum, urine, organ weight, histology, gene expression, skin integrity, and immune phenotyping as part of this study. So, very, very broad in what we're looking at to explore this in this study, and I'll give you some indication of our findings in just a second on that study.

The second study I'm going to go over around toxicology is specifically looking at acute toxicology from firefighting foams. This is an *in vitro* study, and we're partnering with Harvard for this study. Specifically, we're looking at five different AFFFs, six different SFFFs, which remember are PFAS-free. And we're looking at cell viability, live cell counts, mitochondrial membrane potential, intracellular reactive oxygen species, gene expression via RNA sequencing. And the project lead for this one is Todd Stueckle.

Let me get into what we're finding in these two studies. I'm going to start with the top one. So our toxicology following dermal exposure shows us that some PFAS are dermally absorbed—long-chain and short-chain. Some PFAS alter organs—the weight, histology, phenotyping, and gene expression. Some PFAS disrupt the skin. We measured that by looking at the fibrosis, mild or moderate inflammation, and cell death. And some PFAS produce liver toxicities that are not associated with the carbon chain length. So the idea that the chain

length gets longer, the toxicity would go up, we didn't—some of the PFAS, we did not find that association, but there is one exception: sulfonic acid PFAS showed the opposite association, that there was in fact an association. You can see here we have multiple publications out about this work. If you're interested in this, please look up our published work and reach out to the authors.

Dr. Moore said the second study, which was acute toxicology with the firefighting foams, again an *in vitro* study—and I want you to notice right away, there's two caveats, and I'm going to go over those caveats. So when I read where our current findings are from this study, remember there's key caveats so don't make too big of an assumption when I say this. So what we've found is that exposure to AFFFs—remember, this is a PFAS mixture, AFFFs are PFAS mixtures—so exposures to PFAS mixtures in the AFFFs have substantially greater acute toxicology than single PFAS exposure, but lower acute toxicity than SFFF, which is a PFAS-free alternative.

Now why did I say I want to point out the caveats? Okay, basically what that says is, in this study, we're finding the AFFFs had lower acute toxicity than what is supposed to be the alternative PFAS-free, and this gets back to the question Pat Morrison was asking and Miriam was talking about, where we have to be thinking, do we sometimes, are we bringing in unintended consequences and how do we make sure we do that. Again, major caveats with this, this is not a final finding. Big caveat number one. PFAS is only one type of surfactant that's in the foams, okay, only one type. The other surfactants and solvents could be what's responsible for the higher acute toxicity. So this is being explored by us. It's ongoing work.

Caveat number two that I want to really point out here is the dosages that we used in this study were above those that have been recorded in serum levels for firefighters. So our ongoing work is also looking at reducing those dosages to subtoxic levels to see what the relationship looks like then.

Dr. Moore said the point here I really want to show, we're doing some great work here, we're finding some good things, and we're doing very robust science, not jumping to any conclusions before we've done a fully-fledged sequential series of studies to really flesh out all of this interaction.

She continued that we've done toxicology, we've done exposure assessments, we've done PPE and dermal exposure. I want to talk about methods development now.

This work I'm about to describe is ongoing and the project leads here are Jen Roberts and Cynthia Striley, usually goes by Cindy. And this, this is really the air sampling and biological monitor is being developed to support other studies that I've already discussed, or future studies that NIOSH want to do. It's making us independent and capable of doing more studies intramurally. So the air sampling activities that we have going on, we're looking at developing standardized method that can differentiate between PFAS forms, and we're specifically targeting 12 different PFAS analytes as a part of what we're looking for there. The biological monitoring, now that's an animal study, and we're looking to support toxicology studies by doing this, and looking to find both high and low PFAS concentrations. That's what we're doing here. And the images here are just to give you an idea. You know, for air sampling we're using a custom OVS-2 sampler you can see here. For our analyses for both the air sampling and the biological monitorings, we're using LC/MS. And this

just gives you an idea of the biological monitoring, the types of liquid extraction techniques that we need to be using from the mouse serum to do this kind of work. And again, this work is ongoing.

Dr. Moore then introduced the technical assistance and help with hazard evaluations that are ongoing. Let's talk about the technical assistance first, and this is work that Jess Rinsky and Jessica Li have been the project leads for. So requests for technical assistance—we've received a request from ATSDR and the EPA. There's no published reports here; we just provided the technical assistance. There are recommendations to improve training materials for public safety staff, mainly firefighters in Pennsylvania, that came out of ATSDR. And the EPA, we looked at possible PFAS exposure during field inspections.

For health hazard evaluations, we actually did one in 2016. It was acute firefighter exposure to AFFFs and, at the time though, I want to be clear, although this was AFFFs-related, it was an acute exposure, we did not actually do PFAS-specific monitoring as part of that HHE. Most recently, we actually have two new HHE requests, one in an airport and one in an aerospace occupational setting. Very new, and there's not much we can say about it at this time. However, it may be possible that the reason we saw requests for these two HHEs is because for other worker populations that are in this same workplace setting, there has been some evidence to suggest PFAS exposure. So that might be why we're seeing these particular workplace settings reach out to us and ask for HHEs. Again, Jess Rinsky and Jessica Li are the project leads for the HHEs as well.

Dr. Moore then talked about how after we had our 2012 published work, we had all of these different things. And one of the things was in 2015, work that we had done with our extramural program. So I'm not going to go into details here. These slides are here for your reference after the fact. But I need to mention, we've been exercising our extramural program just as much as our intramural program, developing monitoring technology, exposures, looking at exposures, and we have multiple currently funded extramural projects that are looking at these issues. You can look them up with the information I've provided on the slide here.

She then talked about where we're going from a priorities perspective. So at NIOSH, we have our strategic plan that guides the work and research that are the priorities that our researchers should be exploring. As part of that process, every year, we reach out to all of the subject-matter experts in the Institute, and we have a dialogue about whether or not we want to make any updates to that particular strategic plan, given the evolution of what's happening in the occupational safety and health space. This past year, we had a number of discussions specifically related to PFAS that I want to highlight.

The top half of this is looking at the fire services, and the bottom half here is looking at manufacturing. So I'm going to start with the fire services.

Dr. Moore said first and foremost, if you're not familiar, this past October, the U.S. Fire Administrator held a summit and during that summit, there was a roundtable discussion. There was a lot of activity from the Biden/Harris Administration, really engaging and sending some very top, high-level political appointee positions to hear and participate in this roundtable. And one of the asks that came out of it is right here. We asked the federal government to establish a comprehensive firefighter strategy that invests in research, provides access to cancer screening for all firefighters, and reduces and ultimately eliminates PFAS exposure. Okay, so that was a key outcome and testimony from that summit.

We considered and reflected some of these things. I'm going to go to the upper left here. So one of our goals is that management groups, labor organizations, and consensus standards bodies will use our information to prevent exposures to known or suspected carcinogens among public safety workers. This year, our subject-matter experts submitted a request to revise some of the text that supported that goal. So, specifically, we have—if you're familiar with NIOSH—we put burden, need, and impact information to justify the types of goals and studies we think should be done. The need is, you know, what specifically is the need for this work. We had people submit saying we would like to amend this to include this statement, “Research assessing newer, emerging, and unstudied sources of PFAS exposure are needed to address gaps in exposure assessment, toxicology, and worker protection for the fire service.” So this change was submitted, and it was accepted and adopted into our strategic plan. So this language is specifically added now for our researchers.

Dr. Moore stated that we actually had a couple of different submissions, and I want to talk about the two over here. So we also had one where we were looking at, again, consensus standards bodies, labor organizations, management groups, we want them to use our information to reduce the risk to cardiovascular disease among public safety workers. Our subject-matter experts initially requested that we would add some content about PFAS's link to cardiovascular disease. Similarly, a similarly worded goal, they requested to add content about PFAS's link to immune suppression and how that might be affecting things. And as we discussed that as an Institute, one of the things that came out is, while we have this wonderful organic process where our subject-matter experts are filtering information up to us and then we have a board or a panel that reviews it and determines the appropriateness of making those changes, we started to have a really big discussion that from 2012, when we published that first major study that was our foundational work, through all the studies I've been sharing with you, we had to start thinking about the importance of this area of work and whether or not NIOSH should invest in a specific research agenda for PFAS. And in fact, you're going to find out in the next slide, that is something we ultimately decided to do, and so we put additional changes for the fire service on hold until we complete that specific agenda. So that is where we would see those discussions perpetuate going forward.

