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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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RELIABILITY AND PROBABILISTIC RISK ASSESSMENT

SUBCOMMITTEE

+ + + + +

WEDNESDAY

SEPTEMBER 23, 2020

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The Subcommittee met via Video Teleconference, at 9:30 a.m. EDT, Vesna Dimitrijevic, Acting Chair, presiding.

COMMITTEE MEMBERS:

VESNA DIMITRIJEVIC, Chair

RONALD BALLINGER

CHARLES BROWN

WALTER KIRCHNER

JOSE MARCH-LEUBA

DAVID PETTI

JOY REMPE

MATTHEW SUNSERI

ACRS CONSULTANT:

STEPHEN SCHULTZ

DESIGNATED FEDERAL OFFICIAL:

CHRISTIANA LUI

NRC STAFF PRESENT:

FRANK ARNER, Region I

JAMES CHANG, RES/DRA

MICHAEL CHEOK, RES/DRA

SUSAN COOPER, RES/DRA

JONATHAN DeJESUS, RES/DRA

MICHELLE KICHLINE, NRR/DRA

SEAN PETERS, RES/DRA

JING XING, RES/DRA

ALSO PRESENT:

ROY LINTHICUM, Exelon

JOHN STETKAR, public commenter

C-O-N-T-E-N-T-S

P R O C E E D I N G S

(9:30 a.m.)

CHAIR DIMITRIJEVIC: The meeting will now come to order. This is a meeting of the Reliability and Probabilistic Risk Assessment Subcommittee of the Advisory Committee on Reactor Safeguards. I am Vesna Dimitrijevic. Unfortunately ACRS Member Dennis Bley is not able to join us today and sends his apologies. Therefore instead of Dennis, I will be chairing this subcommittee meeting today.

ACRS members in attendance are Ron Ballinger, Charlie Brown, Walt Kirchner, Jose March-Leuba, Dave Petti, Joy Rempe, and Matt Sunseri. In addition, our consultant, Steve Schultz is also in attendance. Christiana Lui of the ACRS staff is the designated federal official for this meeting.

The subcommittee will hear presentation and hold discussion with NRC staff and industry representatives on the updated draft noted from NUREG-4198, the general methodology of an Integrated Human Event Analysis System, referred to as IDHEAS-G. And the associated software, tools, data and recent applications. The subcommittee will gather information, analyze relevant issues and facts and formulate reports, position, and action as appropriate for deliberation by the full committee.

So we'll say a couple of more words about the agenda today. IDHEAS-G was last presented to and discussed with this subcommittee about a year ago on September 18th, 2019. During that meeting, the staff also discussed other related activities that were near completion, plan, or ongoing at that time.

In addition to IDHEAS-G, during today's meeting, the staff will also discuss applying the methodology on Event Condition Assessment and associated software too, referred to IDHEAS-ECA, which is on the agenda, and IDHEAS-DATA sources. They are all on the agenda before the lunch. And after the lunch break, we will discuss applications of methodology and tools the FLEX human reliability analysis. And the subcommittee will also hear NRC and industry user feedback on IDHEAS-ECA. Given the large amount of material to be covered today, we will try our best to keep the schedule. But there is a good chance that we will finish later than 6:00 p.m. Eastern Time, which is listed on the agenda, so please plan accordingly.

The ACRS was established by a statute and is governed by the Federal Advisory Committee Act. The NRC implements this act in accordance with its regulation found in Title 10 of the Code of Federal Regulation, Part 7. As such, the committee can only speak through its published letter reports. We hold meetings to gather information and to perform preparatory work that supports our deliberation. The rules for participation in all ACRS meetings were updated and announced in the Federal Register on June 13, 2019.

The ACRS National Agency public website provides our chapter bylaws, agendas, letter reports, and full transcripts of all open full and subcommittee meetings including slides presented at those meetings. The agenda for this subcommittee meeting is posted there.

We have a bridgeline established for interested members of the public to listen in, to preclude the interaction of today's meeting, the phone bridge will be placed in listen-only mode during the presentation, visitation, and member discussions. We will add you to this bridgeline when we proceed to public comments agenda items.

As stated in Federal Register notice and the public meeting notice on the NRC website, interested parties who desire to provide written or oral comments may do so. And should contact the designated federal official five days prior to the meeting as practical. We have received requests from Mr. John Stetkar for time to make oral statements today. In addition, there will be time set aside for spur of the moment comments from other members of the public listening to our meeting when we proceed to the public comments item on today's agenda.

Due to COVID-19, we are conducting today's meeting virtually. A transcript of the meeting is being kept and will be made available on our website as mentioned. Therefore we request that all speakers identify themselves and speak with sufficient clarity and volume so that they can be heard. Please make sure your microphone is muted if you're not speaking to minimize any interference or background noises. All presenters, please pause from time to allow members to unmute and ask questions. When ready to move on the next slide, please also clearly identify the slide to be discussed.

Okay, so we will now proceed with the meeting. I call upon Sean Peters of the NRC staff to begin. Sean, you will be beginning because in the agenda, we have introductory remarks. So are you going to be making introductory remarks too?

MS. LUI: Sean, your microphone's muted.

MEMBER PETERS: Interesting. Sorry about that, it was showing non-muted from my -- on my screen. So, yeah, thank you, Vesna. I'll be putting the introductory remarks into my presentation here. And so I really want to put a thanks out to the entire ACRS Subcommittee and the members of my staff and our HRA teams who have put together all this work.

So today we're going to be talking about the Integrated Human Event Analysis System. We call it IDHEAS. And this is a human reliability analysis methods that we've been building over the last decade. And I'm going to go ahead and go to Slide 2.

So not every member of the ACRS has been here this entire time. This program has been going on since the 2006 timeframe. And so why are we here? So in 2006, then ACRS Member, Dr. George Apostolakis had a concern associated with the variety of HRA methods that were out there in the world. He was concerned that they were built for very specific context. And that people were starting to use them beyond those initial contexts. And so he kind of wanted the ACRS to review them and try to see, you know, where those various HRA methods can be applied or where they should be applied.

And so he sent a suggestion to the

Commission. And the Commission sent the assignment back to the ACRS. And the assignment told the ACRS to either propose a single model for the Agency to use or guidance on which model should be used in specific circumstances. I tend to use the words differently. I call them methods. To me a model is more -- a very plant-specific analysis or something like that. So when I look at that guidance, it says that the ACRS needs to make some type of recommendation.

So let me go to the next slide. This is just a timeline slide. This is Slide 3. So when we look at what the -- where the SRM fell in the timeframe. So we already had the PRA policy statement for the Agency. And the HRA staff and the NRC had already developed a good practices document that indicated what types of good practices HRA methods should have to be complete or quality HRA methods. And we had just completed an evaluation of those methods versus the good practices.

So this is a good time for us. The ACRS and the NRC staff and the research staff, we worked together at that time when the SRM came forth. So the very first things we did after that was to do an evaluation. And you'll see that on the International and U.S. Benchmarking Studies.

And I'm going to go to Slide 4 real quick. Slide 4 is just the references to that timeline slide. So it's not very important for us right now. But it's just a good item for feedback or when you're looking back at the methodologies.

So now to Slide 5. So when we're trying to answer the SRM, which method should be used in what circumstances, we actually needed to understand what the -- what is a good HRA method. And we didn't really have any real way to benchmark methods because there's not set standard for human performance. We don't know in a particular situation in a nuclear power plant, what the true success rate or failure rate of that is because there's no -- we don't have thousands upon thousands of accidents in similar context that we can determine true error rates.

So what we did was we went forth in an international benchmarking project. And this is a project that we worked -- and we presented this to the ACRS about a decade ago, the work we were doing. The benchmarking project, it took teams of international operators up to the Halden Reactor Project. And we run those operators through a set of experiments. These experiments ran them through complicated and simple accident scenarios. And what we also did was we teamed with a bunch of international researchers and we ran various HRA methods to try to predict the performance of those international operators.

And when we got that information back, we also had a second question. Well these are international crews in an international simulator. And not only that, but we didn't really run multiple teams using the same methodology. So we did similar experiments. I mean different scenarios, but similar experiments in the United States. We partnered with the U.S. Utility and ran crews through these similar type scenarios. And then we had HRA practitioners -- multiple HRA practitioners use the same methods. And we had just a small set of methods we were evaluating at that time.

And what we learned during those benchmarking programs was that we learned that every method had strengths and weaknesses. There wasn't one method that really stood out as the optimal way to do HRA for all the scenarios that we found. But what we determined, our international team, our U.S. team, we determined that if we were to tackle this SRM and we wanted to get a method or set of methods for the Agency to use, we could feasibly take the high quality bits and pieces of those existing methods and combine them together. So some methods may be better in quantification, others better in qualitative analysis. If we took those high quality qualitative analysis pieces and those high quality quantitative pieces, we can combine them together into a method. And so that was the approach we decided to take.

In addition, we decided that we needed to update the scientific basis for these because, again, the scientific basis for each method was built for a very specific context. So we started down the process of building a cognitive basis report. We did extensive literature reviews for the cognitive basis report, thousands of literature documents on human behavior, human performance. And it helped us develop a common structure for human reliability analysis, which we built the IDHEAS program off of. And we presented this to the ACRS. This is NUREG-2114.

And at the time, there was at least one member of the ACRS that kept referring to this as very, very high quality work. What he called the bible of HRA at the time. And we continued down and we worked with our industry partners and international partners to develop a methodology for at-power with the goal of reducing variability. And so that method is complete. However we had a major interruption into the development process.

Prior to the Fukushima accident, almost all HRA -- we were concerned with -- was internal events at-power. This was the primary focus of HRA at the time. Post Fukushima, we had a different problem. We had a lot of interest in ex-control room activities. And so what we -- and maybe even post-accident scenario activity. So when we took that back, we had to take a second look at the SRM and say what do we really want to do with the SRM? And if the SRM is a pick-up method or set of methods for the Agency to use, we started having to think a little more broadly. That we can't just have for internal events at-control and at-power. We needed to look at all the possible applications of HRA in the future for the Agency.

So I'm going to go to the next slide. This is Slide 6. And so on the development process, we decided to build a general framework -- the IDHEAS general methodology. The point of that general methodology is to organize all of our future development activities under a particular framework, so we can say hey, we have a set of methods the Agency can use. That framework allows us to develop application-specific HRA methods. It helps us generalize human error. And also it gives us a way to integrate data as a bonus, analyze human events, et cetera.

And from IDHEAS-G, we've developed this sub-methodology. This is IDHEAS-ECA. Because the primary use of HRA right now in the Agency is the SPAR-H methodology. And it's a very simple to use, simple methodology. So we had this kind of challenge in building IDHEAS-ECA. We needed to make it scientifically -- strong scientific foundation -- data foundation, but still yet very simple to use. And so we built IDHEAS-ECA based upon that cognitive basis framework, based upon the IDHEAS-G framework. And it's a very -- it's a human-centered approach.

And the nice thing about being human-centered is once you incorporate the influencing factors that are associated with all the context, you can start utilizing that human-centered approach to almost all NRC applications. So it can be used for both in and ex-control activities and other nuclear and we believe, even non-nuclear domains based upon the science that we use to do it. So if other agencies, entities, or other applications in the world want to use this, we think our methodology is very sound for those applications. Also we've developed --

one of the big differences between IDHEAS-ECA and IDHEAS-G is the build-out of the quantification model. And we have an easy to use software tool that we'll be presenting later today.

Next slide. This is going to be Slide 7. And finally, one of the big pieces of interest to the ACRS from the last meeting was the data that underlies our IDHEAS work. So this is new data that we've acquired and helped fill in for the IDHEAS quantification schemes. We are constantly evolving this data. We tie it to all the NRC data collection activities. So we have a scenario offering characterization -- a debriefing application. We call it SACADA where we are actively collecting crew training information from our utility partner.

We also have our own human performance test facility where we conduct experiments ourselves on student populations to gather more data to fill in our blanks. And we also work with the Halden Reactor Project. And we're trying to team with them right now to start an international HRA data collaboration where people from around the world shared their data -- their analyzed data on human reliability. So you'll hear about the IDHEAS-DATA report in the next session.

So just to give a little bit more

background on the IDHEAS program, again we've been doing this for over a decade. We've roughly had one ACRS review per year -- one ACRS Subcommittee review per year. When you look at the IDHEAS-G method, I really can't tell you off the top of my head the exact number of reviews we've gone through with the ACRS Subcommittee on this. But my best guess is around seven or eight reviews of the IDHEAS-G methodology. Because the SRM directs the ACRS to work with the staff. So we were bringing concepts and ideas -- ideas without the H -- to the ACRS to go over and what should be constituting in this method.

We've had two formal external peer reviews. And those were very helpful in the development process. They helped point out where we needed to make changes to the methodology. But I think the most -- the most helpful review we did on top of the ACRS feedback was our internal peer review. We had a couple experts in the development of PRA and HRA methodologies give us feedback that was really quintessential to finalizing our work in IDHEAS-G. We've tested this. We've utilized it to analyze events in Fukushima. We've went through those U.S. benchmarking events again with the IDHEAS-G framework. And we also applied it into new realms like fuel cycle facility events.

IDHEAS-ECA, you're going to hear about the testing today. We've tested it on FLEX scenarios, both on NRC and industry studies. And again, IDHEAS-ECA is built off that IDHEAS-G framework. So the testing that was done above on Fukushima, U.S. benchmarking, et cetera, that testing is highly applicable to the IDHEAS-ECA method also. And we're currently using it to look at ASP events. This is Accident Sequent Precursor events and significance determination process events. And over the next year, we're going to be incorporating user comments. People are out there utilizing this right now. And we're going to be taking feedback from those user comments and incorporating it into our revised reports and updating our software, too.

And finally with IDHEAS-DATA, we have opened up a contract for an independent party to review our data and help guide some of the development process for say on timing. And you'll hear a little bit more about that later. And we're also -- it's also possible, depending on what we do, that we may institute a peer review thereafter once we have that data more filled in. And we continually plan to update this based upon the data we collect. So our data collection activities are directed towards areas where we think there are weaknesses in the data report. So this is a continually growing process, constantly improving HRA and the Agency.

So that is the very last slide that I have. And with that, I can open up to questions or we can process to the next presenter.

CHAIR DIMITRIJEVIC: Okay. Do we have any questions from the members on this part? Okay, if there is not any questions, Sean, then we can continue to the next presenter. All right, is Jonathan's mic on?

MR. DEJESUS: I am working on it. Good morning.

CHAIR DIMITRIJEVIC: Good morning. Okay.

MR. DEJESUS: So okay, I guess I'm next. So good morning. My name is Jonathan DeJesus. I am a reliability and risk analyst in the Probabilistic and Risk Assessment Branch in the Office of Nuclear Regulatory Research. And the purpose of my part of the presentation is to provide you with a brief overview of IDHEAS-G. And tell you what changes we did based on our meeting last year.

Moving to Slide No. 2, so just some acronyms and terms. The only note that I'll make here is that IDHEAS-G uses the term performance influencing factor. And you may hear other presenters say performance shaping factors. They are intended to be -- They have the same meaning. They mean the same thing.

Moving on to Slide No. 3. Slide No.3, what it shows is essentially what Sean presented but in pictures -- as a picture. Oops, sorry. So it shows the overall framework of developing IDHEAS as a general methodology. So the framework starts with the cognitive basis for HRA, which as Sean mentioned, was published as NUREG-2114. So my colleagues -- I'll focus on IDHEAS-G and my colleagues will focus on IDHEAS-ECA and IDHEAS-DATA. IDHEAS-ECA is an example of an HRA application based on IDHEAS-G. And IDHEAS-DATA is the collection of human reliability data from many domains, which were generalized using the IDHEAS-G framework.

Slide No. 4, next. IDHEAS-G provides a cognition model and a process to implement that cognition model. So the cognition model consists of a cognitive basis structure and a performance influencing factor structure. The process to implement the cognition model consists of four stages. Stage 1 or scenario analysis, its purpose is to understand the scenario and collect information about human actions, which are used as the foundation to quantify human error probabilities.