Dr. Moore then shifted to talk about manufacturing. So again, same kind of process. We work with our subject-matter experts. In this case, one of the manufacturing goals looks specifically at folks using our information to prevent exposures to known or suspected carcinogens among manufacturing workers, or adverse reproductive outcomes among manufacturing workers. When we dialogued with the folks that oversee the manufacturing sector, they said, you know, the challenge they're experiencing is there's insufficient burden data to explicitly name PFAS in our plan, in their opinion. But they were very quick to say the lack of data, they don't necessarily think should be equated with a lack of an issue. The challenge is we don't have concrete data yet to definitively say that it's an issue. And so that, in and of itself, is something we really need to be thinking about for a research agenda in this space is where is the lack of information a potential barrier to us moving forward in key areas.

And lastly, as it comes to our NIOSH priorities, over here on the far right, we also had some folks looking to say, again, we have NIOSH information being used to prevent immune and dermal diseases among manufacturing workers. And program leaders had submitted, you know, that they were planning to request PFAS be added as an example exposure that can be leading to immune suppressive disorders, specifically as it

came to goals we have for our extramural program. Remember up here, immune suppression was also discussed in the fire services. Ultimately again, for the same reasons up here, we felt we need to hold off on some of these changes and really get a focused effort on a PFAS research agenda so that we can explore this in detail as an institute. So that's what we're doing.

Dr. Moore said that in January of this past year, NIOSH specifically initiated the effort to develop a PFAS research agenda to focus our future NIOSH investments in this whole space, and that is where we're going to be going. You'll see that coming out from us in the coming year. I want to just provide this contact information for Miriam and myself. Again, just a reminder, Miriam is actively looking for organizations, worksites that would be willing to participate in that exposure assessment and health indicator study. That's a feasible study, if you're interested there. It was manufacturing and services sector. Please reach out to Miriam for that. We'd love to take some clarifying questions right now, and then we have some specific questions for you that we'd like to ask.

Dr. DeGrasse asked if PFAS are found in clothing and materials that are treated with flame retardants? Because if so, then there's another population who potentially is exposed, and those are folks who work in airline industry, flight attendants, also the workers who apply deicing fluids to airplanes. They wear a lot of thermal gear during that time, as well as the folks who work as characters, like at Disney parks or some other parks where you have to wear costumes.

Dr. Calkins said this is a really good question, a good topic, and it fits into a little bit of the area of we don't totally know. But it is something that we've talked about a lot. So typically, my understanding of the application of PFAS into a lot of textiles, although there certainly are some maybe specific applications that would not fit into this, is for their either stain- or water-resistant properties. So they may be applied as part of a durable water repellent to help keep water off of the textile itself so it doesn't get waterlogged and then create additional hazards, add weight, things like that. And they may also be applied to enhance the performance in terms of keeping the person dry and warm, so for example a lot of outdoor gear. So this would go from everything from shoes, like leather shoes you might wear out in like a snowy or a wet climate, to like rain gear and things like that. And then also for their stain-resistant properties. So I would think character coatings probably don't want stains to occur so it's entirely possible, but I haven't seen any data to actually support that so I can't speak to the presence of them being either added as part of the textile itself or as a coating on top, which is the other two ways that it's added. So as Susan was describing, it can either be added basically to the surface layer or integrated into the textiles themselves, and those are very different processes and utilize different PFAS, and then also would affect the availability of the PFAS in terms of how they may be either sloughing off or being released in different ways. I know I've received questions from people specifically about uniforms for the airline industry. I don't think anyone's looked at that yet. But I think it's something that we are aware of. Definitely fire-resistant clothing, you can actually, if you look on certain retailers, you can even see that it's advertised as having PFAS or not having PFAS. So when I've looked up, for my own, for you know, buying my own PPE if I want to go into a certain industry sector, you can see it there. So, yes. Yes and no, I should say.

Dr. Moore added that one of the challenges that we face is that oftentimes, in most cases, it's a proprietary blend. So what it is you have a manufacturer who has something proprietary that they're trying to protect, and we are trying to study and understand it. And so oftentimes, we have to actually first do some exploratory work to even identify what types of PFAS might be on a garment of any particular type. And then from there, we can go and do actual studies about that. So not having ready access to that proprietary information requires us to first do some exploratory work to even identify what we might be working with. And from a resource management perspective, the challenge we have there is just imagine the cost of, like, having to explore that for every potential type of garment. So I think when we start talking about the research agenda, one of the things we're going to have to spend some time around is, strategically, how can we prioritize what areas and what work sectors we're going to go into, or what types of work tasks we're going to prioritize and why, because we're going to have some of those resource limitations that we have to address.

Dr. Calkins added that she tries to approach the lifecycle of a hazard. I think it's important to remember it's not just the workers who are wearing the product but it's also the workers who may be constructing and creating the product at different stages of either the textile creation or the sewing and cutting and putting it together, and then the people who are dealing with the products at the end as well. Like, used gear goes somewhere, and it may be put into a landfill, it may be incinerated, it may go into the waste stream. It's also washed somewhere. So if it's coming off in the washing cycle, it may be going into the water. And so is there a need to capture it at that point? So there's a lot of different things that are certainly important to consider, and then including like the storage. So is that person putting it in their car? Is it with the rest of their clothing? Are they treating it like PPE or is it something like a uniform that you may just throw with the rest of your clothes that you don't think about the potential for it really being true PPE versus just something to make everyone look similar? So there's a lot.

Dr. Moore said going between what you described are the employees who are actually working with, actually making the product itself versus the people who are using the product. Think about the difference in the hazard assessment for their employers. The amount of information that the person who's actually manufacturing, the folks who are manufacturing the product, when they are doing their hazard assessment, the level of information they might have versus an end user of a product where there's proprietary information there. So it really does matter a lot if we're talking about users or if we're talking about creators of the products.

Dr. Moore continued that Dr. Demian mentioned the health education piece and in the strategy that we're talking about, the research agenda, that is something we're really going to have to talk about. Because there's a thirst for answers and yet some of the stuff you have seen is just how complex and how many studies might need to be done to really feel confident in the outcome of what we're saying. And so when it comes to giving that sort of education and pairing it with some high-quality research, the first question we're going to ask you here in a minute, when we're done with clarifying question, is you know, what are the key areas that can be addressed with high-quality research? Because that's what we need to deliver.

Dr. Reponen asked what are they replacing PFAS with, and do we understand the toxicology of the replacement?

Dr. Calkins said it varies. PFAS have this really incredible ability to have these properties that apply in such a diverse set of applications that even when you try to replace it within one setting—and the one that I'm really just personally the most familiar with is AFFF or the Class B firefighting foam, which is firefighting foam used for liquid fuel fires, and the efforts that have been underway to develop products to replace AFFF, where AFFF really, for the most part, similar formulations work really, really well, with a number of different types of liquid fuels. So they're very diverse in their application. And some of the information that's coming out from a performance perspective looks like the products—you need more specific products for different settings. So that's what some of the early research is suggesting. Now, there are certainly, companies are working to develop products, and so that may be changing. This is information that I looked at about a year ago. But the discussion in that setting was that you may need different products for different applications. And so the actual ingredients that are replacing PFAS in those products may be different. And so it's not simply a one-to-one, can we look at whatever is replacing PFAS and just do the toxicological assessment on that group, that new chemical. It may be a number of different chemical groups that are replacing PFAS in different settings.

Some of the research that Susan was summarizing from Dr. Stueckle was trying to get at that. And so looking at some of those replacement foam products and finding that when you do dig into them, they show some different signals, whereas a signal for the different AFFF that were identified were actually a little more consistent. It seems like there's definitely differences in the ingredients that are going into those products. It's challenging. I know that there are efforts to look at the toxicological effects and the health effects of replacements, but those studies also take time. So if you're developing a new chemical to replace an existing one, you may not—especially one that is a hazard of concern that we want to remove from products—there may be efforts to put it out there while some of that work is still, you know, underway, so.

Dr. Reponen said we touched on the first question, “with PFAS being incrementally phased out, what are the key areas of impact that can be addressed by the types of high-quality research that NIOSH does, with all of those considerations” Before we go further on that, there's a comment from Michael Foley saying that the legal structure in the U.S. protects proprietary information, and this makes it really difficult to determine what chemicals are being used. And then he has a question that in the EU, these other requirements that allow more transparency in what is being used.

Dr. Calkins said I think you're probably referring to some of what's included in REACH. I'm not a legal scholar and I'm not intimately familiar with the regulations in the EU. But there are some differences and in how the EU approaches chemicals and regulations and hazards than how the US does. And so I do believe that there are some differences in there but I can't speak to exactly how that's applied to PFAS overall, as a category.

Mr. Morrison thanked Susan and Miriam and said there's a lot of work getting done, and I'm really pleased that you're going to take a pause just to make sure that you have your research agenda kind of complete, with making sure that we're looking at things that maybe we've forgotten about because we've jumped into this. And I think the question earlier about stationwear for workers—not just firefighters but for construction

workers, for people in the industry, the manufacturers, anybody that's having to wear some sort of flame-retardant protection, and the hazard with that. I think that's something we really have to take a look at because when we talk about exposures, we do have that, that piece of textile is right on your skin and it's usually worn much longer, for longer periods of time. So I think we do need to take a look at that.

I think in the European side, there's pluses and minuses. Europe is struggling with this too. They're going through a lot of discussion on this across the board. Some of the stuff they have is probably better and more transparent than the U.S. I know on a lot of stuff that, for workers, I think that they want to know what is in their material. Is there a right for a consumer or for a worker to know? And that's a label law, you know. That's basically saying that this material contains... And that is something that has met some resistance. It doesn't really help us because it doesn't take the substance out. It just tells you that you might have something in here. But it does force manufacturers to look at competing products that don't have that there too.

Dr. Reponen posed the question, with PFAS being incrementally phased out, what are the key areas of impact that can be addressed with high-quality research? And one already brought up was the toxicity of replacement chemicals. Actually, that same comment goes to question number two, "What unintended worker health and safety consequences could be..." It could be the replacement chemical could be more toxic. So any other comments or suggestions for these questions from the Board?

I had, for the question number one relating to exposure assessment, I think in Miriam's presentation you showed briefly that there was a study on sensor development. But that, at least the paper that you put up there, was a review about the feasibility of sensors. I don't know if there is any hope on having some sensors or some, like maybe these nontargeted analytes, so to have a screening tool that would alert if there are potential exposures, and then you could go in with the more detailed analysis. Because the one is, now is used is the sampling with this specific device that has a filter and then absorbents for the volatiles. But it's a pretty complicated and expensive analysis, to do that whole thing, because one time we were buying some of these analyses and it was like \$200 per sample. So just talking about the sensors, I don't know if you can give any insights on where that's going.

Dr. Calkins said to touch on that cost, it can be much more than \$200 a sample. So you're right on point with how pricey some of these analyses can be, especially if you want to do all the panels that are available. I mean, you can be looking at in the thousands. In terms of sensor development and screening, so that would be more, most likely in the nontargeted assay area. I have seen some commercial products that are starting to become available that would do just that. But they're very new and I haven't had a chance to actually dig into them too much or evaluate them. It is something that we've actually looked into purchasing one of them so we can do our own field testing and do some comparison. I think that is a direction that the sensor industry is going for PFAS but keep in mind, it really would just be a screening and so any further characterization of what's in that product would require a targeted analysis, which gets back into the cost and things. But it is something that I know is being developed. It's not something that we are working on developing a technology for at the moment, but it is something we're aware of and we're looking at what is available. So I think that's a great suggestion.

Mr. Morrison said I think a lot of workers just want to know what the health risk is. That's their primary concern is I'm wearing this for a long period of time, I'm doing this, what is my risk? And I think you're really hitting that. We're starting to get to that. That research takes time and that, but we're going to get, I think with everything going on, with all your partners, everything, and I'm really pleased to see all the universities that are really jumping on board and making sure they're helping with this.

The other thing too that I wanted to just ask, on new materials, you know, are we bringing in materials scientists into this equation, as to say sometimes we try to look at the problem with, "This is in this gear." Maybe that's not in your purview in this thing in here, but is there a time for industry—such like the fire service—to start to take a look at what are we using and what could we use? And I think, Miriam, you brought it up in the hierarchy of safety. These are things that we have. Do we need to start to look at other materials to do this? And that's going to be interesting coming into the future, because I know in the fire service, we really have to take a look at what is that next generation. And the next generation, right now we know we don't want particular chemicals in that, but what are other components that help us offset what we're going to lose when we remove that? Can we do that? You know, it's a real balance about protecting the worker with the PPE and then the health assessment, protecting the worker with the health effect of that, you know, and that balance is there too. So do you see materials scientists playing a big role in this? And do you see any other industries that you've seen that are really spotlighting this in other ways?

Dr. Calkins said there are materials scientists who are working on this. Most of my familiarity is definitely with the fire service, just with the research that I do, so I can't speak to other industries in terms of some of those textile materials. But yes, I think materials scientists are certainly involved. We can probably pull them in more. NIST has definitely been working on this area, and they have a number of materials scientists, I believe, over there.

Dr. Moore answered I was thinking about the research agenda and how to think about what you're saying. And you know, while yes, there are materials scientists working on this, I think that what struck me by your comment is I was thinking how does NIOSH best engage that expertise, that discipline, in what we're doing and supporting. And you know, if you look at the studies that we presented today, ones that are focused on actually the development of new materials, that wasn't one of the topics that we listed.

And so, I'm thinking, as you were talking, who—other than NIST, who's an awesome partner here—but who are the other entities that we might need to add to our partners, because yes, things are happening. Miriam's right, things are happening. But we have to be thinking about we, NIOSH, can uniquely control and position in an effective way. And that's where this research agenda will come into play. So I was just loving your comment. It's really got me thinking around, strategically, how does NIOSH do that? And I don't have any answer for you today but I think that's worthy of significant discussion in NIOSH as we start planning that research agenda. Not just what work might be appropriate for us to do, right? NIOSH, we look at that burden, need and impact, so to justify what we're best positioned to do. And as part of the "need" aspect, we ask ourselves, where do we, NIOSH, have the advantage over the other services or other organizations that provide similar service?

And we have two types of advantage we look at: comparative advantage, which is saying to do the same thing, someone else who can also do the same thing, where is our advantage; and there's something called competitive advantage, and that's where we say what is it that we, NIOSH, are uniquely offering or uniquely capable to do that no one else in this exact space is capable of. And we look to that so that we can prioritize, across the nation, all the various folks that are contributing to these issues. Where are we the most—where is the most important place for us, specifically, to be?

And so just thinking that has me thinking we really need to maybe gather some information about what other folks—the manufacturers and so forth—are doing, some of the universities, and then circle back and ask ourselves some of those hard questions, and figure out the lane that we are best positioned to offer support there. So, don't have an answer today. I have an approach to mention, I guess.

Dr. LeMasters then said this is a follow-up to my first question that Tiina read of what are they replacing PFAS with. And then the response really alarmed me even more because it said, "Oh well, PFAS is being replaced with a variety of chemicals with different combinations depending on how it's going to be used." And then I was thinking, oh my God. This could be just a disaster here. And so I was wondering if there was a way that you could begin documenting what are those chemical replacements, what are they going to begin replacing them with, and in what industry is it? You know, is it the foam, is it the textile industry? What industry will be targeted with these new agents? And it seems like just an ideal time to begin that, developing that historical record, current record which will become a historical record over time, so we'll have a better idea of which group to study, given the toxicity of the chemicals that are being replaced per, like the ski wax is a lot different than foam, I'm sure. So if NIOSH could begin tracking that and then identifying the worker population, it seems like it would be a golden opportunity to get ahead of an exposure for once, rather than always playing catch-up after it's out there and everyone's been exposed, literally.

Dr. Moore said this is a great comment because it really talks to point 1. So we study something, we start to find a challenge, boom, they switch. And we're like oh, okay, now we've got to run over here and try to study that and then switch because we find some challenges. And it's like, in a certain way, if you always take that approach, you're behind. They're always going to be pivoting to something that's an unknown, that's not well-characterized, and then we learn about it and there's a pivot.