Stage No. 2 or modeling important human actions, its purpose is to model the important human actions for the structure analysis and again, quantify human error probabilities. And I'll go into more details about these stages later. Stage No. 3 or HEP quantification as its name implies is just to quantify human error probabilities. And this is where the -- as you can see in Slide No. 4, where the human error data comes into play in informing the quantification of human error probabilities. Stage 4 or integrative analysis, its purpose is to address dependencies in important human actions and to document the uncertainties in the scenario and the analysis.

Now moving on to Slide No. 5. The first part of the cognition model is the cognitive basis structure, which describes that any human action can be divided into several tasks. Each task consists of cognitive activities which demand brain resources. Some simple examples of cognitive activities include like monitoring a parameter at a control room or operating equipment. The cognitive basis structure is a way to model cognitive demands of a task. And it is based on the concept of the macrocognitive functions. So these macrocognitive functions are the high level brain functions that must be successfully accomplished to achieve the cognitive activities of a task.

So IDHEAS-G uses five macrocognitive function as shown in this slide; detection, understanding, decision making, action execution, and inter-team coordination. Detection is to notice cues and gather information in the work environment. Understanding is the integration of various pieces of information in the work environment with a person's mental model and to make sense of the situation.

Decision making is selecting strategies, planning, adapting plans, evaluating options, and making judgments on qualitative information or quantitative parameters. Action execution is the implementation of the decision or plan. To make a change in some physical component or system. Inter-team coordination is related to how various teams interact and collaborate on tasks. One thing about these five macrocognitive functions, the first four can be performed by an individual or a single team. And inter-team coordination is the coordination between teams.

Slide No. 6 summarizes how, in general,

the cognitive basis structure explains the failure of human actions. At first, the failure of any macrocognitive function leads to the failure of a task. Underneath each macrocognitive function, there is this set of what we refer to as processors. So the failure of a macrocognitive function results from errors in one of those processors. And next, the error of a processor may occur if one or more associated cognitive mechanisms do not work reliably. And after that, it's the performance influencing factors which affect the capacity limit of each of the cognitive mechanisms.

Moving on, Slide No. 7. The second part of the cognition model is the performance influencing factor structure. IDHEAS-G uses performance influencing factors or PIFs to model the context. The contexts are the conditions that affect human performance of an action. As the slide shows, the PIF structure has four layers. And it starts at the top with the context categories. The first one, the environment and situation context consists of the conditions in which (audio interference) to perform actions. The personnel context describes who performed (audio interference) an individual, a team, or organic (audio interference) their skills and abilities, how they work together and the fitness to perform those actions. And the task context describes the cognitive and physical demands and the special conditions when performing a task.

The second layer of the PIF structure is the PIFs themselves. And as you can see, there are 20 of them. And each of them -- each PIF has a set of PIF attributes. And those are the -- that's the third layer. And a PIF attribute is an accessible trait of a PIF, what can be measured if you will. And the fourth layer is the link to the cognitive mechanisms. And as shown in the slide, we describe this is in Section 3.4 and in Appendix B of the report.

So moving on to Slide 8. IDHEAS-G as I mentioned has a process to implement this cognition model. And again, it consists of four stages. So Stage 1 includes developing the operational narrative, identifying the scenario context, and identifying important human actions. The cognition model provides guidance questions to collect information about the context that is pertinent to the macrocognitive functions and the performance influencing factors. And it organizes that input to be used in subsequent stages.

Stage No. 2 includes identifying and

analyzing critical tasks of the important human actions that were identified in Stage 1. Identifying the cognitive failure modes of the critical task. And assessing the performance influencing factors relevant to the critical task. The cognition model represents the failure of the important human action with the cognitive failure models, which were derived from the cognitive basis structure. And the scenario context are modeled with the PIF structure.

Stage No. 3 is the estimation of the human error probability or HEP. And the human error probability has two parts. It is the -- the first one is the error probability attributed to the uncertainties and time available and time needed, which we call P_t. And the second part is the error probability attributed to the cognitive failure modes, which we call P_c. The estimation of P_c is based on the cognitive failure modes and relies on the human error data that is generalized using the cognition model. And Stage 4 documents the uncertainties of the scenario analysis and assesses the dependencies between the analyzed important human actions in the scenario.

Slide No. 9. In this slide, I just want to show an overview of the human error probability quantification in IDHEAS-G. So as I mentioned, the human error probability has two parts; P_t. Again, the error probability attributed to the uncertainty and time available and time required. P_c, error probability due to the cognitive failure modes of a critical task. And the overall HEP is the probabilistic sum of P_t and P_c using the equation that I'm showing on Slide No. 9.

So Pt is calculated as the -- I'm going to use a fancy word, I guess -- convulsion of the two probability distributions of P_t and P_c. And P_c is calculated as the probabilistic sum of the error probability of each critical task. Then the probability of each cognitive failure mode is calculated as a -- of each critical task is calculated as the probabilistic sum of each error probability of a cognitive failure mode. And each of those -- each P_{CFM} is a function of the performance influencing factors.

Next slide on Slide No. 10. Here I go a little bit deeper into the P_{CFM}, what it is. And it can -- So P_{CFM} can be estimated using a 1 or a combination of the following ways. The first one, it's a database estimation. The second is expert judgment. And the third one is the HEP quantification model, which is what I'm showing in this slide. And it's what I'm going to focus on.

So this quantification model has two assumptions. The first assumption is the use of base performance influencing factors and their receptive base human error probabilities. After a review of the cognitive literature, we found that three PIFs that can change the HEP from a minimum value, very small number, to a value of one. And these base PIFs are information availability and reliability, task complexity, and scenario familiarity. The remaining PIFs -- the other 17 -- typically modify the base PIF by a weight factor, which is the W sub I that is shown here in this slide. And the definition is shown as well.

The second assumption is that the HEP -- that the quantification model does a linear combination of the W sub I's or the PIF weight factors. The linear combination is based on a limited metadata analysis we perform. At this time, there is no data, nor the cognitive literature has explained the mathematical relationship between the PIFs and their combination to HEPs. So we set this C factor to 1 for the linear combination. Next is the recovery factor, which we set to 1 unless data shows otherwise.

Moving on to Slide 11. The other part of the HEP -- I just described P_c and now I'm going back to P_t -- and this -- So this model for P_t was developed in response to ACRS comments. So we added -- a comment we received last year, we added a reference to this -- to the model we use in our report. So what this slide shows is a graphical representation of P_t, which is the area underneath the inner section of the two probability density function. And something else I should say, the P_t -- another way of seeing it -- it's the probability that the time required is greater than the time available.

Slide No. 12 provides a brief list of changes to IDHEAS-G since we met last year. We addressed ACRS and public comments. And a few examples of those changes include, we clarified the distinction between inter-team and intra-team of cognitive failure modes and performance influencing factors. We added language so the reader of the report can go directly to the HRA process in Chapter 4 without reading the technical basis for the cognition model in Chapters 2 and 3. We added a PIF attribute in the PIF staffing and physical demands to address personnel safety considerations. And each PIF in Chapter 3 has its own description table. So there are 20 performance influencing factors. So you'll find 20 tables in Chapter 3, describing each of them.

We added the list of reviewers in the acknowledgment section of the report. We received a comment about the use of "and others, et al." in the references. We addressed that. And many other editorial changes. One significant change I would say is that we proposed a dependency model. And this was encouraged by ACRS comments. And this dependency model is documented in Appendix K of the report. And this is where I am going to -- I'll briefly describe it in the next few slides.

Moving on to Slide 13. With respect to the dependency model, let me first describe what we call dependency context categories in this proposed model. The first category is consequential dependency. And it means that the outcome of a human failure event directly affects the performance of a subsequent human failure event. For example, taking a long time to complete a task results in less time to complete a subsequent task. A specific example of consequential dependency from operational experience occurred at Millstone Unit 3 in April 2005 where a spurious safety injection signal triggered a safety injection actuation and a reactor trip. The operators failed to control the safety injection flow. And that resulted in the pressurizer going water solid. That in turn increased work load and delayed subsequent operating actions.

The next category is the resource-sharing dependency. And it means that a task shares the same resources as a subsequent task. For example, there is limited staffing to perform multiple tasks. And a specific example of this type of dependency occurred at Palo Verde in May 2005 where the licensee simultaneously performed a boron injection system test and an atmospheric dump valve test that should have been performed in sequence. The boron injection test limited the charging flow and the atmospheric dump valve test increased the let-down flow. And that caused a high temperature in the regenerative heat exchanger. And a pressurized to level transient above the technical specification limits. And this also caused a loss of let-down.

The third category is the cognitive dependency. And this refers to the cognitive flow of two consecutive human failure events. And it occurs when the human failure event causes a biased mindset of the situation. An example of this is that a staff may fail a task because he or she has the wrong mental model. Or a staff may skip a peer check because they believe that the teammate is highly qualified, so he or she would not make a mistake. A specific example of this type of dependency occurred at Catawba Unit 1 in March 1990, where the licensee staff forgot to reopen sensing lines in three pressure sensors after maintenance. And which resulted in the RHR or residual heat removal system being over-pressurized. So those are the three categories.

Moving to Slide 14 --

CHAIR DIMITRIJEVIC: So Jonathan --

MR. DEJESUS: Yes?

CHAIR DIMITRIJEVIC: -- let's go back there. Because this is something -- I mean most of the other things we already saw before. But this dependency cited (audio interference) discussion that -- so if you have a consequential human action in the same sequences -- are you actually asking for those three types of dependencies to establish is there a dependency at all?

MR. DEJESUS: Well and that -- that was my next slide I was going to go like through the whole process.

CHAIR DIMITRIJEVIC: Okay.

MR. DEJESUS: So if you still have that

question after I go through my next slide, please ask.

CHAIR DIMITRIJEVIC: Okay.

MR. DEJESUS: I'm sure you will. Okay, this is Slide 14 and it's the process. So let's say that we have multiple human failure events in a cut set. In this case, human failure -- human failure event 1 occurs first. And then human failure event 2 occurs after HFE1. So the first step is to identify these dependency context categories that I just described.

Then moving to Step No. 2, for the subsequent human event -- or human failure event or HFE2, the analyst would ask okay, what changed for HFE2? Did the definition, visibility, critical task, time required and time available, the cognitive failure modes, or the PIF attributes -- did any of those change? If all of them didn't change -- so the process says okay, the two human failure events are determined as independent. So their joint probability is the product of the human error probabilities for each human failure event. That's going through this route here, the all-no in Slide 14.

So in contrast, if any of those is yes, then what the analyst would calculate it's a conditional probability. And probability of HFE2 given the occurrence of HFE1. And as the slide shows, it's based on the context changes. And this is calculated using the same method as individual HEPs. Or in other words, the HEP quantification model that I previously described. And if that is the case, then the joint HEP is the product of the marginal human error probability for HFE1 times the conditional probability of HFE2 given the occurrence of HFE1.

And if I -- Vesna, can you answer or --

(Simultaneous speaking.)

CHAIR DIMITRIJEVIC: Yeah. Well you know, I'm thinking about the -- so it's not only that you establish the dependency context first. Then you ask these additional questions in the No. 2. Right?

MR. DEJESUS: Correct.

CHAIR DIMITRIJEVIC: First you have to establish dependency context and then you ask additional questions. And then it changes to the -- yeah, this is becoming very complex actually. You know, before there was the simple questions and you sort of, you know, saying similar groups performing tasks in the similar, you know, timeframes. And here, this becomes a little more challenging. But you have all of this information if you already perform the evaluation of these human actions. Okay, all right.

MR. DEJESUS: Yes.

CHAIR DIMITRIJEVIC: Okay. I still have to think about that, but thanks.

MR. DEJESUS: Sure. And my Slide No. 15 -- what I wanted to illustrate here is the concept of the context changes as a picture. So the top figure here, what it shows is the -- what I say is the hypothetical case to that the occurrence of human failure event 1 does not affect the human failure event 2. And I say hypothetical because it's very hard to justify that they are independent. This is just illustration.

And the bottom figure, what I'm trying to illustrate here is, okay, the occurrence of human failure event 1 actually affecting the context of the subsequent human failure event or HFE2. And this is just illustrating Slide 14 in a different way, if you will. And for that, that concludes my prepared remarks. And yeah, I open it up to questions from members.

MEMBER KIRCHNER: Jonathan, this is Walt Kirchner.

MR. DEJESUS: Yes.

MEMBER KIRCHNER: Could you go back a few slides to your PIF structure? What I -- as Vesna observed, this gets pretty complicated. Yeah, so let me just pick on this one. Is there a danger double-counting -- if you look at environment and situation and you look at task for example, you've got things like workplace visibility and such. And then over on the task side, you have things like mental fatigue and so on. Do you run the risk of double-counting? If you already -- if you already say the environment is poor -- say the visibility is poor, then if you do a PIF for the actual task, how does this bookkeeping -- do you see where I'm going?

MR. DEJESUS: Yeah.

MEMBER KIRCHNER: Do you have double counting so to speak? And then propagating -- if there's a problem over in the workplace visibility, that's clearly going to impact execution of the task. So I was just trying to think through, how do you avoid double-counting these different factors?

MR. DEJESUS: Others may chime in; James, Jing, if you will. But my take on that question is with respect to the PIF attributes, an analyst -- and I'm sure James will describe this later. I hope I'm not like stealing his thunder here. But an analyst would select the different PIF attributes for each PIF that is applicable to the scenario being analyzed. So in that way as we went through the development of the PIF attributes, we tried to make sure that the PIF attributes don't -- And this has to go -- has to do also with the orthogonality or independence within the PIF. It's a goal that they are independent from each other, but it's really hard to do.

MEMBER KIRCHNER: Yeah, that was my concern that some of these are not truly independent.

MR. DEJESUS: Yes. And again, it has to do with what PIF attributes the analyst selects as he or she is analyzing the scenario in question. I'm not sure if I answered the question to your satisfaction or not.

MEMBER KIRCHNER: I'm just trying to mentally think through whether you -- as I said, I'm not expressing this very well. You're double-counting things. Obviously at the risk of repeating myself, if you have problems over in the first box there in the environment, they're clearly going to impact the task. So they're really not totally independent. So when you propagate -- If you had poor visibility, you would probably have problems with the task as well for an example. And therefore, do you multiply the two together? Are they additive or -- that was the kind of issue I was trying to think through when you do your bookkeeping and you propagate all these. Is there, like I said, a double-counting that goes on that skews the answer?

MR. DEJESUS: Yeah, yeah.

MS. XING: Jonathan?

MR. DEJESUS: Go ahead, Jing.

MS. XING: Okay. This is Jing. I want to make some comments on Jonathan's answer earlier. Yes, double counting was once in our mind when we started to develop this structure. So while the criteria was set up for this structure is trying to make this independent as much as we can. Also we can never achieve complete independence. So I agree with your PIF level. You would think, okay, if I've been working in a noisy environment, that would cause mild fatigue which is moderate in task. But those were addressed. We tried to separate as a factor in the PIF attributes. So for the environmental PIFs, the attribute will only take care of the aspect, let's say it's the physical factor. So the noise will physically interfere -- give you some noise information to your task performance.

And then the mental fatigue part will only attributes -- like some attributes; your mental fatigue were addressed. You've been working for very long hours, sleep deprivation, and after an intensive vigilant period. So those addressed the fatigue aspect. We cannot completely guarantee no double counting. And we hope like they still in the coming testing, people try out, either they say they're double counting (audio interference) of guidance to address the problem. That's my answer.

MEMBER KIRCHNER: Thank you.

MR. DEJESUS: Any more questions -- additional questions?

MR. SCHULTZ: Jonathan, this is Steve Schultz. Could you go back to your last slide on dependency?

MR. DEJESUS: Last slide. Let's do this, 15 enter. Yes, got it.

MR. SCHULTZ: Perfect. My question is general. I understand from the examples that you gave, the importance of including dependency in the model. But when you have those examples in retrospect, it's clear that those dependencies are in fact important. As you go forward then and put together the model, it looks like a good approach. It's going to -- It's going to set a stage that will allow you to reflect dependency as you've described them.

The question is how do you establish completeness in your overall evaluation? In other words looking back, you can see where the dependencies are. Looking forward, in order to establish a complete model, the analyst is going to have to do a lot of thinking in order to set up the models that are required. Maybe when we talk about application, we'll get into this. But it seems very difficult to establish these dependencies a priori so that you can determine the overall evaluation of human failure probability.