And I think what you're saying is take a step back, look at the chemical classes, look at the families of the chemicals, and start asking yourself, "How can I categorize the chemicals and different things that are being used here, and do some evaluations on that to predict what they might be going to, and to then prioritize what we're studying in that way." So instead of reacting, being predictive and proactive. And really, it's got me thinking about a study that at the National Personal Protective Technology Laboratory we did, where we're, NIOSH's Respirator Approval Program, that's where we administer that program, and we were really work—we worked with the Department of Homeland Security a few years ago, because we were looking at the types of chemical agents that could potentially be used in various malevolent acts, where we were asking ourselves if some of the respirator types we have that are supposed to protect against those chemicals would, in fact, protect and do we have the right test representative agents? So the agents that we pick, are they reflective of the whole chemical family? And so, as you were talking, it just really got me thinking about

the researcher who did that, researchers who did that work with the Department of Homeland Security, and got me thinking that we might be able to really bring together some folks who've done work in other parts of our Institute, and bring them into this discussion, and they may have some creative approaches to propose to us along the lines of what you're saying is, you know, try to stop reacting and repositioning, and start trying to predict based on some of those things.

Dr. Reponen then posted question two, "What unintended worker health, health or safety consequences may be created as PFAS are phased out?" So we already discussed about the substituting materials could be more toxic. And I had here a comment, also what substitutes might not be so effective? So let's say, for example, for heat stress. Maybe they will not be so effectively blocking the heat or the moisture or whatever it's supposed to be blocking in material.

Mr. Morrison said I think what we have to do too for the workers is make sure that whatever we move to, that it still has the standard it has to meet. It still has whatever that standard is applied, where companies had used a certain chemical. Most of the time, companies use that certain chemical because it does the job. It does maybe not necessarily—definitely not on the health risks side, but they do the job. It just takes it outside of the turnout gear, for the water-repellent. When you phase something out, you want to make sure that you're not putting a worker in a situation that is more dangerous right now. What have we created, you know? You sort of, you do this and then you create something else. So I think, again, we have to talk about it in that if anything is replaced, that that replacement is tested, is certified, does exactly what we want it to do. And that's the challenge. We want to make sure that we just don't say, okay, let's clap our hands, we got rid of this one. But we've created something else. So I think, with this, for both of that, is that we are looking at not only the unintended consequences of new products but the safety advisory for workers, across—not just firefighters, across the board—that when we do something, have we made their job more dangerous by not making sure that we've understood exactly what we've done

Dr. Moore responded the thing that you said that just like hit my ears as you were saying it, you're talking about the standards, where standards are in place. And where we have standards in place, there's a mechanism to catch where we might have unintended consequences. Where there's no mechanism are going to be—is situations where there is no standard, there is nothing that we're testing against. So it got me thinking, just from the sake of how we might want to structure some of our activities, is specifically looking at doing some sort of analysis of where our—where might they get phased out, where there's an absence of standards. And there's going to be many situations where that's true. But that might be an interesting starting point for us to really figure out, because there's unintended consequences, but the second part of the question I don't think we thought about when we crafted it was unintended consequences that won't be caught by current occupational safety and health scheme or mechanism, right? So, at least in where there's those standards, we'll catch them. We'll know. Gosh, it would be terrible to have the ones where we don't catch it at all. And so that's really got me thinking about the second half of this question, that maybe we didn't actually have in here the first time, that you got me thinking about.

Dr. Calkins added I think one of the drivers when we talk about the replacements, and what's pushing to either better replacements in use or in the development of the replacement, with PFAS is largely that

environmental contamination component. And maybe that worker component is sometimes an afterthought. So there may be a push, where there is substantial environmental contamination from the use of a certain product, to get a new product in there so you stop that environmental contamination, which is certainly a very valid reason to push a replacement. But we also need to consider all the other components that are involved in that. So who's using it, when it is being developed, and not just the exposure that may result from contamination of the water source but exposure that may result from use of the product earlier on, before things transform in the environment, things like that.

Dr. Reponen moved to the last question, “what else should we consider to assist employers and protect workers against exposure to PFAS?” There was already a comment from the Board about the education of workers about the potential exposures and the health effects of PFAS.

Mr. Morrison said the workers want this information. They want to know how can I minimize my exposure. And I think that education, the material, we're doing that in our industry. We're trying to say, okay, if we have this, this is what you can do to protect yourself. And that's incredibly important. That's what we have to continue to drive home to make sure it's there too, that they understand that. Because sometimes, we can put it out there in the field right now for the workers and that, so what am I doing? We have to just make sure that we're giving them as much information—and realize that we don't have all the answers just yet. We're working towards that. But I think that's incredibly important for the workers, is to let them know exactly what is going on. What are we doing, why are we doing it, and how we can possibly get through this, not only to protect them but to protect, in some cases, their families when they're bringing this stuff, when they're bringing this stuff home to their houses, so.

Dr. Moore read the question in the chat, “What position statements of American Chemical—the American Chemical Society and other professional groups are there on PFAS?”

Dr. Stueckle said he looked at the ACS websites, and didn't see any position statement there. They may have one but I don't know about it. But in the slew of papers that did come up in my search, a lot of the issues that we've talked about this morning are being talked about in publication at least ACS. So I think everyone is involved in this, and I think maybe reaching out to some colleagues at ACS or those that publish in ACS journals, especially those materials scientists, may be worth an idea, at least for reaching out to.

Dr. Reponen thanked everyone and turned to lunch.

Public Comment

There were no public comments.

OSH Economics

Dr. Pana-Cryan introduced herself as the NIOSH Chief Economist, and I'm also a co-manager of the Healthy Work Design and Well-being Program. The Economic Research and Support Office or ERSO in the Office of

the NIOSH Director was established in late 2014. Economics was prevention a cross-cutting program in NIOSH but had no home in a division, laboratory or office. We currently have five economists in this office, and expect to recruit a sixth one soon to fill a position that was vacated late last year. And I also wanted to mention here that the list of publications that Maria has forwarded you include everything that these six individuals that have been in the office have published while in NIOSH. We have not included a much, much longer list of publications that have to do with economics that NIOSH has sponsored, so work by external partners or anyone else who has done economics in NIOSH but is not in the office. So, again, it's a small universe of publications.

Our mandates are to develop and implement an economics research agenda. Conduct applied economic research on economic factors and the value of prevention. Evaluate the economic impact of NIOSH programs and recommendations. Perform economic analysis and review of regulations. Provide technical assistance and training. And promote the use of economic metrics. Today's presentation I will touch upon all of those, but mostly I will tell you about our applied economic research.

Dr. Pana-Cryan showed the matrix and said that the previous presenters today mentioned different programs and goals, and our strategic plan. So this is the matrix of programs. What you see here is, on the top row, the sectors with their names, and then on the first column you see they're mostly health-focused outcomes. So I'm saying mostly because we're at the very bottom there, where the yellow arrow is, which is Healthy Work Design and Well-Being. So this cross-sector is new in this decade of NORA, the National Occupational Research Agenda, and is a collaboration between economics—among economics, work organization and stress-related disorders, and of course Total Worker Health. So that's where we fit in the matrix. I also wanted to mention that we have many core and specialty programs, and those are reflected—you know, the work of those programs, the research they do, the goals they address are reflected in the different cells of the matrix that are, you know, that represent also the shared interests of these core and specialty programs with sectors and cross-sectors.

Dr. Pana-Cryan continued that we co-lead the Healthy Work Design cross-sector. I included a couple of links. So you can see more about the programs and you can see more about the NORA Councils. Again, I'm pretty sure you're all familiar with what these are. So this particular cross-sector focuses on protecting and advancing the safety, health and well-being of workers by improving the design of work, management practices, and the physical and psychosocial work environment. In, we share a holistic perspective, the kind of merger of programs here in this cross-sector, on how work affects overall safety, health and well-being, including physical, psychological, social and economic aspects. So you can see more about the Healthy Work Design outcomes of interest, so I'm going to tell you a little bit about them by accessing our strategic plan.

The presentation purpose is to highlight the need for considering public health and economics together. I say this because for years, we've been hearing about the conflict, if you will, between economics and public health, and of course here also occupational health. So I think, you know, the pandemic made the world realize that it's not an either/or situation; it's a this-and-that situation. So, hopefully, I mean I'm sure you already have an understanding of this, but you know, that's part of my purpose today, to highlight this need. I will provide you with a few illustrative examples to discuss how we have been addressing our goals, focusing

on applied research. I will briefly discuss next steps, and then I'm looking forward to getting feedback from you all.

Dr. Pana-Cryan said first, I'm going to tell you a little bit about the research agenda. So, to this day, we're keeping our research agenda very broad. Over the years, before we became an office, we were a program with no real resources. We tried to be more specific under these broad categories, but here's where we are today. We still present this broad agenda of economic factors that affect worker safety, health and well-being so, in other words, say the incidence and severity of injury. The economic burden of worker injury and illness, that's a big one. And we also study the value of prevention. So pretty much, you know, what do things cost and what do we get out of our prevention efforts? How much does the prevention cost? How much do we get out of it in terms of the broad term of well-being? You can check out our goals and objectives throughout the NIOSH strategic plan and the National Occupational Research Agenda.

Here's an example of our priorities. You'll see some illustrative examples of these topics. I wanted to recognize Michael Foley, who serves on our NORA Council, the Healthy Work Design and Well-Being NORA Council. He has been doing work in this area, the broad area of work arrangements and contingent work. That's a priority area for us, both internal to NIOSH and through our externally facing councils. We are interested in mental health, we are interested in fatigue, opioids, and the overall Total Worker Health approach, the holistic approach of looking at protection and promotion in many other ways that Total Worker Health is interpreted.

Dr. Pana-Cryan explained that economics traditionally has a holistic approach. For example, economists do analysis at the family level or at the household level. I mention this because we are very interested in, for example, consequences of burden not only to the worker but also the family and beyond. I'm going to give you some examples of our applied economic research. The first one is employment, the next one is paid sick leave, the next one is work arrangements, and finally precariousness, and I will tell you a little more about the definitions of these things.

The first looks at employment categories and health-related metrics, among U.S. adults of prime working age. I believe it was 24—25 to 54-year-olds. I tried to include something about data at the bottom of the slides, and you also see at the bottom of each slide that is about research, the reference and in bold is the economist, in other words the ERSO economist who participated in this research. So again, a lot of what we do is collaborative.

This study compared employed workers to those who were self-employed, short-term unemployed, long-term unemployed—so the short-term was a year or less—and those unable to work. And the study found that short-term unemployment and self-employment were associated with poorer health outcomes, and the conclusion was that short-term unemployment is a particularly important focus for intervention and allocation of resources to prevent health declines that may hinder reemployment. That wasn't the only conclusion but this is just a snippet of this study.

Dr. Pana-Cryan continued that the following slide is about a follow-up sort of commentary that was published because our readers got excited about this schematic that you see that presents work as a social

determinant of health. And this is not complete. If it were complete, it would have arrows going any which direction. So the authors highlighted certain pathways, and this is what the slide is about.

I wanted to say that this was one of many, many efforts that NIOSH has been doing over the years with many partners inside and outside, to establish at least we think the CDC environment, this concept of work being a social determinant of health. And we have finally arrived to this stage, which is very exciting.

Dr. Pana-Cryan then transitioned to paid sick leave. This is one of the first studies we did in terms of understanding paid sick leave as an economic factor. And this one showed the association between paid sick leave and nonfatal occupational injuries. We used data between 2005 to 2008, and we found that workers with access to paid sick leave were 28% less likely to be injured when compared to workers without. And the association, there's association right across sectors and occupations, and the greatest differences were found in sectors and occupations with high risk of injury.

So, over the years, starting in 2016 or maybe a little before that, Dr. Howard ushered us to this space with a seminal publication that was focused on the legal understanding of work arrangements. Highlighting this chapter in the third edition of the *Handbook of Occupational Health Psychology*, because this reflects everything we have learned since that. There is a lot of confusion about the definitions of work arrangements, how to classify work arrangements, and therefore limited understanding of what the prevalence is. And also, there are related concepts. For example, some of them have something to do with temporariness, like contingent work where there is an expectation that someone's job is not going to last. And then we provided a summary and a curated literature review on the impact of work arrangements on healthy work design and worker well-being, and they're all in *The Future of Work*. Thankfully, this was co-authored by Dr. Howard, and we are very excited and looking forward for this to get out.

Dr. Pana-Cryan continued on the category of work arrangements, so this is an example on work flexibility and work-related well-being. This one used data that is published every four years, and the period is 2002 to 2018, and you can see, we defined flexibility in three ways: the ability to work at home, the ability to take time off when needed, and the ability to change schedule. You can see in bold the numbers are statistically significant at the 0.5 level or lower, and that's how I am presenting all the tables.

You can see that working at home increases the probability of experiencing job stress, increases the likelihood of experiencing job satisfaction. It shows, we show here that it increases healthy days. Let me explain to you what healthy days are. It's a simple metric that CDC uses that uses questions in surveys that ask, "In the last 30 days, what was your health status?" and then people have five options usually, all the way from poor to excellent. So then, different authors use different ways to express what is good health and what is poor health. And so when we talk about healthy days, the number of days in good physical health and good mental health are added together. And the days with activity limitations are sort of the same concept, except you have difficulty with daily life activities. The gist of this table is that, depending on the aspect of flexibility that one uses, the results are sort of nuanced. They're not straightforward.

Dr. Pana-Cryan showed another slide and said the authors here were trying to mimic European efforts to develop a precariousness scale. So, you know, we have data limitations in the States that didn't allow us to

fully mimic the European efforts but the authors were successful in constructing a work precariousness scale that included large buckets of temporariness, disempowerment, vulnerability, and wages. And so they assessed prevalence, the prevalence of different levels of precariousness, and the association about these levels of precariousness with well-being outcomes. The scale was a numeric scale, and then the authors took the top, the most precariousness, they called it high. That would be one-third of the scale, of the observations in the scale when the folks, the workers that they are assessed their survey responses. And then the moderate was the middle third, and then the bottom was the low precariousness.

For example, you can see at the first table here, that the folks who were in the high precariousness category, over the years, from 2002 to 2014, it went up and then it came down again in 2013. And you can see that there were more, a high percentage of workers was in the low precariousness category in 2014 than say in 2002. Then the second table here uses a comparison of the moderate and high categories of precariousness to low precariousness. And you can see that there were significant results for high compared to low, and you can see that the job stress was increased. And here, it's like kind of the flipped outcome of unhealthy days. So in other words, how many days your health was poor during the last 30 days, again considering mental and physical together. And so you can see that those in high, the high precariousness category, had about 0.4 days more that they considered their health status as poor, and they also had more days with activity limitations.

Dr. Pana-Cryan then transitioned to the economic burden. Very briefly, I will say that we define this as the broad economic consequences of injury and illness outcomes. What happens after the injury and illness? How big is the problem helps us to set priorities and to track changes over time. We're interested also in levels of analysis, who benefits and who pays. The majority of public or occupational health studies focus on the societal level, in other words, without consideration of who pays and who benefits. But again, I told you a little bit about the burden on the worker and the burden on the family. Then there's burden on employers and of course society overall.

There are three broad approaches to estimate economic burden, and here I'm just going to mention those to kind of orient you a little bit. The first approach is the most common. It's the medical costs and productivity losses approach. There is a seminal study by Paul Leigh published in 2011 where he estimated the national level societal costs of occupational injuries and illnesses. This type of method or approach is also used for analysis at the organization or employer level. So again, the decision-makers here are the public health, community, and employers.

There is another method that is about risk-money tradeoffs. This is the method that the U.S. Government uses, and the states, when they implement regulations. When they propose regulations, they are required to do an economic analysis and also look at the impacts in small businesses and what have you, and this is the main method used. So to estimate this, they ask people about their willingness to pay to avert something, for example occupational dying and in which way they die. People have opinions and rankings that, surprisingly, are consistent about these things. So that's what the government uses for regulation. So again, this is mostly used by decision-makers in the regulatory community.

Then there is a very broad category about reductions in health-related quality of life, or even quality of life, not necessarily only health-related. So one example here is the Global Burden of Disease metric of disability-adjusted life years. And that again is mostly about the public—used by the public health community.

Here are some examples on burden. I'm going to tell you about the burden at the national level, by health and well-being outcome, over time, and beyond work.

Dr. Pana-Cryan said at the national level, there is the cost of COVID-19 study. During the first year of the pandemic, this study estimated the costs comparing them to data before the pandemic, 2017 to March 2020, and then the first year of the pandemic. And also, this study looked at the reasons, you know, why did people lose hours of work. So you can see here the detail on the economic reasons, for example the slack work or business condition, and could only find part-time work; workers' own health; and other COVID-related reasons. And then I'm only highlighting here that the cost, the overall cost, regardless of reason, was estimated here with this data at \$138 billion.