MR. DEJESUS: Yeah. And I agree that it's really hard to set those aspects a priori. And in my mind, this has to do with the iterative nature of PRA. So it's like, okay, going back and forth.

MR. SCHULTZ: Yes.

MR. DEJESUS: And so if -- if something is missing or deemed missing later, I guess the analyst would have to go back and requantify. And I say this not knowing like all the -- all the things that have to happen in order to requantify a model in this very, I guess, simplistic view. But yeah, my take on your question -- yeah, again the iterative nature of PRA.

MR. SCHULTZ: Will help you get there.

MR. DEJESUS: Yeah. Yes.

MR. SCHULTZ: Thank you. I'll keep that in mind as we go forward. Thank you.

(Simultaneous speaking.)

MR. SCHULTZ: -- examples later on today. Thank you.

CHAIR DIMITRIJEVIC: Did you establish an overall number for, you know, the multiple like human actions in a row? Like you know, now this is ten to minus five or ten to minus six in industry? Did you guys look at that? You know, if you have some areas where you have like three, four, five human actions in the row. Is there some -- did you establish a number which limits how low probability you can get with these multiple actions?

MR. DEJESUS: Oh, I -- yeah, go ahead, Sean.

MEMBER PETERS: Yeah. Hi, Vesna. This is Sean Peters, the Branch Chief of Human Factors Reliability Branch again. Yeah, we are working on that project right now. I'll discuss that a little bit at the end. But minimum joint HEP is kind of what we're talking about here as a minimum joint human error probability. There are industry standards out there that set that limit. But we are trying to work to refine the scientific basis under that. So there are limits based upon industry standards.

CHAIR DIMITRIJEVIC: Okay, all right. And my other question if you can turn to the one slide before that. Because that was my previous question I had some time to think about that.

MR. DEJESUS: Yes.

CHAIR DIMITRIJEVIC: Okay. So see here this Box 1. Right? If you don't identify every dependency context, do you still proceed to No. 2?

MR. DEJESUS: I would say yes, but the whole reason -- We talked about this. Like the main reason for identifying this dependency context is try to focus the analysts' attention when they go into Step 2. So for example, if you go consequential dependency, the example that I provided had to do with the time available for the subsequent actions. So if the analyst identifies, oh yeah, there's consequential dependency, then he or she may focus on yeah, going into the time available and time required element in Step 2.

CHAIR DIMITRIJEVIC: Okay. But it's not -- this Square 1 is not there to eliminate dependencies, just to focus on the analysts on the No. 2. Right?

MR. DEJESUS: Yes. Yes.

CHAIR DIMITRIJEVIC: Okay, all right. And that was actually my main concern because I could think of a lot of examples when there's no really sharing of the time or any sources that is now cognitive dependency either, but there is dependency related to, you know, PIF attributes and things like that. You know? Okay. All right.

MS. XING: This is Jing just to make a basic comment here. You know, that's a way you can think of those basically 3 steps. Each step is like a screening process for the next step. So hopefully that will reduce analysts' efforts in assessing dependency.

CHAIR DIMITRIJEVIC: Okay.

MR. DEJESUS: Any more questions?

MS. XING: Dr. Schultz has his hand up.

MR. DEJESUS: It's down.

MS. XING: Yeah, okay.

MR. DEJESUS: Hearing none, I guess we'll stick around for the rest of the day. And if anything comes up -- And with that, yeah thank you for your attention. And I'll stop sharing my screen so the next presenter, I think, James can share his screen. Thank you.

MR. CHANG: Thanks, Jonathan. I'm sharing my screen. Is my screen sharing okay?

MEMBER REMPE: Yes.

MR. CHANG: Shall I proceed in my presentation?

CHAIR DIMITRIJEVIC: Yes, please.

MR. CHANG: Thank you. My name is James Chang. I work for the Office of Research, Division of Risk Analysis Human Factor and Reliability Branch. My presentation topic is the IDHEAS-ECA. IDHEAS-ECA as shown in this IDHEAS series figure is located on the upper bottom. It's a design to implement the actually -- Jonathan, you are sharing your screen again. Sorry for the interruption. It's the preferred method to support NRC's regulatory implication. And as shown here, it's an HI application -- method HI application -- based on the IDHEAS-G as the framework --

MS. XING: James, please pause a little bit. Your screen is not showing.

MEMBER PETERS: We're still seeing Jonathan's, I think.

MEMBER BROWN: Well, we're seeing a really small version of it. It's not across the screen like the rest of them -- about two-thirds. It's hard to read.

MR. CHANG: Let me close my screen share and then share it again.

CHAIR DIMITRIJEVIC: Yeah, actually do --

(Simultaneous speaking.)

MR. CHANG: Actually I saw that Jonathan -- It seems Jonathan's screen is showing.

MS. XING: No, it cannot be Jonathan --

(Simultaneous speaking.)

MR. CHANG: Okay, let me -- Is the screen showing properly?

MEMBER PETERS: Yes. It is, James. Thank you.

MR. CHANG: Okay. Okay, so the IDHEAS-ECA was based on the IDHEAS-G framework. And then with the data coming from the IDHEAS-DATA that has been documented in the DATA reports.

MEMBER BROWN: James, what's ECA again?

MR. CHANG: Event and condition assessment.

MEMBER BROWN: Oh, I see it. I got it. It's on the slide. I got it. Thank you.

MR. CHANG: Yes. It's a method developed specific for the NRC's event and condition assessment in the NRC's recent informed regulation. Specifically that for significant -- determination process and accident sequence precursor. IDHEAS-ECA is an HRA process that was consistent with the IDHEAS-G process, but implement in the IDHEAS-ECA. That process is to analyze the event -- to identify the human failure event modeled in the PI model. And the critical task of this human failure event and associated context -- all this information to calculate the human error probability. It also contain has a software tool -- to implement -- to calculate the error probability and do documentation.

The IDHEAS-ECA is a method for all HI applications. That means that we plan for the action before core damage for reactor safety, spent fuel safety, and material safety. They are all HI applications. The reason we can do this was based on the IDHEAS-G that used the human-centered, system-neutral, the framework to assess the human reliability in all these applications. The parameter states on documents -- use in the ECA document in the IDHEAS-DATA that will be presented in my subsequent -- Dr. Kichline will present this subject.

Recently we had a workshop conducted to evaluate using a prior IDHEAS-ECA method for the FLEX action. That will be presented this afternoon. So the IDHEAS-ECA is -- the goal to the topic is to try to calculate the human error probability of the human failure event model in the PI. And the quantification element has a full quantification element. Pt is simply calculated the failure probability because of insufficient time given that the upper performance as planned and then all the requirements all the equipment things is all there. It's simply that there's no absence in perform this task. And the failure probability is because the time is not sufficient.

The second element is PCA is a cognitive failure probability. It's because the human error occurred in performing the task that caused the task cannot be performed, satisfied the success criteria. We modified cognitive failure mode that can compute to the PC that's including detecting information, understanding the situation, make decision making -- making the decision, or physically perform the action institution to change the event cause and that there's inter-team coordination.

The third element is the error recovery. In the IDHEAS-ECA that the data would put in there, that's already considered in the individual cell recovery. And the normal team -- recover within a normal team. So the error recovery here that we mentioned was that this resource -- error recovery opportunity typically could not exist within the normal team of scope. And there's a dependency that Jonathan talked about that I will address some of the committee's question on dependency data in my slide. So my data slide that I will talk about is four elements and we saw a demonstration of how we implement each of these elements in IDHEAS-ECA.

This diagram is showing the IDHEAS-ECA HI process. In the event sequence --

CHAIR DIMITRIJEVIC: James, would you just identify when you change the slides? You know, identify slide number, you know, when you change the slides?

MR. CHANG: Yeah, thank you. I'm on Slide 5. IDHEAS-HI process. For the event condition analysis that we typically have the PI model exist. And for the sequence -- we analyzed it based on these are PI models sequence. And then from there, we defer the scenario narrative that including what's the initiating event? What's the initial condition? What's the final condition? And given the system -- the automatic response in that sequence and then the upper trend response in the sequence -- this type of information provide a high level scenario of context.

Our interest then is to estimate the error probability of human failure events. So in there, we have identified a human failure event -- defined a human failure event. What's the success criteria? What's the scope of the -- this failure event? And then that goes into detail. What are the critical tasks? And then what are the cognitive function or cognitive failure mode involved in this critical task? So all this information together, that allowed the analyst to specify the context that's represented by the IDHEAS-ECA performance influencing factor. And then from there, that you calculate the cognitive failure probability Pc.

And the other path that once we have a human failure event identified -- scopes defined, that also calculates the high end sufficient probability. That was determined by two parameters. One is the time available and the other is the time required from there to calculate the probability. That's time required that will exceed time available. And these two, Pc and Pt together, that's to calculate the error probability of these human failure events.

Now I move to Slide --

MEMBER REMPE: James, before you leave that prior slide. When I was looking at your report, as well as seeing this figure here, I was puzzled why you don't show Step 8 on this diagram, which is related to assessing uncertainties. And as emphasized in the last presentation, ACRS often emphasizes the importance of considering uncertainty analyses in such an evaluation and a process. And so I'm not only bringing that point up here for your presentation, but it's a point I would like to see considered before you finalize this report that you ought to explicitly note all eight steps in this figure.

MR. CHANG: Yeah, thank you. Yeah, we discussed that Step 8, I'm certain in the report. I'm not showing in the figure. We will modify the figure to include the uncertainty in the process.

MEMBER REMPE: Right. And you even say in the report, not shown in the figure. Well, why not? Go ahead and please put it in the figure. Okay?

MR. CHANG: Yeah, thank you.

CHAIR DIMITRIJEVIC: James, I have another question which I actually had in the previous discussion, but never got to ask. Do you guys consider Pc and Pt independent?

MR. CHANG: Yes.

CHAIR DIMITRIJEVIC: Even the performance inference factor, which is time dependent? And you know, influenced the time stress related to tasks? So obviously that is a factor in Pc, which is Pt dependent?

MR. CHANG: Yes, Pt is a -- Pt, the time insufficiency is in the condition that upper (phonetic) -- performed a task without making mistake -- any mistakes. That's upper -- is available. And the reason, it has less failure probability is simply the time given this located for the test is insufficient. There's no upper error -- except simply success by terrace (phonetic) too limited. And Pc is the upper big error. So there's two as you can see today, excluded to each other and independent to each other.

CHAIR DIMITRIJEVIC: Well they both have human error probabilities. Right? One is the time, but do you have sufficient time, as you call it, fancy evaluation in the graph it is -- allowable time and the required time. But this probability, which tells you that you have a sufficient time. But you can have a more or less sufficient time of course. Right?

MR. CHANG: Yes. Yes.

CHAIR DIMITRIJEVIC: So therefore that influenced your task stress, doesn't it, which is one of your performance influence factors.

MR. CHANG: Right. But that is considered in the -- When we have the involved this performance inference factor, these belong to the Pc -- the scope. In the Pc, in the upper, make an error that could take longer to complete a task. And then that exceeds the time available for the task. That is insufficient time. But the reason of that time insufficient is because of error in performing the test. Not if upper -- didn't make an error in performing the test, that would be coming -- belong to the Pt, that category.

CHAIR DIMITRIJEVIC: All right, okay.

MS. LUI: Sorry, James. I need to interrupt briefly. Whoever is calling in on the public bridgeline, please mute yourself. You are interrupting the other listeners. If it does not improve, we will disconnect the public bridgeline, wait five minutes and reconnect. Thank you. Sorry, James. Please proceed.

MR. CHANG: Now I move my slide to Slide 6. Title, HFE quantification structure. This structure is showing the -- is the way that we implemented in the IDHEAS-ECA tool to calculate human failure events error probability. The error probability of HFE consists of human Pt and Pc. The Pt, this portion is calculate probability -- is probability sum of these error probability of these is critical tasks. Each critical task error probability is the probability sum of its cognitive failure mechanism -- sorry, cognitive failure modes probability. That included detection, understanding, decision making, action execution, and inter-team coordination. The error probability of each cognitive failure mode is the function of the performance influencing factor and their attributes associated with that cognitive failure function.

From here, I'm going to talk about each of these error implementations in the IDHEAS-ECA. I prepared three slides to talk about this. But I think the best is going to move through the software -- use software to explain this concept that makes the explanation easier. So from this point, I will switch to software and then come back to the PowerPoint presentation after the software demonstration.

This is showing the IDHEAS-ECA tool that the NRC staff has developed to implement the ECA method. This tool -- calculation is to calculate one human failure error HFE's error probability. It has a component of the Pc and Pt two elements. So Pt is simply based on the distribution of the time required and the time available. The software provided this distribution for the user to specify the time required distribution and the time available distribution and then took it and calculated the probability that the time required would be exceeding the time available.

Staff implement this is not used for the tool distribution. We do not implement the convolution equation calculate that exactly. But instead we use the Monte Carlo simulation. Simulate each distribution 1 million times to get the -- to calculate the probability. For the event sequence analysis, a lot -- most of the time that the time available is -- instead of the solution is simply a custom number that we also the software provided a function that simply set a single value for the time available. So that's the calculation of the Pt.

For the Pc, this portion that each critical task has five major cognitive function -- that is shown here; detection, understanding, decision making, action, execution, and inter-team. Each cognitive failure mode associated with this software performance influencing factor as shown here -- detection shown here that's on the drive that's showing this influencing factor related to the detection. This set of performance influencing factor is subset of these 20 performance influencing factors identified in the IDHEAS-G. It was because that some performance shaping factors affected one cognitive failure mechanism mode, but does not contribute to the other cognitive failure mode.

For understanding -- Here is showing the understanding -- there's a cognitive failure mode is associated with this performance influencing factor. The factor in red text is the basic PIF. Their effects on the error probability is to provide a basic HEP as shown in -- Jonathan presented that equation in calculating in HEP in IDHEAS-G presentation. The PIF improved -- their effects on error probability is to modify the basic HEP. So together that these sets of PIF affected the error probability. For each performance influencing factor, it contained a number of attributes. These attributes provide the specific condition that's in that performance -- the specific effect on the human error probability.

So you presented earlier that one of the members asked about this overlapping question. This overlapping question that we're addressing in here, it's one of the -- my answer was this attribute -- we presented the condition. The condition that when we're performing the task, if the condition exists that is simply a check -- that analysts will check that condition. And then that software will calculate the aggregated error probability.

So in this case here -- that scenario for me for example. And then the understanding was that -- assumed that analysts identify SF-1 that's unpredictable dynamic in the long scenario of this condition that presents in this HFE and then the user would check that. And that was -- a pop-up screen will pop up. That's the analysts to provide specification why -- what's the specific that this PIF attribute is checked? Once it's checked that all the information shown on this corresponding display panel. And then the effect that the HFE of that specific cognitive failure modes is calculated. And that is the process -- this condition exists that user sends checks the Pi attributes and then that's the attribute will update it.

Well some of these PIF attributes presented a range of effects. For example in this SF-3, it's infrequent that you perform this scenario. That infrequency presented a large spectrum. That's from the scenario simply that it's trending, but not frequently performed to the degree that extremely rare performed. So for this type of PIF attribute, we provide a scale of one to ten. And then provide anchor points with discretion that analyze to judge what's the appropriate level that these PIF -- we present in this situation? And that's sent into -- into the effects and then come to the top.

The user goes through this thing, goes through that, identified all these PIF attributes -- prior to a different metacognitive function. For the metacognitive function not included in the critical task that we allowed the user to de-select the function. So that the attribute was not included in the calculation.

Before we enter into each one, you see that for each metacognitive function that we have a basic attribute. This represents as residual attribute that's human -- given all the conditions; performing the decision making, even all the condition is good that humans come to the data -- that humans still end up -- one thousand decision making skill has evolved 1 at will make an error. So that was the minimum attribute for each metacognitive function we implement in the -- in the IDHEAS-ECA method. So the user can go through this process to calculate each critical task error probability. And then if there's more than other critical tasks included that -- I've come to the end of the error probability on the Pt and the Pc will be probabilistically calculated to become the error probability of this human failure events.

So this conclude my presentation of this software. Now I go back -- Before I go back to the PowerPoint presentation, is there any questions from the Committee?

MEMBER KIRCHNER: Yes, James. This is Walt Kirchner again. Just looking at the chart that's up, is there default in the IDHEAS-G framework or now in this framework -- ECA framework for detection, understanding, action, and so on? I'll just pick on one. Look at the action number. That's 1 in 10,000. Simple things like operating the microphones in our ACRS meeting room have a much higher probability of failure --

MR. CHANG: Yes. Yes.

MEMBER KIRCHNER: -- than that. I wish that we could go back to our conference room and try it. But seriously, so is there a set of defaults for all these in IDHEAS framework?

MR. CHANG: Yes, before this number that you see here that's --

(Simultaneous speaking.)

MEMBER KIRCHNER: Okay. So these are the standard defaults that you start from --

MR. CHANG: Yes.

MEMBER KIRCHNER: -- for most exercises.

MR. CHANG: Yes.

MEMBER KIRCHNER: Have you data to demonstrate that these are good numbers? And how does that correlate with your -- you know, your benchmarking based on exercises at Halden and elsewhere since?

MR. CHANG: The development team that internally we compare this with the past Hi calculation provided by different methods that we think is consistent. But this afternoon, the FLEX implementation will provide more information in this aspect.

MEMBER PETERS: Jing, can you elaborate a little bit more on the data that backs this up? Thanks.

MS. XING: Okay, this is Jing. So I think after Jim's talk, I will -- Yes, these numbers -- the base number which is what you mean by default number when you don't select any PIF attributer, so the lowest HEP for action would be E minus four. And this number is developed from like 20 other different sources from the data. So we have a good data basis for these numbers. If you're interested, I think I can talk about this in my presentation.

MEMBER KIRCHNER: Sure. I think it's -- you know, to make it more tangible and correlate with your exercises and benchmarking, I think that's useful insight at least for myself as a former operator. So thank you.

MS. XING: Thank you. And please remind me of the question in my talk, so we don't forget. Thank you.

MR. CHANG: Any more questions? Okay, hearing no questions, I'll switch to the PowerPoint presentation.

MEMBER KIRCHNER: Madam Chairman, is it possible that we may have a break?

CHAIR DIMITRIJEVIC: Sorry, I cannot find my microphone for the moment. Yes, I was going to propose that we have a break in this moment. It's 11 o'clock -- 11:01. So let's take break of 15 minutes to 11:16. And then we will continue with the next presentation. So far we are ahead of game, which is good sign. All right? So see you all at 11:16.

(Whereupon, the above-entitled matter went off the record at 11:01 a.m. and resumed at 11:16 a.m.)

CHAIR DIMITRIJEVIC: Okay, it's 11:16. Right now, we will continue with our meeting. James had additional slide he would like to present to us from his presentation before we go to the next one. James?

MR. CHANG: Yes, thank you. Thank you, Vesna. This is my final slide. Before that, I talked about the calculation of the Pc and Pt. And those two other elements; error recovery and dependency. Error recovery already mentioned. That is we only credit the resource that's not normally available within the scope -- the typical work scope that's including the self recovery and team recovery. That's because the data -- we implement that the HFE calculation data, we consider that this type of recovery has been included in the data. That we only saw error recovery only including that moment, that additional resource that's able to reduce error probability that typically is not available in the normal team situation.

The other was dependency earlier -- the discussion on the dependency. IDHEAS-ECA implemented the same dependency assessment process. Because the development team thinks IDHEAS-ECA coverage -- has extensive performance influencing factor coverage when you narrate the details. That is sufficient to capture the dependency effect. So the team decided not to -- decided to -- by modifying the -- based on the dependence contact to update the PIF status to reflect that the dependency effect, instead of using the five level dependency. That is typically considered whether performed by the same people in the same location as the same queue -- the time is close in time, the manpower, all these factors. For that reason, I mentioned that we have extensive Pi coverage we can -- we think that can cover these dependency effects.

The second is that when we use IDHEAS-ECA PIF attribute to capture the dependency effect, we know exactly what's -- the dependency mechanism and impact. And that allows us -- some of them allow us to improve human reliability by reducing the dependency. That's improving human reliability aspect is not available using the current five level dependency model.

And the other aspect -- and the other aspect about these dependency from each perspective aspect and the predicted aspect, my third thought is that dependency -- yes, there's uncertainty. How the dependency mechanism may or may not occur. So in the assessment, this could put into the sensitivity and that allows us to understand the bound of this dependency impact. That concludes my presentation.

CHAIR DIMITRIJEVIC: All right. Thank you, James. Okay. Will we have some examples of dependencies when we speak to the FLEX examples?

MR. CHANG: I will let the FLEX team answer that question.

CHAIR DIMITRIJEVIC: Okay.

MS. COOPER: Let me just answer it real quick. This is Susan Cooper, Office of Research. I'll be one of those presenting the results later. No, the dependency model was not ready when we did the FLEX HRA.

CHAIR DIMITRIJEVIC: Okay, all right. Well I was curious because James just expressed doing it this way, you know, give us opportunity to identify source of you know, dependencies and therefore reduce potential dependencies. But okay -- I mean it's always better to see this in example if possible. But if not, we will abstractly think about it. Okay, thank you.

MEMBER PETERS: Yeah. Thank you, Vesna. This is Sean Peters again. The dependency is very, very new. It's a very new addition and it's based upon the last feedback from the ACRS. So yeah, we haven't had a chance to fully exercise this new dependency model.

CHAIR DIMITRIJEVIC: Okay. But you know, you guys sort of the dependency actually most of the time, you know, dominating the PRA sequences. You know?

MEMBER PETERS: Yeah. And based on the feedback from the ACRS -- the ACRS in the last meeting was not very happy with existing dependency models. And they indicated to us in the meetings that the way IDHEAS has already calculated human error probabilities was very, very close to what they considered a complete dependency model. That being utilizing the context from the first failure and then recalculating the subsequent dependencies. So this model we're implementing is actually one that was kind of recommended to us by the ACRS. And we agree with that.

We think we are very close to providing more salient contacts to our dependency calculation. So as James said, given that we do a contextual based, instead of just these five screening questions, we can actually get to the root causes of the dependency and help people that utilize this method to break that dependency. So that's all I have to say.

CHAIR DIMITRIJEVIC: All right. Okay, thank you. Okay so --

MEMBER REMPE: Vesna, this is Joy. I guess I've been listening to this and thinking about what I've been reading to prepare for this. And again, this isn't my area. But there's been some recent issues with the FLEX equipment where error has contributed to failure. They have -- like these diesel generators because of their being commercial grade, human error led to them perhaps not having appropriate maintenance or testing programs in place because they were used for a different application than what the vendor intended. And I'm just kind of wondering -- I mean is something like that going to be considered?

I don't expect it to be -- I didn't see anything about what I read to prepare for this meeting. But while Sean's on the line and we're kind of opining about things, how would that be considered? And it's mainly -- my question is focused on the FLEX equipment. But I mean clearly it led to higher failure rates. So is that a failure rate that -- or an uncertainty that should be considered in the equipment performance? Or is it something that should be considered in this human error program?

MEMBER PETERS: I hate to do this, but is Michelle Kichline on the line? I would love to kick this question over to NRR because, you know, from our perspective --

MS. KICHLINE: Hi.

MEMBER PETERS: Oh yeah, Michelle is here. Wonderful.

MS. KICHLINE: Yeah. Sean, I'm here. So I would say that the human error associated with the failures of the FLEX equipment when it's not being operated to perform its normal -- it's FLEX function. You know, they haven't had -- they're not using the procedures to implement it. They're doing maintenance. Those error probabilities would be covered under the equipment failure probabilities.

MEMBER REMPE: Okay. And I assume that somebody's talking -- I mean again, we're learning and hopefully a lot of these things will disappear as people become aware of it when they're doing their maintenance and testing. But jeepers, if they needed it for something, plus the FLEX equipment, some folks are saying we're going to start trying to use it for other non-FLEX type events. People need to think about that.

MS. KICHLINE: Yes.

MEMBER REMPE: And the human error folks need to communicate with the other folks to figure out --

(Simultaneous speaking.)

MEMBER REMPE: Say it again, I'm sorry.

MS. KICHLINE: Industry shares operating experience. And in NRR, we also have an information notice that's going to go out about --

MEMBER REMPE: It has gone out. That's how I saw it.

MS. KICHLINE: Oh, it did go out already? Okay.

MEMBER REMPE: Yeah.

MS. KICHLINE: About the failures to inform the industry and ensure they're taking actions. So that is regularly shared. And the Owners' Group is working on a report that puts together what the equipment failure probabilities should be.

MEMBER REMPE: Great. Thank you. Sorry, I know it's off topic, but it's been on my mind.

MS. COOPER: So if I could jump in just real quick on this too. This is Susan Cooper. It's not part of the presentation planned for this afternoon on the FLEX HRA, but it was part of a joint presentation with Mary Presley from EPRI at the NEI FLEX forum a couple weeks ago. And that we identified that the way in both of our efforts we applied HRA was using assumptions that the FLEX equipment was indeed robust and simple to operate.

And we indicated in our slides that -- something about, you know, some of the anecdotal OpE that we've seen. And that if there needs to be something -- a different characterization of the equipment that would change the HRA -- our HRA evaluations. Because you know, it's not like we can go and watch demonstrations of the equipment like we can watch operators in a simulator. We have to base it on you know, planning and walk-downs and so forth. So we can't actually watch them do things. We have to take some of the information on you know, just what we're told. So if that's different than what we're told, then we would evaluate things differently.

MEMBER REMPE: Thank you. I'm interested. And if it's possible to send that presentation to Christiana, I think it would be nice for us to be aware of it.

MS. COOPER: I think Michelle Kichline has all of the NRC presentations. I know she was working on getting them into ADAMS. That would -- But otherwise, I can certainly just send my -- you know, send that particular presentation to Chris.

MEMBER REMPE: That would be great. Thank you.

CHAIR DIMITRIJEVIC: I would like -- I

would like to add something just for the general information and for us when we think about this what happened with these multiple, you know, failures with the FLEX equipment. So with the multiple equipment fails for the same reason is called common cause. Often the result of common cause -- very often in very high percentages, common cause is the result of the maintenance items. In the PRA -- these common cause errors that actually we have a specific date for them of course, not for the FLEX equipment because this is relatively new.

Also in the PRA, when we tend to put the maintenance error or what they call pre-initiator operator errors, they are included in the model. However, FLEX is also new with inclusion in the PRA model. And it's definitely not on that level of detail that pre-maintenance errors can be included in that. So you know, these type of errors, we just need the more date to be included in the FLEX inclusions in the risk assessment. So that's my take on this. I don't think anybody at this moment is ready to -- you know, to have data on how the maintenance error review. This is the first events we are seeing. So very soon we will have data on how to include this, you know, maintaining the errors in the common cause factors for the FLEX equipment.

MEMBER KIRCHNER: Vesna, this is Walt. I would add -- Maybe to Susan Cooper, I would just point out that perhaps the IDHEAS staff team could observe some FLEX deployment exercises to gain data. I don't want to say there's -- you know, obviously they're designing the FLEX equipment for ease of connection and so on. But it's a non-trivial thing to power up with FLEX equipment and demonstrate functionality. And there's a lot of -- how should I say it? A lot more human factors involved versus say a control room exercise.

What I mean by that is the equipment itself, taking a play on words, you're deploying the equipment in real time and connecting it and powering it up, et cetera, et cetera. And there's a lot of opportunity for problems I should say. More so than you would expect like in a control room where the equipment is fixed. You drill all the time or you operate all the time with it. It's an interesting area to take a look at from a standpoint of human factors.

CHAIR DIMITRIJEVIC: Okay. So if anyone -- Any more questions or should we proceed? I think we can proceed now. So Jing Xing, please proceed.

MS. XING: Okay. So does everyone see my screen?

CHAIR DIMITRIJEVIC: Yes, we see your screen.

MS. XING: Okay, great. So I can start. Glad that we have a smooth transition here. Okay, so this is Jing Xing, a Senior Human Performance Engineer working in the human factors in the Reliability Branch for Sean Peters. So I'm going to talk about IDHEAS-DATA and show you how we use human error data and IDHEAS different work to support IDHEAS-ECA that Jim presented earlier.

Okay, Slide 2. Okay, so you have seen this -- This is the third time you've seen this slide this morning. And so the red circle is where I'm going to talk. As you see from this diagram, IDHEAS-DATA takes its basic structure from IDHEAS-G, the general methodology and its inputs are the -- all kind of human error data such as the SACADA. And it's output goes to IDHEAS-ECA to support HEP quantification there.

Next, Slide 3. So here are the four topics that I will be going over. First, I will introduce our approach of using human error data for HRA. Then I will brief the status source evaluations, so you have an understanding of what kind of data we have there. Then next I will talk about how we generalize the data sources. And at the end, I will talk about the -- I'll tell the story of PIF in combination from data perspective.

Sorry. Okay. Slide 4 is the overview of our approach in using human error data for HRA. It's a three step process. The first step is the evaluation of the human error data sources. When I say data source, it can be a research paper from the literature, it can be an organizational report like a NUREG, or it can be a database like SACADA. So each of these, I call them a data source.

So human error data exists from various domains in different formats and very complex in the level of details. Because of all this variation, we take the next step, data generalization to generalize them. And we know that IDHEAS-G has an inherent structure for generalizing human error data. So it's a five mega-cognitive function can represent failure of practically any human actions, regardless which domain it comes.

And then the 20 PRFs can represent the context that affect human performance of an action. Specifically attribute PRF attribute can represent to a very detailed level of the context. So once we generalize the data in the same format, we can integrate them to inform human error probability. That's we call the data integration.

Slide 5. In this slide, I will walk you through our source of generalizing human error data. So there have been two hurdles or two issues in using human error data. One is all this data variations, different domain, different context, different format, and different levels of details, all those. So we hear people saying the data format -- these data formats do not match my HRA factor, therefore I cannot use them.

And another hurdle is we know every piece of data is context specific. So people say that's in a different context. It's for aviation. It has nothing to do with nuclear. We cannot use it. But however look at the commonality between -- among these data sources. It's a human combination. So we use the generalization as to generalize this difference, difference, difference in the combination level.

So if we look at this diagram -- if we look at the left panel, we have a data source probably from a nuclear power plant operator simulation. And we have the error rater for a particular nuclear power plant has and the certain context that's the internal at-power event. So these are very specific. And we identified the tasks -- represent the tasks in common failure mode. And we represent it's in a context in PIFs. So now we can then make a link between the data source to this generic set of failure mode and the PIFs. So we do the same for another data source, maybe from off-shore oil drilling. And towards the end, this representation, they will come to the same way of planned -- same format. Then we can integrate them together to inform the ITP.

MEMBER REMPE: Jing --

MS. XING: Yeah?

MEMBER REMPE: -- before you leave the prior slide -- I'm not sure where to make this comment or question. But my understanding of why we started this project was to try and have some sort of consistency with HEP analysis or human error analysis. And one of those underlying reasons is of course to have a publically available database that would be available for various analysts to use. And so I believe, reading your report, that yes this database will be publically available. I think it's important to have some sort of peer review. And I know Sean mentioned that it's possible there would be a peer review, but I think it should be done.

And then I'd even go further and say that the peer review should not just be from the NRC staff, it ought to include industry or a broader spectrum of people, perhaps the international community, I don't know. But what is the goal for this effort that you're leading right now? Are you going to -- Is it going to be publically available? Is it now already available to the public? Are you going to have it peer reviewed? And who would be in that peer review?

MEMBER PETERS: Hey, Joy. If it's okay if I tackle that question. This is Sean Peters again. Yeah, the document right now -- the encapsulated data is publically available. They're making it publically available for this ACRS meeting is where that document is. Not all the data that underlies it is publically available. For instance, the SACADA database by agreement with the entity that we collected from at this moment is not all publically available. So the scrubbed data is and we have that posted on our website. Our goal is to get it more publically available, so we're working with the utility to try to let us make that out there.

The end goal is to have this particular encapsulation and this IDHEAS-DATA report to be fully publically available and to have people weigh in on it. The only reason I haven't fully committed to a peer review is I wanted to see the feasibility of it before we commit to the peer review. But we were doing a lot of work, all the way up until just a few weeks ago, getting all this wrapped together just for this ACRS presentation. So we haven't even gone through those planning steps yet for how to do it. My inclination is there's a very high probability we will be doing a public peer review of this for not just internal NRC. So that's my inclination. I just want to make sure it's feasible and we have the resources to do it before we commit to it.