This study is at the national level again about opioids and injuries that happen at work versus injuries that don't happen at work. So this study used data from 2010 to 2019, and found that occupational injury-caused conditions resulted in 33% higher odds of opioid prescribing, 32.8 more opioid prescription supply days, and a \$134 higher average cost. The study concluded that we need to focus on making work safer, and the role employers may play in supporting worker recovery from injury and opioid use disorders.

Dr. Pana-Cryan then detailed a study by health and well-being, this one is about hearing loss, and you can see that the years, they are 2003 to 2012. This study assessed the impact of quality of life expressed as annual disability-adjusted life years or DALYs that I mentioned to you a couple of slides ago. And the study found that among nine industry sectors, mining had the highest prevalence of workers with any hearing impairment, because they used different levels of hearing impairment, and followed by construction and manufacturing.

Over time, I will tell you a little bit more about this in the technical assistance couple of slides that I have. This is an effort that we are participating in for years with partners outside NIOSH, both academia and the Social Security Administration. This body of work links state-based workers' compensation systems data with federal data. The federal would be the Social Security Administration data. So this particular study estimated suicide and drug-related mortality following occupational injury. So much, much later at the workers' lives, that were injured, compared to whatever comparison group they have available. So this study found that there was an almost threefold increase in combined drug-related and suicide mortality—mortality hazard was the metric—among women, and a substantial increase among men. And the study concluded that drug-related deaths and suicides may be important contributors to the long-term excess mortality of injured workers, again, over and above the burden that these workers experienced for a few years after their injury, in the long, longer term, they also experienced additional health consequences.

This next one considered opioid prescriptions beyond work, opioid prescriptions not only in the workers' compensation system, like beyond the workers' compensation system there is additional burden. So the authors looked at the case of private group health insurance, and they found that the odds for injured

workers relative to non-injured workers to receive opioid prescriptions from the general, for the group health insurance, within 60 and 180 days from the index date of injury were 4.9 and 1.5, respectively, so higher. And the number of opioid prescriptions received within 60 days of injury was 2.5 times higher.

Dr. Pana-Cryan said beyond work is association or parent injury with emotional and behavioral problems in children, and the authors used different metrics. This, in the fourth column, ECBR, is emotions, concentration, behavior, or being able to get along with other people. In this case, they're looking at the children so "other people" would be children. And you can see that compared to the children who didn't have an injured parent, occupationally injured, the children of injured parents had more likelihood of being worried, depressed, having ECBR difficulties, and they had a lower attention span, and the last two columns, one was sort of a control column. There weren't significant. I think "gets along with an adult" was what they were checking, a category that won't be affected.

Dr. Pana-Cryan then showed the value of prevention examples. So cost-effective interventions. These are hard studies to do and so I only have a couple of examples. So this one is the impacts of paid sick leave in reducing overall absence due to injury or illness. So there are many, many benefits of having paid sick leave, and this study looks at one small portion of that, basically hypothesizing that the people who have paid sick leave, when they are infectious with influenza-like illness, if they have paid sick leave, they're going to stay at home and not spread it. And if they don't have paid sick leave, they are going to go to work and spread it. And so this study looked at what, if you will, the savings for employers would have been if they had, if they provided paid sick leave, looking at specific years of data from a specific source. The basic conclusion was that providing paid sick leave could have saved employers up to \$1.88 billion in reduced influenza-like related absenteeism costs, and that was the metric of the costs saved, because absenteeism is a metric that employers care about, per year during 2007 to 2014.

This next one is a study with the NIOSH Center for Workers' Compensation Studies. We have one economist bolded here at the bottom, Tim Bushnell, who is working about 25% of his time with the Center. And of course they're doing fabulous work, the Center does. And so they assessed the cost-effectiveness of, basically, subsidies that the State of Ohio, the Bureau—the Workers' Compensation Bureau in Ohio—is subsidizing health engineering controls for some employers, and whether or not this intervention, if you will, paid. And so the study found that for the years 2003-2009 that the total workers' compensation claim frequency rates decreased, and you see the other metrics. The lost-time workers' compensation claim frequency rates decreased by more, 78%. The workers' compensation paid costs per employee decreased 81%, and of course reductions varied by employer size, specific industry, and intervention type.

Dr. Pana-Cryan then went to another huge bucket of efforts, the economic impact of NIOSH programs and recommendations. I would urge you to go the links here that are the short story of this work we did with RAND. We contracted with RAND to construct six case studies over multiple years. The first report that RAND provided—and you can find the link to the report from the first blog link there—were the first three case studies, and then you see the years. 2018 was the first one published, and 2020 was the second one published. We had to pull out of other projects to assist RAND with this in that work. And then recently, we published sort of our insights after this experience, and that's the second bullet.

Dr. Pana-Cryan read the the title says “six case studies”. The topics were the development of silica dust controls in asphalt pavement milling, so the short title of this is asphalt milling. Building and disseminating evidence on firefighters' cancer risk—so listening to the presentations this morning was very interesting because this looked at many NIOSH and partner efforts to reduce firefighters' cancer risk. And the one I remember that was very applied in the different fire departments across the country, you know, implemented having, of course, the clothes washed. And then this last presentation about risks that have to do with washing the clothes, from firefighting activities. Also assessing the impacts of Ohio safety intervention grants for safety equipment. I already told you about the published study, and this was a little more broad in terms of the case study that RAND developed. The fourth one was developing continuous personal dust monitors for coal miners, and the last one listed here is re-design of ambulance patient compartments for safety. This would be the back of the ambulances and how, through NIOSH and partner efforts, injuries are shown to be reduced.

She said that we had criteria for choosing the case studies. The criteria were feasibility, in other words, do we think we have enough data, which of course you're not sure when you're trying to choose case studies. What would be the potential impact? What is the NIOSH contribution? Is there a balance among the case studies? For example, did we look at different sectors, did we look at different health outcomes, etc.? And then, of course, last but not least, institutional priorities.

The NIOSH advantage has something to do with the needs. What are the needs, how are these needs manifested, etc.? So perhaps, if it's a hot topic, the Institute has an existential reason to focus on the topic. And then I will also tell you that the way that the case studies were constructed, they're pretty much like you would do any cost/benefit analysis. First, we try to make sense—with a difference that we had to understand the NIOSH contribution.

Dr. Pana-Cryan said we had to construct a timeline of NIOSH activities. We had to basically guesstimate the number of workers affected, estimate the reduction or potential reduction in exposures, so that we could get the number of injury and illnesses cases averted, and how many of those were due to NIOSH, they go back to the contribution of NIOSH; monetize the health outcomes; and, when we could, compare benefits to costs. And we didn't do much of that because it was also difficult to collect the data in terms of the costs that NIOSH incurred.

She showed one example from the asphalt milling case. We found that—you can look at the first column, you can see what we were able to count in terms of illness and injury cases averted. And these are expressed as annual averages. So we were able to estimate 17-22 fatalities due to lung cancer, nonmalignant respiratory disease, and end-stage renal disease. And also, we were able to estimate about 71-77 nonfatal cases. And then you can see in the following columns, the monetary results using different metrics. Remember, there is the medical costs and productivity losses. For this one, we could only find data that had to do with fatal lung cancer. So not all the costs of all the cases, the fatalities, is included here. And then we also used willingness to pay values for the deaths and nonfatal cases averted.

She then talked a little bit about economic analysis and review of regulations, and technical assistance and training. I already mentioned some of these things. So I told you about the metrics used in regulations. All

regulations include economic analysis, and I mean all of them do. So when other agencies request feedback from partners and the federal government, we get requests from NIOSH to review this economic analysis. At minimum, you know, what is—did they do the basics, you know? Did they do a good job? For all regulations that come to us, versus other subject-matter experts that are focusing on their topic of interest.

Dr. Pana-Cryan also mentioned that we have been assisting with World Trade Center Health Program regulations. You can see how many of those were produced at your leisure. Regarding technical assistance, I talked to you about our long-term project with the Social Security Administration and what we do with them. I told you about the Center for Workers' Compensation Studies. I told you a lot about Healthy Work Design and Well-being. And I also wanted to mention, because we're still at the end of the pandemic, that during COVID, economists were deployed and also they took details to assist with the response issue. And given this experience, now we are involved in the disaster science response research portion of our Emergency Response and Preparedness Program. So we are now represented in the steering committee for this program and we're very excited about the opportunity to understand more about crisis.