MEMBER REMPE: Okay. So I'm going to summarize. Your goal is to have a peer review. And that peer review will be including external stakeholders, not just staff.

MEMBER PETERS: Absolutely. We typically do them with mostly just external reviewers. The IDHEAS-G was a little different. We actually had an internal one also.

MEMBER REMPE: Okay, thank you.

MS. XING: Okay. So I will continue on Slide 6. So with that approach, this slide summarizes our effort in the last decade in using human error data to inform HEPs. And at the beginning of our IDHEAS development, we've been collecting human performance literature and whenever there's data there. I would say we reviewed somewhere between like -- maybe between 3,000 to 6,000 original papers. And that we specifically documented the ones that had human error data in those data sources -- in those sources. And so far, we think we've documented somewhere around 600 to 700 data sources or papers for our use.

And that starting in 2018 and 2019, we started a Step 2 generalization, which is what we talked -- we represent the data sources, these ideas and the PIFs. And initially these were documented in the bunch of files. Inspired by ACRS, we migrate the small files in one place, which we call IDHEAS-DATA now. And then in 2019, last year, we integrated data -- we generalized it and get the base HEPs and the PIFs rate for IDHEAS-ECA. And we also used data to inform other elements in IDHEAS-ECA such as the PIF in correction and the low-risk to HEPs.

Okay next, Slide 7. So we go to talk about the daily glimpse of data sources. So out of all those data sources, we classify them into these five categories. The first category is nuclear simulator data and operational data like SACADA, HuREX is human operator -- is a nuclear power plant operator performance database by career. German nuclear power plant maintenance database analysis. We didn't have access to the database, but they published a paper, they did very good analysis of that.

And Category B, operational and performance data from other domains such as transportation, off-shore oil, and military operations, and manufacturers. There, there's a huge amount of data sources in expert studies in the literature -- in the cognitive behavior science team of factors and even neuroscience. And the limited amount of data, we take from expert judgment of the human reliability. For this category, we only collect the data in nuclear domains because every expert of judgment activity already has their mindset assumption context, which may not currently spell out in their documentation.

And there's this final category, which is called unspecific context where you could use -- We often save the data -- let's say medical, medication, administration errors is 5 percent. But it doesn't give you the context behind this or their ranking frequency of errors and the causal analysis. So we also collected this data for the purpose of calibration of validating -- of verification of our HEPs.

So these are the different data sources. And like we said, how we drilled down from those several thousand original data sources, we reviewed to the several hundreds that were selected. So here are some criteria we -- inclusion criteria we used. First, we look at the number of the participants. They have to be of the step from that data collected. So they had to be normal adults. And if they're not trained profession, at least they're trained for the tasks they performed. And has to be a good sample size.

And then the measurement of course of human error rates is what we preferred. But sometimes when a human error rate is not available, we also take in the human task performance measures as long as they are related to human error rates -- if there's a way to make the inference to human error rates.

And we look at specificity. That means the data source have to have clear information detailed enough. And allow us to identify what failure modes and what are PIFs there. For example if you're report to talk about well we wrote a 20 minute scenario of an astronaut. Then we find they made five errors. We couldn't tell what is failure mode and what is PIFs. So we wouldn't use that kind of data. And in certain case as we know, every piece of data has uncertainties. You cannot avoid uncertainty. So we evaluated uncertainties in the data source. Ideally uncertainty control them or at least, we know what uncertainty is there. They are traceable. If there's too much uncertainty, we can't use the data.

And also the rest of the data representation and the first part data should be every data source we selected should be repetitive like there should be at least two or three or more other studies that use a similar approach and get the similar result. And representative, we don't want the data selected overly represent a particular area.

For example, we can easily find over 1,000 research papers on the effect of monkey testing or distraction. We don't want to dump them all to our data collection. We select a few, most representing study. If this lab have done 50 published 50 paper on the effect of monkey testing, we may only select the one that is highly cited and highly recognized. And we balance between the different data categories.

CHAIR DIMITRIJEVIC: Jing, I have a just

sort of slight comment, what does it mean, non-male adult? Non-male adults, is that opposite to abnormal adults or?

MS. XING: Yes. So it's a study the visibility and in that studies, they have two set of subjects, so one set of subject are between the age of 20 to 45, the other are between 45 and 65. We will use the more representative. This is a people-based number that is in the age that are comparable to our working force.

CHAIR DIMITRIJEVIC: Well, I think it will be just enough to say adults, normal adults, sort of --

MS. XING: Yes.

CHAIR DIMITRIJEVIC: I don't know what does it mean, actually normal adults.

MS. XING: Yes. So that's actually a term also used in the company team, a related term, when you say the word, normal adults, means that they don't select a particular special type of subject, but I will change that word. Okay. Other questions?

MR. SCHULTZ: This is Steve Schultz. Do you have -- when you make the evaluation of the data source, are you eliminating the data source or are there some data sources where you take some features that are provided? They may not have all of the information that's needed, but they might focus, for example, on the performance influence factors.

Do you just -- do you have some sources that are only focusing in some areas of the human error likelihood?

MS. XING: Yes. In fact, I would say a lot of the data sources, we don't take every piece of data in that source, we take the ones that we needed or the ones that we have a confidence about and certainties that's based here in measurement.

MR. SCHULTZ: Okay. I think I understand. So of the large body of information, then you pared it down to what you call several, well, 600 or 700, sources that are going, then, to be categorized, catalogued, for the overall database, is that right?

MS. XING: Yes.

MR. SCHULTZ: And the rest are out there in the bibliography somewhere.

MS. XING: Yes. Somewhere in my computer.

MR. SCHULTZ: Yes, yes, just so --

MS. XING: And also, I have been deleting them when they're too much.

MR. SCHULTZ: Yes. Okay. But somehow you want to catalog them so you don't come back --

somebody else doesn't come back to them in the future and think that they're -- they haven't been used.

MS. XING: Yes. I, myself, already went back couple times, like, later on when we want. Initially, our focus was on human error rates, then later, we went, oh, we would also like to collect the data that's how's the test performance time, or time required of what's changed by weather or by other factors.

MR. SCHULTZ: Yes.

MS. XING: Then we went back to some data sources that did not have human error rates, but has performance time.

MR. SCHULTZ: Okay. Good. Thank you. That helps.

MS. XING: Okay. Thanks.

MEMBER KIRCHNER: Xing?

MS. XING: Yes.

MEMBER KIRCHNER: This is Walt Kirchner again. So since on the advice of the ACRS, you've added dependencies into your overall model, when you go back and look at data, how do you unwind dependencies? My example from earlier this morning, where you have -- in the PIFs, you have environmental factors and then task factors.

What's your technique to unwind the data and then bin it into one PIF versus another when there are dependencies probably buried in the data, the raw data, that you're getting?

MS. XING: Okay. I will go into that in detail later on, but the brief answer is, if the study, let's say, is primarily studies an environmental factor, like noise, and they measure -- the people performing the very complicated task, so which you have other factors involved, we document all the factors.

So we categorize them in the noise PIF, but there's a separate field we document, what other PIFs exist in this study? And when we use the data, we need to, which I call, detach the effect of other factors. Does this answer your question?

MEMBER KIRCHNER: Yes. You know, ideally, you would want data such that it clearly bins nicely in one PIF versus another, but the actual data that you're probably evaluating, probably has numerable factors affecting the results.

So it's -- I was just curious how that -- if it's like the example you said, noise, and then it impacts a task, just, you know, what your -- do you -- I guess, well, first, you would stick with your -- the structure you've created, of course, and then go to that, but I was just thinking of the complexity of unwinding the data and then binning it in PIFs and weighting, how much goes in one versus another, or do you just try and opt for data or sources of data where you can clearly make an identification of which bin the -- you know, say it's an outright failure of some kind, which PIF is identifiable as the causal -- you know, the root cause, so to speak?

MS. XING: Yes. You're right. It is very complicated, so when we actually, we call it impact data integration when we actually use the data, we label them as a single component data, which is what he said, the ideal data with only one PIF involved.

And then call the multi-components, so maybe it's two or more PIFs involved, but we can have some -- there's a way in the data source we -- somehow, we could detach the effect for different PIF, then we have undetachable data, which is more like because at some point I talked earlier.

In this scenario, people made five errors, we tell you what kind of error, but you don't know which PIF affect what error. So, you know, then we can -- so it's a complicated process, but general approach is, we start with clear data, make initial assumption, make an initial estimation, then use the clean data that -- to detach the effect of other PIFs, so we keep doing this each iteration until, like, the number we get is representative for the dataset we have.

That's what we went through for every numbers in IDHEAS-ECA.

MEMBER KIRCHNER: Okay. Thank you.

MS. XING: Okay. Okay. So we will go to the next topic, locate human error data generalization. So our first -- we are on Slide 10 and this slide shows IDHEAS data structure.

So IDHEAS' data has 27 tables, we call them, IDTABLEs, and the document is a generalized human error data and some empirical evidence. And so we can locate in this table -- on these slides on the left, column, Table 1 to 3 are for base HEPs, so one table for one PIF, for scenario familiarity information, availability, and reliability test the complexity.

Table 4 to 20 are for the rest of 17 PIFs, as Johnson described this morning earlier. Then Table 21 is for lowers to HEPs of each CFM, like Jim's showed, even you don't select any PIF attribute, its number, its HEP number, is not 0, it is E minus 4 for execution and E minus 3 for Position 18.

So this table collecting data that give the basis for those numbers. Table 22 is for PIF interaction, or you will say, PIF combination, so this, I will talk, specifically talk, later on. Table 23 is for collecting nuclear data distribution of the task needed, or task required, to complete the important human actions.

And the purpose of this table is to provide the HRA analyst the guidance in estimating the time required. And Table 24 is for the same purpose, but it's collecting the data. How the various factors that PIFs or other factors change the time needed, because the HRA analyst often need to estimate the time in a scenario different from where the time performance data they have, so this will give them some guidance and the basis for their adjusted time needed due to, let's say you're doing the -- you're connecting the wires in dark versus in the daytime.

And Table 25 to Table 27 are slightly different. This table was not only just to collect the numbers, because we don't have much numbers, they're also collecting empirical evidence, so Table 25 is to collect empirical evidence, regardless of qualitative or quantitative, the dependency information, the dependency examples, and dependency impact.

Table 26 is to collect information on recovery of human actions. And Table 27 is to collect main drivers in past human events, specifically, we think we like to focus this on nuclear event. What was meant contacts in those, meant driving the human failure, and what -- how those contacts should be represented by PIFs.

We hope that this line of information will help HRA analysts in their scenario analysis to capture the important error contacts and help them mapping the contacts to the proper PIFs.

So these are all the IDHEAS data tables. Okay. Slide 11 talk about the data generalization process. Actually, after Johnson and Jim's presentation, there's no mystery here. Generalizing a data source, it's the same as you performing an HRA using IDHEAS-G, starting with analyze data source to understand the context and then analyze the test, identifying the applicable CFMs, mapping the context to relevant PIF attributes.

And at the question earlier, identify other PIFs that were presented in the study, in the data, and analyzing documents and certainties, and finally, put all this into IDTABLE.

MEMBER PETTI: So a question.

MS. XING: Okay.

MEMBER PETTI: All of these steps are documented in the table so that people can follow the thought process?

MS. XING: Yes, the outcome of all these steps is in the table, only the table is very brief. So we are actually in our contract verification of our data tables, we ask them, put some more details of these steps so that can be useful information to help HRA analyst, they can see what were the contacts and what PIFs that contacts is a transfer.

MEMBER PETTI: And the data that didn't make it in the database, is that documented somewhere as well, why it's not selected, so people don't do the same thing, you know, ten years from now?

MS. XING: Yes, the why part is not -- well, some of why part documented in our own working files, but not in any public place, because it just took too much time writing. And that's -- but hopefully our data verification contract, we asked them, whenever they have a question or disagreement, to some of these steps, they said, no, we think it should be a different PIF always and it should be different.

We ask them to document that information and how we resolved that, so eventually, many of this will be documentated and we would like to make them publicly available.

MEMBER PETTI: Okay.

MS. XING: Okay.

MR. SCHULTZ: Xing, this is Steve Schultz. One question, could you walk through the bullets for the PIF attributes? In the first one, you're going to map the context to relevant PIF attributes, and then the next bullet, I wasn't sure, you're going to identify other PIF attributes present in the study.

Could you provide a differentiation example or some additional information on that?

MS. XING: Okay. So next I will walk through two examples. I hope the example can answer your question. If not, I will --

MR. SCHULTZ: That will be fine. Thank you.

MS. XING: Yes. We are on Slide 12, so we look at the first example, a data point for the base HEP. So first part, let's focus our vision on the lower portion of these slides and look at this table first. So this table shows the structure how we document the data.

So the first column from left, it's documented what the PIF's data represented, so basically, we can go down to the level of specific PIF attribute. The second column is the CFM, the failure mode. The third column is the actual error rates reported in the data source.

And you see two numbers here, you would often see two numbers here, and in parentheses, it shows the number of the error versus the number of times the test was performed.

And the fourth column, next column, is the task. That's what, like, was in the early slide, so what the task performed from which the error was measured.

And the next is a PIF measure, like, how the PIF measure or what was the context that he took this PIF. And, yes, this is a column, other PIFs, and their uncertainties, so we documented in this column, and of course, references.

So now let's come to this example. Okay. So this example is from the NRC's SACADA database. SACADA database collects operators and task performance data in simulator training for re-qualification examination. And the rate of unsatisfactory performance called UNSAT for training objective task were calculated from SACADA data.

And so in this source, we used the UNSAT rate as the error rate here. And so far, we only generalized the data, used the SACADA data, for the base -- for the three base PIFs because analysis for other PIFs hadn't been -- hadn't done yet. That's exact problem we talked earlier, every failure, every error data, involved too many PIFs.

And we had to figure out how to deal with that. So now let's look at how we use this. SACADA characterizes scenario familiarity and the three options, so standard, means standard scenario, or normal scenario, or anomaly scenario.

So we take the -- so normal and -- so this represents three levels of scenario familiarity and here are the two examples we take. So the first one is, the PIF attribute is SF3.1 and I think 3.1 is, scenario is, unfamiliar, and that could be mismatched from what he normally trained.

So that's SF3.1 And the -- we -- for this set of data is for understanding, which, in SACADA data, is classified as diagnosis, so we have the error rate, 8 failure out of 69 tests performed, and the test was operators perform diagnosis in simulator training.

And the PIF data lead to measure, lead to SF3.1 as the anomalous scenario. And in this case, we didn't clearly spell out the other PIFs, because out of these 69 cases, some cases, they may also experience the test for complexity, and maybe in other cases, they experience HSI, because it's a bigger variety, so we just document them as an uncertainty, so means this data, even -- they all have share the same common PIF, which is the scenario familiarity, however, there are other PIFs exist.

So I think this doesn't quite answer the earlier question how we document as a PIF, but this is more demonstrating, we documented the uncertainty in the data we have. So any questions on this example? Okay. I go to the next.

So next example is from the data point for PIF waste. So look at the table structure, it's pretty much the same as the base HEP, except, in the third column, the error rate, you have more than one numbers. The two subcolumns typically shows the variation of the PIF status from a good condition to a poor condition, so we can use this to calculate in the change in condition.

So other than this, everything else is the same. So let's look at this example. This is experiment study, measure the human errors for military operators reading dials as you change the illumination of the dials.

The luminance was changed from really dark, 0.015 to 150 lux. Just the general recommended reading illumination should be between 20 to 50 lux, so 150 is certainly enough, and the lower was really very dark.

And of course, the error rate decreases with the luminance. And when the luminance was greater than 15 lux, the error rate was low and it remains the same, even if you still feel uncomfortable at data level, but it doesn't produce more errors on this data source.

And the many other studies recorded a similar relationship between luminance and the error rates. So this is a relatively simple study. The task in this study is reading the dials, so that belongs to detection.

And the context was simple because it's a controlled experiment. They use military operators to do this reading and in a normal working room. And so we take the error rate and so the original data source actually presented more data than we put here, so it changed gradually from the very low level to very high, so we only take this as really represented point, whereas error rate start changes and can make the kintalay (phonetic).

Like, at the very lower rate, luminance, the first raw in the data, the reading error is 16 percent. And when the luminance is beyond -- the lux is beyond 15, the reading error stay at 8 percent and stayed there, no more reduce, even you increase the lux into 150.

And so in this case, there -- we documented, you know, other PIFs. So this 8 percent reading error is currently a lot higher than what we would get in the lowest reading error we could get. We look at the description in the method.

One thing, there's no peer checking there, so only one person do the readings. No verification. And it wasn't clearly spelled in the data source because this is a very early study, back to 1960s or '70s, but the good thing was they used many operators.

And so we suspect there was an HSI issue in reading the old-fashioned dial, like, reading -- like when the point is between two numbers, should that be 3.5, from left to right, or 4.5, from right to left. That's a very typical kind of reading error for old-fashioned HSIs. We don't have detailed information, but we know there should be -- the most likely, there's some HSI problem, human system interface problem, there.

We document in the other PIF the uncertainty in the study. So any questions on this example?

CHAIR DIMITRIJEVIC: What you're telling us here, even with the best lighting, in reading those instruments, they're going to always make 8 percent error?

MS. XING: In this particular study, yes, that's what the data's showing, but we see the column of other PIFs, this error is not 8 percent error, because no -- for sure, no peer checking. And there's also, very likely, a poor human system interface.

CHAIR DIMITRIJEVIC: So wouldn't that impact your diagnosis error when you -- okay. You are treating this as performance influence factor, right, but what is your best diagnostic error if you are using this type of instrument? Shouldn't that be best that you can accomplish for diagnosis? Because I saw the raw numbers there, right, in 10 to minus 3 or something?

MS. XING: Yes, this is -- this study,

because it's controlled, were controlled, so the only -- they only do the dial reading, so it's only for detection. And while I don't have a slide here for diagnosis, let me --

CHAIR DIMITRIJEVIC: That's okay. I mean, detection diagnosis, I mean, you know, I was just looking in some more channel alternative than reading instrument, that you can transfer this error probability.

MS. XING: There also is an early example on Slide 12, the first raw --

CHAIR DIMITRIJEVIC: Good eyes.

MS. XING: -- test for diagnosis. Yes, the 8 error out of the 69 cases.

CHAIR DIMITRIJEVIC: So that's higher than 8 percent. Okay.

MS. XING: Yes. So anyway, here's -- given the overview of where we are in IDHEAS data, up to 2020, for the data sources, we only -- so far we only have limited use of nuclear operation in the simulation data, because realize, that's probably the most valuable data sources and we want to really be careful with those data.

So as we said, for SACADA data, we only analyze the PIF, the three base PIF. And for Chris

HuREX database, we want to work with them, make sure that we use their data, we map their data properly to the PIF and failure mode, because their -- in that database, they describe the error, the failure, on a particular type of task, not on -- not just say detection or diagnosis.

So we want to better understand their categorization. And also, many -- Halden has been conducting human performance experiments for 30 years. They have lost data. We only generalize the very few important studies. The main issue with most of Halden study, they did not report or measure human error. They measured situational awareness, workload, or operator task performance score.

We know those are related to errors or probably somehow proportionate to error rates, but we need to be careful. We want to work with Halden to figure out the relation between their test performance measure and the error rates.

So overall, I think up to now, we have over 300 data sources generalized and the other 200 to 300 data sources evaluated and select them, but we haven't had time to generalize them yet.

And we also located several hundred related first on test completion time more specific modification to test for completion time. This is going to be generalized in 2021.

And look at the IDTABLEs. So the datas in Table 1 through Table 21, we already used them, integrated them, for IDHEAS-ECA. And Table 23 and 24, for test the completion time, they are on the way for generalization and we haven't used them yet. We haven't get to step 3 using them yet.

Table 25, for dependency, 26 for recovery, and 27 for main drivers, we would say they are in piloting. We put some examples in this table for demonstration, but we are still piloting what would be the best way to document this data for use.

And overall, we certainly don't have all the data we need. In fact, we have a substantial number of PIF attribute we don't have data for the specific -- for that combination of, let's -- attribute and the CFM.

And in general, we lack data in the -- particularly in the inter-team coordination. While I would say we lack human error data, there are actually lots of human performance data, like, for example, measures amount of communication, measures commander's failure of how many times people needed to rehearse data, like, number of times you fail your command and control, but we don't know if that's the denominator for that data.

So this is the error we need the clean data. And look at the PIF, the two PIFs that we really like the data, some attributes in work process and some attributes in team organizational factors.

So we have lots of qualitative information, for example, we can -- this report will tell you up to implementing safety control and our rating for the plan safety on the scale between 1 to 7, it goes up from 5 to 6.

That is data, but it's not -- we don't have a way to relate that data to human error rates, so they are the errors that we need to work on in the future.

Okay. If no question on data generalization, I will move to the interesting story of PIF combination. Okay. We are on Slide 17. Starting with story of PIF combination. So look at this story scenario, like, operator's error rate, or HEP, is 1 percent for whatever task, let's say, for reading a dial in normal conditions, and it's 5 percent in loud burst noise environment.

And it's 10 percent, or .1, in the poor visibility. So what is his HEP while working in loud noise and poor visibility, means the two PIFs combined together? So we could have two answers.

The first answer, we call them additive, so you simply multiply the error rate together, so you get 15 percent. The second way is multiplicative, let's say, noise increases the error rate five times and poor visibility increases the error rate ten times, therefore, I can get the error rate would be the base error rate, 0.01 time 5, times 10 equal to 0.5.

So which one we think is more reasonable? And these two answers, I mean, if you look at across more than 40 HRA method, I would say most method will give you the answer 2, a few method will probably give you answer 1.

So we look at what's in data, what data tell us, so I use these three diagrams showing the three ways of PIF combination. And for each diagram, the horizontal axis represent PIF1 from good to poor, from good to bad.

So vertical axis represent the error rate, and the two corridor lines represent when you add another PIF, so the orange is for the PIF2 good, and the blue is for PIF2 bad.

So if the effect is answer 1, additive,

then we should see if these two lines in parallel or like shown in the dashed line, they could be less than additive, so it's lowered down somehow.

So then we look at the graph in the middle, if the effect is multiplicative, then the blue line, the dot on the blue line, represent both PIF were bad, which really goes up more than the additive factor.

Well, of course, we could see some good situations, subtractive, in the literature, they often call this kind of -- the two lines are crossing, they call this interacting, which means when the two PIFs come together, the effect is actually less than the individual PIF.

This sounds odd, but you can think of one PIF is noise, the second PIF -- another PIF is mental fatigue, specifically, it's sleep deprivation. Okay. This is what we observed in the IDHEAS data sources, so we had over 100 studies that actually give you the error rate in the individual PIF and with the PIF combination.

So we look at those data, most of the data points are roughly additive, and some data points do show multiplicative, and very rarely, but like the example I talk noise and sleep deprivation, shows subtractive.

Okay. So we want -- when we start this, we want to have a further understanding, what makes multiplicative, because that's really where the high risk comes.

So Slide 20, I apologize, I might have talking of some jargon of complicated terms here, but please ask me if I use some weird jargon.

So our observations showed, if both PIFs remained the same cognitive resource, and the demand from a single PIF is already approaches to the capacity limit, then quite often, not definitely, the combined effect can be more than additive.

And this actually reflected the catastrophic effect of the exceeding the capacity limit. So I like to walk you with these two examples of this capacity limit. So on the left is a study show the working memory capacity.

So horizontal axis showed the number of items that an operator or air traffic controller have to maintain in his working memory in order to complete this task. The vertical axis shows the percent of errors.

So at each triangle is the actual data calculated from the number of errors air traffic controllers made here. And the big orange triangle shows where you get -- where the capacity limit is, which, for most humans, for most people, the capacity limit for this type of working memory is somewhere around nine, so we will say nine, plus or minus two.

And so when the demanding for working memory is only -- is less than four items, the error rate was really low, less than 1 percent. And then it's mostly increase. Beyond 11 item, which is what the orange triangle, the error rate dramatically increase.

So I think up to 15, the last triangle, the error rate was 35, and we didn't bother to analyze the error rate beyond 15 items. You have to remember, that's just a crazy task.

So therefore, look from this curve, if you think -- if the two PIFs demanding your working memory, on those blue triangles, the effect, most likely, can be thought of additive effect, but if the demanding move, you are already on the last blue triangle, you already need to remember eight items, now I'm adding another task to you, ask you, you have to memorize another four things to do this task, you are pushing to the limit. The effect is more -- become more than additive. They can be modeled with multiplicative or other ways.

So that's an explanation for why we see different PIF combination effect. So on the right graph is an example actually shows the multiplicative effect. This one shows the working memory capacity and the multitasking or interference.

So the horizontal axis shows the three situations of interference. For number one, there's no interfere; a single task. Number two, you have an interfere from a previous task. Number three, you have interfere from two previous tasks. All these tasks are demanding your working memory.

And the vertical axis, the original data, showed the number of words recalled from ten, so from ten original set, so if you say, number six, which means you get 60 percent correct.

So in the red and the blue lines shows the two memory capacities, which you can imagine a single task, or demanding less working memory, in the blue, and the more complex task were demanding more working memory, in red.

As they started from no interference in the first one, the difference between the red and the blue is small, and the difference getting larger and larger when you have more interferences. So this is the combined effect complexity or demanding for working and interfere is really more than just added together.

Okay. Any questions on this slide or the examples?

MEMBER KIRCHNER: I had not a question, Jing, but just an observation. I would not have expected PIFs to be linear, anyway. So what your examples point out, even the simple one on luminescence, is that you get either cliff phenomena, or very non-linear, or divergent results, depending on what the PIF is, if the -- for example, if I could pretty much guess that if you constructed something based on noise, you would get a curve just like the lower left curve.

When you got to a certain decibel level, people can't function, and you go off the charts. So it's not -- you know, up to a certain level, perhaps, it would be linear, and hence, additive, and then you get to a point where, in something like noise, a real human factor like that, you just can't function.

So that begs the question, then, what rule set do you develop to determine when things should be additive and when they should be multiplicative?

MEMBER BROWN: Can I make an observation, Walt, relative to your noise example? This is Charlie.

MEMBER KIRCHNER: Yes, go ahead, Charlie. I'm just observing.

MEMBER BROWN: Well, I would posit, based on personal experience, that not everybody has the same level of discrimination even on background noise, so how do you codify or quantify that particular parameter?

I mean, I seem to be very sensitive to background noise in terms of conversations, take away background noise, I hear fine, but if you -- certain frequencies of background noise is also a variable that you have to account for and how well a person's hearing responds to various frequencies.

They may be diagnosed based on hearing tests as being able to hear, but yet, the higher frequencies or lower frequencies may be more influenced by lower levels of background noise than would be expected for others.

So that variability, in my own mind, is extremely high relative to noise background, as well as just straight old memory-type issues. I just think there's more involved in the noise factor than anything else.

MEMBER KIRCHNER: No, I was just trying to come up with a quick example that --

MEMBER BROWN: But it's a good example, Walt. It's a good example.

MEMBER KIRCHNER: Yes.

MEMBER BROWN: And the thing is, you know, ideally, we would like everything to be linear, but we're human, and the variability, as Charlie points out, in humans is enormous, so, yes, it's -- but I'll go back to my question, then, Jing, what is your -- is there any kind of guidance that you use to say that, well, we'll be additive because things are, I'll use the word, linear, but then we'll go off the chart, like you show in your diagram here where, you know, you get to a saturation point in terms of mental capacity, and then the error rate just goes off the charts.

MS. XING: Okay. So I think your questions are actually a good test of my working memory, and I will see how much I remember, so I'm answering the questions in the reverse order.

Okay. First, let's talk about the question, different type of noise, and you were right, in the noise PIF, the different attribute capture the different type of noise. White noise or different frequency of noise, bursting noise, or conversation, like, verbal noise, and we have good data collected, different type of noise, or the frequency range of noise have different impact on the error rate.

So that line of information we captured. And second question, in the original differences, that one, we don't, because when we talk about HRA, we always say HRA models the average person, even, there's actually lots of literature show the individual differences on the noise effect.

So far, we did not collect the data line of the information, we just take the average number out of these 60 people they measure. However, I hope in the future, when we further refine our data collection, we will capture that we're not just documenting the average error rate, but we will also document the distribution of the error rate.

So that, people may say, oh, I have a specially trained group. They completely resistant to noise, so we can use that range to make adjustment. And next question is about your observation of any -- no PIF is linear. That is very true.

So in an ideal world, we probably -- we're going to have a curve, like what's shown on this screen, for every PIF. However, for now, we need to consider the fact, we don't want to overload our HRA analyst. When you give them a full curve like this, how are they going to judge which -- like, which level I -- which point, I don't know how many working memory item, it could be four or it could be ten.

So we, right now, in IDHEAS-ECA, we use the combined strategies. Some PIF, we use the, like, step levels, low or high, low, medium, high, some think that is really, like, poor visibility for instance, for working memory. We actually give a more refined, like, we give a ten scale, basically, it's like the chart you are seeing here, so we give -- if the scale -- we give -- we also give benchmarks, if it's less than four items, that's a scale between 1 to 3.

From anywhere, four to ten, that's in a scale between 5 to 7, for item above ten, you will give a scale between 7 -- or 8 to 10. So we basically map this curve to our IDHEAS-ECA database. So that's when you're using IDHEAS-ECA, you have this multiple scale PIFs.

And for your last question, or first question --

MEMBER BROWN: Well, can I stop you there?

MS. XING: Yes.

MEMBER BROWN: I'll test your memory and see if you can remember the last one, so just an observation again, we saw this morning, an example of changing these factors and, like, an importance factor, or weighting factor, have you -- when you run all these, kind of, analyses, and this -- I'll use the word, sensitivity, now instead of uncertainty, and what I mean by that is, what if you had phenomena like this for the PIF, where you had data, would it behoove you to do what I would do as an engineer, I would count, as an engineer, like this, one, two, five, ten.

And then if you ran, you know, those weights in sensitivity-type analyses, you could probably see, then, the impact of some of these non-linear, kind of like in this example, overload on a PIF factor and its weight.

Do you do that or are you trying to get even more granularity than --

MS. XING: We did something similar, not to that engineer, but I can give you an example. For example, when we look at the effect of temperature on human error, cold and heat, and in there, they have the literature, you can find several hundred studies on this, the literature shows a really fine granularity, but we find in the normal working one, you're not going to put people in a freezing or burning temperature.

In the typical range, like, say from the typical workplace temperature, from 27 degree, which is a little bit below freezing, up to, I think the highest they tested is 95, this is a very broad range, and you would -- the error rate from, like, a normal perfect temperature, 32 degrees to 90, to a very high degree temperature, the error rate only increases in the worst case, were only increased 40 percent.

So in this case, there's really no need to put it in a very detailed granularity, therefore, for that one, we just say, it's, say, hot, like, normal, hot, extremely hot. We just gave three levels to each standard, so this is some -- I think this is probably similar to what you said in sensitivity analysis. It's not a formal one, but we try.

MEMBER BROWN: Okay. Thank you.

CHAIR DIMITRIJEVIC: I have a question and the answer to Walt's last question about --

MS. XING: So don't ask me new questions. Let me finish that question.

MEMBER KIRCHNER: I forgot my own question.

CHAIR DIMITRIJEVIC: Well, I remember.

For combination of the different performance, you know, the influence factors, what do we -- do we recommend additive, or multiplicative, or depending on the case, or how do we recommend considering those combinations?

MS. XING: Okay.

MEMBER KIRCHNER: Yes, thank you, Vesna.

MS. XING: Yes. So the recommendation we have now is what Jonathan showed you this morning in the HEP quantification model, the formula. So between the modification PIFs, it's additive, like, the effect of noise, visibility, temperature, mental fatigue, the WI's PIF weight were added together.

And between the base PIF and the multiplication PIF, it's sort of multiplication, because for base PIF, we don't use PIF weight. Base PIF, we use exactly -- it's directly -- we use the HEP number.