She showed other examples like steering committees and councils. The Future of Work is an example; you have a link here. The mental health, the NIOSH Mental Health Initiative for Health Workers. Currently there is a lot of conversation with the experience of COVID in terms of the quality of jobs. Before the pandemic, we had to beg people to look at the quality of jobs, and now everybody wants to look at the quality of jobs. So it's really an exciting time, and we are involved in conversations, say with the BLS about the upcoming National Longitudinal Survey of Youth that's going to start in 2026. We were also contacted by the Government Accountability Office to talk about work arrangements. Also, the Danish National Research Center for the Working Environment reached out to us. They reached out to us last year, and they identified economists who do occupational safety and health research, and they brought them together in person in Denmark at the end of last year, and they want to continue this collaboration. They're still mostly academics, but we have to reach out to employers and workers like NIOSH is used to doing. And so hopefully, there is a future in this and we can establish some sort of international connection and learn from others and have others learn from us.

We provide training in NIOSH annually, and we also do workshops. We did one at the Total Worker Health symposium, the third one, the recent one, and we are planning one for the upcoming Work, Stress, and Health Conference.

Dr. Pana-Cryan then talked about upcoming activities. We continue research on work arrangements. We think work arrangements; we continue to be interested in paid sick leave. We continue to be interested in metrics for flexibility. Opioids I told you about. Burden, we have to update the national estimates of burden. We want to do more about the burden of stress and overall mental health. Disparities, we are starting to use kind of indicators of disparity as the main explanatory variables rather than covariates. Articulating the value of surveillance, because we're still traumatized with our inability to finish the amputation case study. I mean, that'd be great if we can make some progress on this topic, including training actually. That's another hard one to do, surveillance and training. And we're excited to start work on the economics of emergencies and crises.

These are some ideas that we have about expanding our reach and capacity. So we want to more proactively collaborate with others within NIOSH. We want to convene a virtual workshop with select economists from NIOSH-supported centers, all centers but Total Worker Health comes to mind as probably the centers with the most economists—to identify potential synergies. And again, I told you about our wish to build on the Danish efforts, to build and sustain an international applied research community.

Dr. Reponen thanked Rene and said that was very eye-opening for me just to understand how much wider this field is than what I had thought before. So thank you very much for this very thorough presentation. We first will start with just clarifying questions or comments to Rene before going to these detailed questions.

Mr. Morrison said on that slide that you have work arrangement, paid sick leave. Can you just go into the flexibility? That was work-at-home, time off, and changed schedules. So those are the three factors that you looked at?

Dr. Pana-Cryan said we struggled with this because there are so many things that you could include in this. For example, even the psychosocial questions, like the usual questions that our friends the psychologists are asking, that have to do with, say, autonomy and control on work. That can be a measure of flexibility. So this is not complete, if that's the question you're asking. These are three metrics that we decided to use for this particular paper. But this is not the universe that someone could consider or should consider when they talk about flexibility. A lot of these terms are not mutually exclusive. So I didn't tell you much about work arrangements. Between work arrangements and the case studies, I could spend an hour on each topic and there would still be a lot to say.

The number one question is, "Are you employed?" to define the work arrangement, because some people don't have an employer and they're not self-employed, and I'm talking about the gig workers who get gigs through a virtual platform or something. So that would be the first layer of how to categorize work arrangements.

The second layer has to do a lot with the quality of work. So it has to do with, of course, compensation and benefits. It has to do with scheduling. It has to do with other metrics, "Do you know your schedule in advance?" Horrible shifts, etc. And you can go down the list of the working conditions. So then, you can take some of those and call them flexibility. That's what I mean when I say there is a little bit of—you can cut it in many ways is the story that I'm saying. So, loosely speaking, you could put flexibility under work arrangements.

Mr. Morrison asked what would it look post-COVID?

Dr. Pana-Cryan said for this one, we didn't have data post-COVID. We tried, within NIOSH, we have done—we have done presentations that are not cleared to be presented in public, but just to reach out to our colleagues in NIOSH because that's one of the jobs we have to do. And it's a good job because we identify partners. We have looked at, say for example, which jobs can be done remotely. A lot of people have published about this but there's no one good way to assess it. But it's interesting to see the association of unemployment, unemployment during and, we're still in the pandemic but you know, things are improving, right? So which jobs allow you to work remotely? What does that mean about unemployment? Who has

access to these jobs that can be done remotely? Who experiences unemployment? And the more you dig into the sectors and the subsectors, the more you understand what's happening. So I think the short answer your question is that we're very interested in this topic and we're very interested in figuring out where we are now, and also tracking over time.

Dr. Pieretti asked "Can you expand why manufacturing is not included in the priorities?"

Dr. Pana-Cryan said thank you for this question. So when we put the goals together, the matrix that I showed you and the areas, the priority areas, to keep the goals at the reasonable number—for example, in previous years, not this decade of NORA or strategic planning but in the previous five years and the previous decades—people have difficulty to prioritize. That doesn't only apply to NIOSH. So people have anxiety that if I leave this very important topic off my list of priorities then I might never get to it. But the whole concept of priority is that you have to make the choices. So the reason you don't see manufacturing is because we had to negotiate with only so many programs when we were negotiating goals and priorities. So again, if you remember the matrix, we have the cross-sectors and the sectors, and then the cells in the middle that I left empty. If I could have put the core and specialty programs, for example the Center for Workers' Compensation Studies, another center we have on fatigue, etc., those would be represented in some, but not all, the cells of the matrix, as part of the teams that negotiated goals, and therefore research priorities, through this development of our strategic plan. So it's not because we don't want to pay attention to manufacturing. We hope that something that we learn from other sectors might apply to the sectors that we weren't able to include in our negotiations.

Mr. Foley said I know you have your priorities, Rene, and we all do, and I know you can't do everything. But I would like to urge some attention to be paid to not just the work arrangements but also the actual organization of the employer, like whether it's a franchise, whether it's a small company, whether it's in some sort of a supply chain relationship and therefore can't exactly control its own investment level in occupational health and safety.

Dr. Pana-Cryan said absolutely. And we have kind of dipped our toes in that.

Dr. Reponen posed the first question, "Within the priority areas mentioned, are there others who are doing valuable work?"

Dr. Pana-Cryan clarified now you heard about our partners, you know what the reach of NIOSH is, are we missing anybody who we should know about? And it could be by topic like Michael just did, right? Michael said, "Well, what about this issue? I didn't see it explicitly mentioned." So it's related but, maybe that gives us a hint in terms of what others are doing.

Dr. Reponen said the next question is, "Are we missing any priority areas?" So we already had a question about the manufacturing and you have, of course, selected these priority areas on, like you had to prioritize. But from the Board, are there some that should be included in these priority focus areas? She then asked about the study by Paul Leigh (2011). I was just wondering how relevant that information is, and is there any plans on updating?

Dr. Pana-Cryan said yes, there is a plan. We've been trying to do this for years. So in 2019, there was a study. Paul Leigh had to collect the number of cases, the number of deaths, in different categories. And for some categories, he could do better than other categories, depending on the data he had access to, okay. So he presented, he had to create it because it didn't exist, basically. Paul Leigh had used incidence-based metrics for some conditions and prevalence-based metrics for some other conditions. And so fast-forward, in 2019, NIOSH published a study led by one of our divisions that does field studies and epidemiology. It's DFSE. And they updated the epi estimates that Leigh had, and all of the estimates, the updated estimates now, are incidence-based. Which is an improvement. The trick with that is that if you have incidence-based estimates of lung cancer, then you have to project the future deaths. And thank goodness, the National Cancer Institute does that. So we have actually estimated the cancer portion based on the new incidence-based estimates of cancer, different types of cancer. And the missing piece is other chronic conditions such as asthma.

So that's where we are. So when we have closure, which hopefully is going to be soon, on the other chronic conditions, and for asthma, one way to do it is to say, you know, assume you get asthma and the consequences of that are the same every year for the rest of your life. I mean, there are some diseases that are better studied than others, and maybe asthma is good example. But in any event, we are close to wrapping up what the economists need to do the medical costs and productivity losses. That's where we are right now.