So the overall effect is like -- operates like a multiplication. And so that's the -- that will probably work for 80 or 90 percent of the situations. And then for some special case that's not covered with that situation, that's why we have that, we call the PIF interaction factor.

Say, if you have data support, base to PIF should be multiplicative or they are more than additive. You can adjust that with that multiplication -- with that interaction factor. That's our current resolution.

It's not an ideal resolution, but we think it's our -- a good -- a simple simplification of this complicated problem.

MEMBER BROWN: Can I ask another question then?

MS. XING: Yes, please.

MEMBER BROWN: I don't know that it applies to your words, maybe it's similar to the words recalled graph that you show. I'm going back a long time -- I wish Dick was -- Skillman, was here, because he could correct me if I'm wrong, but when TMI occurred, one of the items listed in the long list of reasons for having the accident progress the way it did was time of recognition.

In other words, there was such a large number of alarms that were always going off in one way or another, even an elevator alarm, if the doors were open, was one example somebody gave, I don't know -- I don't remember that one real clearly. Not so much that they were important, but they were distractions.

In other words, the operator's mental

thinking about something was distracted. Hold it. Alarm went off. All of a sudden he's coming back, just like you couldn't remember Walt's third question, because he couldn't remember it, from a distraction of trying to answer the other questions.

Is distractions a function that's evaluated in terms of how operators react? I know that we took the -- I'm in the naval nuclear program, and we took the TMI report pretty seriously from the distractions.

Rickover used to beat the bejeebers out of us to not overload the operators in the main operating -- the main control room with miscellaneous alarms. If they were miscellaneous, they should not be in there.

So is that a factor that -- something that has been thought about when you're dealing with these things?

MS. XING: Yes. One of the PIF is a term that has multitasking, interruption, and distraction.

MEMBER BROWN: Okay.

MS. XING: So in PIF, it has three attributes for these three items separately. I mean, distraction is not -- if off this -- it's probably the least guided one. And so multitasking is the worst.

MEMBER BROWN: I agree. Thank you. I didn't remember that. I appreciate your reminding me. Thank you.

MS. XING: Thank you for the question.

MR. SCHULTZ: Jing, this is Steve Schultz.

MS. XING: Okay.

MR. SCHULTZ: When you talked about the way in which a group of operators, let's say, would react differently to the influence factor of noise, you said, oh, we -- well, sometime we may have a distribution, and we would like to add that distribution, and we would apply it in our performance influence factor.

Is that -- when you say that you would use the distribution, are you going to apply that as an uncertainty or if you had more information, would you somehow integrate it into your analysis?

And the reason I'm asking is that you've got some other features that you haven't yet filled in in your overall modeling. Things tend to get pretty complicated pretty fast when you're filling in those tail-end features that we talked about earlier in terms of recovery and so forth.

And so when you say you're going to use the distribution, have you figured out how you're going to use it?

MS. XING: No. That's just a thinking. My own thinking is, because the data source -- if the data source has information on distribution, that's valuable. We should capture them.

MR. SCHULTZ: Good.

MS. XING: But exact how to use those in the IDHEAS-ECA, I hadn't thought of that.

MR. SCHULTZ: That's fine. It deserves careful thought.

MEMBER PETERS: Yes, and the other question is, whether or not this is --

MS. XING: We pay the expert. Yes.

MEMBER PETERS: I'm sorry --

MS. XING: So in 2018, we used some of this data, give some of this data, organize it to our expert in FLEX expert adaptation, and that, we include in some distribution data just to give them a sense how this can be -- how things can be varied, but we haven't formally used it, and I appreciate your comment. We want to be careful with that.

MR. SCHULTZ: Sure. Good.

MS. XING: Thank you.

MR. SCHULTZ: John, you had a comment?

MEMBER PETERS: I was just going to say,

I'm not certain we even know how to use that type of data in the NRC's regulatory processes, right? When we do our significance determination process, and we do our ESP analyses, what we understand or we model these based upon, pretty much, standardized crews. We just don't model the individual crew members and their particular attributes.

So saying knowing you have one person who might be better capable of handling distractions or better capable of handling, you know, high heat or high noise, it's just not something we tend to approach in our modeling in the agency.

We still try to reach everything as the average crew responding in that situation.

MEMBER KIRCHNER: Sean, this is Walt again. Yes, I would suspect -- you know, we joked about what a normal adult is, but for your purposes, I would think that's what you would do. You would have, basically, a well-trained crew that the first order, obviously, is physically capable as well to execute the tasks at hand.

So I was going ask Jing, how do you -- when you look at datasets, if you had large tails on datasets, along the lines of what Steve has brought up, I wonder what you would do with that.

If you had a dataset that was based on the original seven astronauts, you would have quite outstanding performance under all kinds of stress and other factors, right? If you had the -- let me pick on someone -- the Navy pilot corps, you would have a very highly physically capable group of individuals who could deal with a lot more stress and other things than, perhaps, the average.

So when you take data, are you looking mainly for data that is along the lines Sean suggested, that is more representative of the working -- you know, an average -- if there is such thing as an average -- individual in the nuclear industry?

Is that the preference for data to populate this data -- these databases and to what extent, then, do you really have to look at tails and distributions?

MS. XING: Okay. One thing we so far used in the tail distribution is in the integration, not in the HRA, not to bring those tails into the HRA measure, but in the integration of data to come up with a single number, HEP or PIF with.

Let's say we have the data for this number, base HEP number, this particular PIF, failure of detection, we have ten data points, which means they're from ten different data sources. Of course, they don't come with one single number. They already come with a distribution.

And that's when we, like, finally, when we integrated these ten data number into one number, either the average or median, that's when we locate the uncertainty information, or distribution information.

We say, well, if we take, let's say, all these number, if we take the average, it's a little bit -- it's far from the lowest one value we have, but if we look at the lowest value, it has a range, and also, this is noted, but we would make a note in the uncertainty that this was performed by high-trained astronaut.

And so that's -- we accept their error rate could be lower than the rest and than the number we eventually use. So that's not the formal way of use it, but we actually use that type of information in coming up with a single number to our model.

MEMBER KIRCHNER: Thank you.

MS. XING: But as far as bringing this distribution to the model, that would be -- we hadn't really -- yes, that, we need to be cautious. Maybe in the future, we find that this can help people do sensitivity analysis so we can say what -- who is the worst performer on this situation. That could be useful, we don't know, so we can't say at this point.

Okay. If no more questions, can we move forward from this slide? Okay. Slide 21, this is just some verification of our own observation, other people's meta-analysis of PIF combination. So we find, like, sometimes -- I found, like, ten-plus studies of meta-analysis on PIF combination and I put four examples here, listed from top to bottom in the chronological order.

So back to earlier, even 1970, this study, they did meta-analysis of 51 reports on the combined effects of noise, temperature, and sleep loss. The finding is a combined effect is no more than the added single effect, so they can be predicted by just adding them together.

And a similar study, the effect between noise and heat, this one studied the 20 to 30 reports, and found that a majority of evidence indicate these two factors do not interact significantly, but this is within the range of experience commonly in the industry psyche.

That means it's just not pretty important for critical data of heat and working environment. So if you really drop people to that, it will come back to -- you will come to that non-linear portion of the curve.

And again, the next one is actually our NRC staff's early study. That was a very limited study only on a very small sample, 23 data point, with data fitting to additive and multiplicative model. And we find the additive fits better than multiplicative for most of data.

And in fact, we also find that even additive can overestimate for some large PIF weights. Well, that's a very small sample. I don't put too much credit on that study.

And the very -- the last study, I find this kind of interesting, is -- this one's not about the effect on error rate, but some task performance measure. They reviewed, I think, several hundred studies and selected 40 to 57 reports. 40 reports means -- otherwise that if they reached the author of the original study and totally, they analyzed 57 reports on this topic.

And that they find additive account for 91 percent of performance data, multiplicative account for the rest of the 9 percent of the -- what they had.

So I think all these studies are pretty

consistent and they're also consistent. I mean, consistent or not contradict with our -- put it the other way around. Our complication model is not contradict to this evidence.

So we think at this point, we have solid evidence that most PIF combinations are additive, then we think of the Table 21 on PIF, that's why we don't call it PIF combination, we call it PIF interaction, we should focus on collecting data that could really show the interaction, like the interaction between a base PIF and the multiplication PIF, or any data that show more than additive interaction, specifically, those red flag combinations, which means you really put the extreme high HEP.

So that's our insight on PIF combination we learned from data and what we want to do for the next. So any questions on PIF interaction? Okay. I think we had enough questions earlier on this.

So then I'm going to conclude my -- summarize my presentation so far. So we say human error data of various sources are generalized to IDHEAS data using IDHEAS in calculating failure modes and the PIFs. And this data generalization is generic with the CFM and the PIFs, which means that they can be used not only by our IDHEAS-ECA, they can be used by any HRA method.

And the data integration, exactly how you use this data, is specific to the HRA method and the application you use. For example, when we use the data for IDHEAS-ECA, one consideration is not just what data provided to us, but also, how our analysts are going to use it.

We don't want go to -- put all the details to overload our HRA analysts. So it's really specific for each application, the way you use the data.

And in the long run, data generalization is an ongoing, continuing effort. Any time we see new data, we put that general item in IDHEAS' data tables. And the data integration is a big effort that still need to be periodically updated, say, every three, five years, with new data you may modify some numbers you had there before.

So this ended my presentation, but I remember this morning -- early this morning, I promised that I will show an example on the data basis to support the lowest HEP. So should we wait for questions or we go to that example now?

CHAIR DIMITRIJEVIC: Well, if there is no questions, we can go to the example. Actually, it would be great to see this table from your additional slides on the minimum HEPs. Do members have any additional questions before we go to the table? Okay. If no questions, then, Jing, please proceed to the example table.

MS. XING: Okay. We go to some backup slides on integration and I will simplify the process, show a high level, then we can go to some detail, which means we are going to Slide 32. This is the summary slide. So this slide shows -- is an example how we integrate multiple data points from multiple data sources to get a single number, which we call the lowest HEP of failure of detection. So, okay --

CHAIR DIMITRIJEVIC: Jing, maybe we can show -- I think it would be very useful to show the Slide 28, which is that slide with examples of the lowest HEPs you have from the data. And explain what those HEPs are versus, like, you know, these detached HEPs, which you have in -- because this is an example of the data, right, which you get, you know, from the various sources, and then you have the -- in the couple slides, you have additional table, which shows detached HEPs versus this minimum, lowest HEPs.

MS. XING: Okay.

CHAIR DIMITRIJEVIC: And this is also very useful for our information to see, you know, the data used.

MS. XING: Okay. I will work through this slide and I appreciate our committee member who put the work in front of lunch. Okay. So on this slide, this shows some raw data we got from Table 21 on lowest HEP for failure for detection, not all, but some.

So each row represented record one data point from either one data source or the same data source, but different aspects. And for columns --- so the first columns were, there's an ID number there, 1, 2, 3.

And then we show the error rates reported and the task that performed. Let's say the first row, this is from SACADA data, it's a nuclear power plant operator's alarm detection in simulator training, and this is for -- the alarm in SACADA, alarms had several levels. This is first -- the easiest level, which is alarms self-revealing, only a few alarms there.

So this is what data we have, then the error rate, you have 4 out of nearly 2000, so it's in the range of E minus 3. Okay. Because we want to be very careful with this, the lowest HEP, so we look all this criteria.

So for the -- if a data point needed

should belong to the lowest HEP, it should have adequate time to perform the task. And there should be self-verification. It's not like use something briefly shown, you take a look, and run away, you verify what he is saying.

And there should be some team verification. This could be a peer checking, supervision, or independent checking. Any of these, but there should be some teamwork checking there. And the recovery, this is a kind of uncertainty.

The data should allow, like, immediate recovery. I didn't see that, but two minutes later, either myself or my teammate tell me, oh, you missed a data alarm, but it should not -- recommend it's not considered, like, two hour later, like, long time later, after you complete this scenario, say, oh, I didn't saw that, let's do it again, so it's not including that kind of recovery.

And there could be other PIF factors potentially there, so if they say, yes, yes, there's other PIF factor. You label what other PIF is there. And if it's no, that's good, or sometimes it's a mixture with -- like in this first row.

We know of these 1872 data points, some data points has other PIFs there, but we didn't go to do a one-by-one content, so we only say other PIFs may exist, which means this number we see here should be higher than the lowest HEP compared, no other PIF may exist.

So we do this documentation from -- for every data point, and then second one, 3.E minus 3 is also from SACADA, but this is for checking indicators versus the first one is alarm detection.

CHAIR DIMITRIJEVIC: Well, you don't have to explain each one of those for us. That's fine. I mean, what I was curious is about how we go from here to this detached HEP, which is the, you know, the -- after you explain this, then we assume, then those -- the, sort of, recoveries, or whatever, the positive performance influence factors don't exist. We go to the alarm, you know, it encompasses lights from here, I think, right?

MS. XING: Yes, I will come there, but we can look at Item 12, the bottom line, this one shows the HEPs, the error rate is high. It's almost E minus 2 or 90 minus 3, for warning detection. However, look at the uncertainty column. The task is a performed dual task, like, they were detecting monitor and they were also simulating driving.

So that's one thing we would -- if we want to use this data point, we have to detach the effect of dual task. Okay. So here are some kind of rules we can't use for detaching, which we call the multicomponent data.

So it is definitely a critical step, so the kind of rule we use. As we said earlier, we started from single-component data -- so clean data -- getting a rough estimation of what the factors are, and starting from there, do the detection.

So because this data, we -- the lowest HEP represents the situation, you have self-verification or team verification, if both of these shows data have no self-verification, no team effects, then we would -- the detached error rate is original error rate divided by a factor of 5.

The factor of 5 was derived from a bunch of data showing what would be the quick recovery or the team recovery we talked earlier this morning. If it was a team recovery, the error rate would be reduced by 5 times.

Then if both are null, then you would divide it by the added factor, by a factor of 10. So it's kind of a process going through this, we do -- like, for dual tasks, there are different types of multitasking and we check if it's a dual task, like, if you're doing --

CHAIR DIMITRIJEVIC: Well, okay. Well, we don't need to go into this level of detail, especially because you're not -- because then this complexity mask and all that, our understanding of the process, so if you just get to this table, what I'm curious -- after you strip those minimum human actions from those factors, then your HEP becomes, instead of 2.1E minus 3, 40 minus 4 --

MS. XING: Yes.

CHAIR DIMITRIJEVIC: -- all the -- in the, you know, the second cases, like, 70 minus 4, is this the aggregate you use as a base?

MS. XING: If I understand your question, yes. So this Slide 30 actually showed what we did. We take the original error rate and the criteria, we looked for criteria on the lowest HEP. If they need to be detached, the next column will show the detached error rate, so we actually use the 2.1E minus 3 divided by 5 to 10, so we get -- then we get another single number. We got a range of 2 minus 1 to 40E minus 4.

CHAIR DIMITRIJEVIC: So with your formula, would this be the base case? You know, you have this probability of base HEP, so would this detached error rate represent a base case probability for this type of whatever diagonal is or anything?

MR. DEJESUS: Hey, Jing?

MS. XING: Yes, this --

MR. DEJESUS: Jing, can I jump in? This is Jonathan.

MS. XING: Oh, hi, Jonathan.

MR. DEJESUS: So, yeah, I guess if I understand your question, Vesna, it's the -- I think you're referring to the P-CFM base in the HEP quantification model, right?

CHAIR DIMITRIJEVIC: Right.

MR. DEJESUS: So that would come from Table 1 or it depends, what is it, the base PIFs, what is it, the information availability and reliability, task complexity, and scenario familiarity. Those three that the -- I guess, the numbers for those three PIFs, or base PIFs, would come from Tables 1 through 3 in the IDHEAS data report.

CHAIR DIMITRIJEVIC: I see.

MS. XING: Oh, thank you, Jonathan. I didn't understand the question. And so this table is for, like, in -- for those base PIFs, you don't check anything. The HEP still not goes to zero. It goes to this lowest number.

Okay. So this shows -- this kind of give you a sense of how we detach the effect of the error rate.

Then after we detach the --

CHAIR DIMITRIJEVIC: Okay. Thanks.