Mr. Foley added at the Karolinska Institute, which is in Sweden, they have done many other papers that also are approaching the issue of precariousness and its relationship to occupational injuries. Dr. Pana-Cryan thanked him for the mention.

Dr. Patel asked "Has NIOSH looked at differences between major industry sectors—this means by employer type and size—with respect to occupational health economics and burden, especially for any of the priority topics such as precarious work, job stress, mental health, opioids and COVID-19 or some chronic conditions?" So basically, looking at this between major industry sectors.

Dr. Pana-Cryan said yes, depending on the data stores that we use for our studies, we have better or worse industry information. So we don't have enough observations to do that. But we do also look at basic demographic variables —age, gender, whatever the database has—and we certainly are interested in industry and occupation. Usually we find industry. What we haven't done is say, "Here is a collection, Manufacturing, about all our findings that have to do with you," you know, like looking back at what we have done and what our plans are and say, "Here, did you know this, this and that?" You know, we haven't done that. So that's a good question.

Dr. Patel added as a follow-up to that, and specifically to the paper on cost of lost work hours for COVID-19, I was looking at that. And I know that one is more like an overall look at what was the impact of COVID-19 and lost work hours on the economy, and what may have been the factors playing a role into it. Was there any analysis done or are there any plans at NIOSH that do you want to look at how it may have impacted some of the essential workforce versus not? Or during the first, initial phase of the pandemic versus now, especially factoring in with the whole Great Resignation and stuff that had been going on in like early to late 2022, or even late 2021? You know, variations again, the same thing by certain states or industry sectors.

Dr. Pana-Cryan said we looked at essential workers and working conditions, as far as we could. And the definition of essential workers shifted over the pandemic. But we're definitely interested in all things that tell us something about why people stay on the job, why people quit the job, the reasons people quit the job. So for example, somebody quits their job, leaves one sector and goes to a different sector. How do people make decisions about changing jobs, if it's a choice?

Dr. Patel said since this is something I didn't see throughout the talk on any of those studies that you mentioned about, have you ever looked at the other health disparities or SDI index or all of those parameters when you do these types of economic analysis? And if not, are there any plans of doing so?

Dr. Pana-Cryan said yes, so I have it on my very long list of to-dos to look at indexes, and there is one that CDC uses. It might be the one you mentioned. We haven't done it but we will look at it.

Summary and Wrap-Up, Future Agenda, Meeting Dates, Closing Remarks

Dr. Reponen summarized that we had very good presentations from the NIOSH staff, and lively discussion. And some suggestions for the specific questions, and hopefully those will be useful for the investigators. Right now, we are going to discuss about potential topics for the next meeting, and I already wrote down, from the discussion with Dr. Howard, that health equity program could be potentially one. Another one was the communications staff to talk about how to improve the communication between state and local governments regarding information that comes out of NIOSH. So those two I had written down during the discussion. Are there any other topics that the Board wants to put on the list? We might not be able to do that many in the fall because we already have standing agenda items, but these can be then used also on next year's meetings.

Dr. DeGrasse said she would like to know if anyone has researched or looked into injury and illness rates for drivers of vehicles that are unregulated, so drivers of vehicles less than 10,001 lb. and folks who are working in that last-mile delivery sector. They are working in commerce, delivering packages in commerce, but those vehicles and that—they are not regulated by FMCSA so I'm not sure who regulates that, who's looking at researching into there. More so the Amazon and personal vehicle delivery drivers.

Dr. Reponen said yes, we can add that.

Mr. Morrison said another topics I'm interested in to see as it has been rising recently is workplace violence—especially in healthcare settings, where the client is the source of the injury. Also among bus drivers.

Dr. DeGrasse said it's really a big topic for us. They are being assaulted at an alarmingly increasing rate by students, parents, etc. and they don't have the same type of protections as maybe a transit driver who can, in some of the buses, has the protective barriers between them and the public. Not in school bus. Psychological safety is also a phrase that has popped up recently in my purview. What that is I think it's kind of a part of

this Total Worker Health framework. This is kind of new catchphrase that I've become privy to. And so how does that all really play into occupational health and safety, and then also psychological first aid is a part of that as far as folks who've experienced trauma while at work. Like if they experience workplace violence scenarios, if they were involved or witnessed it, or if they were involved, like you're a driver and you were involved in a fatality, like a crash-related fatality, and how that impacts mental health.

Dr. Reponen thanked everyone for their input and turned to Ms. Strickland.

Ms. Strickland said we are very much hoping to have an in-person meeting in our new D.C. office, probably some time in October. Pauline Benjamin, our Committee specialist, will be working with the members to determine some dates that would be a good fit for everyone and hopefully we have the new members on board.

Dr. Reponen wanted to thank again – we already said goodbye to these six members, but again want to thank they came back for this Spring meeting. So I have them in alphabetical order here. Tony Cox, Cristina Demian, Jessica Graham, Grace Lemasters, Pat Morrison, and Judith Su. So thank you very much, and particular Grace and Pat, you have done extended time. You were in the Firefighter Subcommittee. So, very much thank you. She then adjourned the meeting.

Glossary

| | |
|-------|---|
| ACGIH | American Conference of Governmental Industrial Hygienists |
| AFFF | Aqueous Film Forming Foam |
| ASPR | Administration for Strategic Preparedness and Response |
| ATSDR | Agency for Toxic Substances and Disease Registry |
| BLS | Bureau of Labor Statistics |
| BSC | Board of Scientific Counselors |
| CDC | Centers for Disease Control and Prevention |
| CMS | Centers for Medicare and Medicaid Services |
| DALYs | Disability-Adjusted Life Years |
| DFSE | Division of Field Studies and Engineering |
| DoD | U.S. Department of Defense |
| DoL | U.S. Department of Labor |
| DoT | U.S. Department of Transportation |
| ECHA | European Chemicals Agency |
| EPA | Environmental Protection Agency |
| ERC | NIOSH Education and Research Center |
| ERHMS | Emergency Responder Health Monitoring and Surveillance |
| ERSO | Economic Research and Support Office |
| FACA | Federal Advisory Committee Act |
| FDA | Food and Drug Administration |
| FEMA | Federal Emergency Management Agency |
| FMCSA | Federal Motor Carrier Safety Administration |
| GC/MS | Gas Chromatography-Mass Spectrometry |
| HHE | Health Hazard Evaluation |

| | |
|--------|---|
| HHS | U.S. Department of Health and Human Services |
| IARC | International Agency for Research on Cancer |
| IAFF | International Association of Fire Fighters |
| ID | Infectious Disease |
| LC/MS | Liquid Chromatography-Mass Spectrometry |
| MIOSHA | Michigan Occupational Safety and Health Administration |
| NASEM | National Academies of Sciences, Engineering, and Medicine |
| NCEH | CDC National Center for Environmental Health |
| NDAA | National Defense Authorization Act |
| NHANES | National Health and Nutrition Examination Survey |
| NIEHS | National Institute of Environmental Health Sciences |
| NIOSH | National Institute for Occupational Safety and Health |
| NIST | National Institute of Standards and Technology |
| NORA | National Occupational Research Agenda |
| NPPTL | National Personal Protective Technology Laboratory |
| NTP | National Toxicology Program |
| NTSB | National Transportation Safety Board |
| OSHA | Occupational Safety and Health Administration |
| PFAS | Per- and Polyfluoroalkyl Substances |
| PFOA | Perfluorooctanoic Acid |
| PFOS | Perfluorooctane Sulfonic Acid |
| PIGE | Particle-Induced Gamma-Ray Emission |
| PPE | Personal Protective Equipment |
| PTFE | Polytetrafluoroethylene |
| RHD | Respiratory Health Division |
| SFFF | Synthetic Fluorine-Free Foam |

| | |
|------|---|
| SNUR | Significant New Use Rule |
| TLV | Threshold Limit Value |
| TSCA | Toxic Substances Control Act |
| UCMR | Unregulated Contaminant Monitoring Rule |
| WHO | World Health Organization |

Certification Statement

I hereby certify that, to the best of my knowledge and ability, the foregoing minutes of the April 21, 2023 meeting of the NIOSH Board of Scientific Counselors, CDC are accurate and complete.

Tiina Reponen, PhD

Chair, NIOSH Board of Scientific Counselors