MS. XING: Yes, for now, we are on Slide 31, we organize all the data available we have. Like, so under each column we have, these are the clean data single component, and then we have multi-component, the detached data, and we could also have bounding data, which means we couldn't detach them, but they give you a big range. In this one, we didn't use bounding data because we already get quite a few multi-component detached data.

And each row, we put the data by the different sources from nuclear operation, other sources, and even the expert judgment. So the simple -- the easiest way we would get a single number is either get the lowest number of here or get an average.

Honestly, we don't have a single rule. We really look at it, what data we have, the data -- uncertainties in each piece of data. Sometimes we see, okay, like in this one, SACADA data is from 2000 cases, so we think that's reliable enough. We are more inclined just to use the nuclear operation data.

In other cases, we may use --

MEMBER KIRCHNER: Jing, this is Walt Kirchner. You know, I make the observation again, here, along the lines of Sean's comment, that if you have a rich dataset from nuclear operations, I would lean there simply because that's more typical of the operating crews and such from the plants.

It would seem to me that that would be the default for coming to the lowest HEP number that you would use in the IDHEAS software as the -- what I called the default earlier.

MS. XING: I pretty much agree most part of what you said, yes, that's the first thing we look at. If we have a pretty good confidence on the nuclear operation data, we would use that data only. However, in this case, we also look at the other data sources because for nuclear data, we don't have a clean and single component data.

We have this detachable data come give us a range, but not an exact number, but we still can take the mid of this range, but we would more likely locate other data for verification purpose, but I completely agree with you. Actually, in our report, we said the top choice is nuclear operation data.

And in this diagram, we show the different -- how the different source of data look like in the previous table. So, like, we have this -- the nuclear operation SACADA data gave us these three ranges, then the other operation, the different sources.

So we actually can come up with a number from Category A, nuclear data, we have the range is the mid -- the average is 3.6E minus 4, and the lower bound is 1.8E minus 4.

And we are pretty lucky, actually. These are all in about different categories, actually all come to the same range, so based on this observation, we take the value, 1E minus 4, as the lowest HEP for failure of detection.

You may ask me, why not take 1.8? Also is because this 1.8 was from that detachment and we only made the estimation, what other factors may count E, so we feel it's more safe to stay at 1E minus 4.

If we stay at 1E minus 4, then we only have these two ranges slightly below 1E minus 4, so we feel pretty confident. And later on, what's not shown in this slides, we will locate those whole event data, which don't have a context -- clear context with it -- well, yes, the lowest is the error rate for a pilot to get into an accident, get into an operational error, which can lead to an accident, it's about E minus 4, so that's kind of consistent with what we have.

Okay. Questions?

CHAIR DIMITRIJEVIC: Any questions, Members? Are we ready to take a lunch break? Okay. So we are a little behind schedule. So I propose that we take a lunch break now. It's 1:26. Like, 1:30 to 2:30 and we get back at 2:30. All right? Is that all right with everybody? Okay. Well, then we will see you back at 2:30 for the -- when we will look at applications on the FLEX equipment and industry experience.

Okay. Thank you, everybody. See you at 2:30.

MS. XING: And thanks to all the Members for your good questions.

CHAIR DIMITRIJEVIC: All right. Thanks for your presentations. They were very enjoyable. Thanks.

MS. XING: Thank you. See you in the afternoon.

(Whereupon, the above-entitled matter went off the record at 1:27 p.m. and resumed at 2:30 p.m.)

CHAIR DIMITRIJEVIC: Okay. So it's 2:30, so we should continue our meeting. I hope everybody had a nice lunch. I think we have everybody back online. Ron, Charlie, Walt, Jose seems to be missing, Dave, Joy, Matt, so everybody but Jose and Mr. Riccardella are here.

So we will continue our afternoon presentation with a presentation on applying this HRA matter which we discussed in the morning to FLEX operation. And we have two presentations. One is the FLEX expert presentation and then one is on -- so calculating HRAs using expert elicitation and then using IDHEAS-ECA, so, Michelle, you will be the first one to present?

MS. KICHLINE: Yes.

CHAIR DIMITRIJEVIC: Okay. Please.

MS. KICHLINE: All right. Good afternoon. My name is Michelle Kichline. I'm a senior reliability and risk analyst in the Office of Nuclear Reactor Regulation. And as Vesna said, I'll be talking about the expert elicitation that was done by research in 2018 for human reliability analysis for flexible coping strategies.

The purpose of the expert elicitation was to use expert judgment to support development of the IDHEAS-ECA HRA tool. We didn't know it was going to be called IDHEAS-ECA at the time, but we wanted to support development of the tool that could be used to quantify the human error probabilities -- or HEPs -- associated with the use of FLEX equipment.

There were three objectives. The first was to quantify HEPs associated with some typical strategies for using FLEX during both a FLEX and a non-FLEX accident scenario. Second was to develop a unique set of performance influencing factors that are associated with FLEX, and third, to quantify the contribution of those performance influencing factors, or PIFs, on the HEPs.

MEMBER PETTI: I have a question.

MS. KICHLINE: Go ahead.

MEMBER PETTI: Just to be clear, these expert judgments were sometimes used in parallel with the actual data we heard before lunch in establishing minimum HEPs, for instance, but were there cases where the only thing you had to rely on was the expert elicitation, so its weight, if you will, was more important?

MS. KICHLINE: I'll have to defer to Jing for that question. I was involved in the expert elicitation. I wasn't involved in any of the data report.

MEMBER PETTI: Okay. Keep going. We'll

just put it on the dock and when you're done with the talk, we'll go back.

MS. KICHLINE: Okay. All right. So the process that we used to elicit that expert judgment was the same process that's been used in the several Level 3 PRA projects, and it's the guidance in NRC's white paper entitled, Practical Insights and Lessons Learned on Implementing Expert Elicitation.

The expert elicitation was formed in spring of 2018 and we had an expert panel of three NRC staff members and three industry experts who were knowledgeable in PRA, HRA, and implementation of FLEX.

And I would say we probably were a little heavy in the experts who were part of implementing FLEX. The expert elicitation -- and you guys got a copy of the documentation -- is the draft research information letter volume 1.

MEMBER KIRCHNER: Michelle? This is Walt Kirchner.

MS. KICHLINE: Go ahead.

MEMBER KIRCHNER: Pardon my interruption. Were any of the experts actually operators?

MS. KICHLINE: So we had one former SRO from a plant.

MEMBER KIRCHNER: Who had actually

deployed FLEX equipment.

MS. KICHLINE: Well, not for -- we haven't had any need to deploy for real, but he had experience with deploying FLEX equipment for training.

MEMBER KIRCHNER: Okay. Thank you.

MS. KICHLINE: And then, we also -- we had two people who were involved in the NRC audits of all the FLEX equipment, so for each site, someone from the NRC or a contractor actually went out to each site to look at their plans and all of their equipment.

We had two senior reactor analysts and then we had a member of the PWR Owners' Group who was responsible for, pretty much, all of the procedural implementation of FLEX.

MEMBER BALLINGER: This is Ron Ballinger. I don't know about the timing of this versus FLEX, but haven't there been a number of plant sites that have run exercises in which they've had to at least deploy partially FLEX?

MS. KICHLINE: So they have to demonstrate -- when they do the inspections, they have to demonstrate that their process is feasible.

MEMBER BALLINGER: Yes, I don't mean the inspection, I mean the actual plant people involved in deploying or simulating deploying the FLEX equipment.

MS. KICHLINE: I'm --- for training?

MEMBER BALLINGER: Yes, I mean, that's a source of people who have actually had the experience in one way or another.

MS. KICHLINE: Yes, yes, so the two people from the NRC who were involved with the inspections would have been there to see the site's implementation plan.

MEMBER BALLINGER: Yes, I guess I understand that, but I'm not -- I know the NRC --

MEMBER KIRCHNER: Ron, this is Walt.

MEMBER BALLINGER: -- people would be there, I'm talking about actual plant people.

MEMBER KIRCHNER: Yes, yes, Ron, you know, one of the things that I think, as a committee, we'll want to come back to in light of the notice that's been sent out -- and I don't want to get ahead of the staff on this -- but, you know, you, I'm sure, have done what I've done, and that's connected to shore power, which is about the equivalent of connecting your FLEX equipment.

What I'm referring to, Michelle, is -- I was on the Savannah. So we would come into Manhattan, for example, and we would connect the ship to shore power, and that required all kinds of things, like making sure you had your phases correctly connected, your lines, and so on, and so forth.

And I suspect, you know, it's aspects like that, that's what I was mentioning earlier today -- I think it was today, or perhaps it was yesterday -- going through that exercise and actually putting load on the equipment and such, really, it would probably have to be done during a refueling outage or another time, not during normal operation, but would really test the human factors aspects of doing this.

And doing it at oh-dark-hundred would even be a better test of, you know, how readily the equipment is connected when you get the lines connected properly -- I don't want to go into a lot of detail, but I think I made my point, and I think maybe Ron was asking a similar thing, do we have people who have actually done this kind of exercise where you actually put load on the equipment in the field under an exercise.

MS. KICHLINE: So as part of the expert elicitation --

MEMBER BALLINGER: They would be good experts for part of an elicitation.

MS. KICHLINE: We did not have anyone who's actually done the process, and in reality -- I don't want to answer that question only because I don't know that we've even made them do that.

MEMBER KIRCHNER: No, this was an observation, Michelle. You don't have to answer it. I just thought I'd put that in the record.

MS. KICHLINE: Okay. And I do agree with you that having actually done it would be far more useful than, in general, the people that we had available were all more either people who went to the site and watched the site personnel do it, as far -- and I don't believe that they connected any equipment, but they went to the site and they looked at the plans, and all of the equipment, and the procedures.

In addition, we had the person from the Owners' Group who went ahead and had developed the procedures as well. And probably later, when -- I know Roy Linthicum is going to have a presentation, but he'll know more about exactly what each site did for rolling out and connecting the equipment, so we can ask him about that.

MEMBER KIRCHNER: Yes, it's one thing to just roll the equipment out of the storage area and deploy it, but not connect it, and put it on load, and it's quite another thing -- and that was the observation I was trying to make earlier -- or maybe this was yesterday -- that unlike operations in the control room where everything is already hardwired, procedures are pretty clear, and everything, going out in the dark, or in the rain, or whatever the environmental conditions are and connecting to power is an interesting exercise, trust me.

Don and I have done this a few times, and the potential for human error, obviously, in that -- those kinds of scenarios is a lot higher than it's going to be in procedural space inside a control room.

MS. KICHLINE: I agree.

MEMBER KIRCHNER: End of observations.

MS. KICHLINE: Okay. And I think in the -- when I do present the results -- oh, sorry, go ahead.

MEMBER BALLINGER: Walt has said it better than I would, but I would say that, lastly, the staff that actually does the work, the technicians and whatever, they know where the bodies are buried.

MS. KICHLINE: Okay.

MS. XING: May I add something?

MS. KICHLINE: Go ahead.

MS. XING: This is Jing. So in our expert panel, at least one or two experts, they had probably not put in hand, but they were part of the team that had used the (b)(5)(B) equipment, which is the reference equivalent to use of FLEX, like, the former shift supervisors, he talked the experience. They spent a whole day, couldn't get the part for generator started, so they had to call the vendor.

So that made -- that's not a FLEX generator, but it is -- it was a very similar situation. Yes, done.

MS. KICHLINE: Okay. So continuing on, this slide summarizes the ten-step expert elicitation process that was outlined in the white paper. So in preparation for the elicitation, the project team developed a project plan, selected the experts that I told you about, and gave them initial descriptions of the human failure events -- or HFEs -- that we would evaluate, and then descriptions of both the FLEX and the non-FLEX scenario that we were going to evaluate.

Then before the expert elicitation itself, the experts all participated in several teleconferences to familiarize themselves with the process and they also used this time to refine the descriptions of the HFEs, and the descriptions of the scenarios.

The experts also completed preliminary HEP estimations for each of the HFEs before the workshop, and we also asked them to include an estimate of the 1st, 50th, and 99th percentiles, so we wanted a range for each of the HEPs.

The workshop was held in 2018 and it was a three-day workshop -- or two and a half, the experts discussed their HEP estimate. So we went through each of the human failure events, we talked about the estimates, and they gave justification for their estimates.

And after the workshop, they submitted their final worksheets documenting their final HEP estimates and some justifications. Then Jing collected the worksheets, summarized them in the research information letter that was on the previous slide.

So as part of the basis for the expert elicitation, the project team compiled an information package that the experts used to evaluate HEPs because the people that we had involved who were more focused on how FLEX is implemented, those people were less familiar with HRA.

And so they got a package with four parts. They had human errors and actions performed external to the control room, a packet of HEPs for human actions similar to using portable equipment, a list of

PIFs that have been demonstrated as important to human actions, and then quantification of how some PIFs change error rates from literature.

MEMBER REMPE: Michelle? This is Joy. I know Appendix A lists the experts that you have, and it talks about their background so that you can see, half of them are not from NRC. I couldn't find that in the main report anywhere, when you talk about you made an effort to go beyond NRC in the main report.

Have I missed it or is it just not there? Because I think that's an important point that ought to be mentioned in the main report.

MS. KICHLINE: No, I believe it's just in the appendix where we put who the people were.

MEMBER REMPE: So I think it would be good -- again, this is a draft report, it's not final yet, but I think it might be good to emphasize that you had diverse backgrounds and what the backgrounds were. I mean, you don't usually -- I mean, you maybe shouldn't list the names, but you could cite, since you did in Appendix A, but we've kind of mentioned that in other times when we've looked at things that the staff has done, to give the reader some perspective, and they're not questioning who was involved.

MS. KICHLINE: Okay.

MEMBER REMPE: Thank you.

MS. KICHLINE: I wrote that down as a comment. All right. So the HEFs that we evaluated, there were five. The first two are similar, it's transportation connection and local control of portable generators, and then the same for portable pumps.

The third one was refilling water storage tanks using alternate water sources. The fourth was an extended loss of AC power declaration, or declaring an ELAP. And then the last was a deep DC load shed.

And this is not the standard load shed that some plants do for a station blackout -- or SBO -- this is a deep load shed that is specifically for FLEX.

For all five of those human failure events, we looked at two scenarios. The first scenario was the non-FLEX scenario. I think the document calls it non-FLEX design scenario, I'm just going to call it non-FLEX, and this one had two parts.

So in the first part, there's one diesel generator out of service, a loss of offsite power occurs, and it's likely the second diesel may fail, so the plant chooses to use the FLEX portable equipment without declaring an ELAP. They start staging it.

And then in the second part, the scenario progresses to the point that the plant actually needs to use that piece of equipment and they need to declare an ELAP.

And then in the second scenario, that's a typical FLEX scenario where an extreme external event happens, that causes the LOOP, it causes the loss of both diesels -- emergency diesels, and then it leads to the station blackout.

So this slide presents the final HEP results for -- from our experts, and it's an average of all of their results. So you'll see that the first two HFEs for using the portable diesel generator and using the portable pump, they were evaluated for four tasks, deciding to use the equipment, transporting and staging the equipment, then connecting and starting it, and then locally controlling it.

And the results for using the portable generator and the portable pump -- so it's the first two -- are quite similar for each of the actions. And one of the reasons we did it this way is, we wanted to know if there was really any discernible big difference between hooking up a generator and hooking up a pump, and the experts didn't think there was a lot of difference.

Now, what you'll note is, the first scenario is the non-FLEX and the second is the FLEX, so the FLEX scenario, the numbers go up, mostly by twice, maybe up to three times as high, so there definitely was an impact due to the extreme environmental conditions that would be associated with having a FLEX scenario.

Whereas, the in first scenario, we call that a sunny-day SBO, so there was no external event in the first scenario.

For the third human failure event, that one just had two tasks, deciding to refill the tank and then refilling it. And again, as you would expect, the results are lower, it's easier to do the task when there's not an external event.

The fourth one is the decision to declare an ELAP, and so HFE 4 is the only task for which the HFE -- the HEP, sorry, result was lower in the FLEX scenario, and so this is something that's being done in the control room, so it's not -- the external event is not making it harder to do the action, it's decision only, and the experts thought that it would be easier to decide to declare an ELAP when there was an extreme external event occurring outside, because you would know something significant had happened and you really needed to make that declaration.

And then the last HFE was for the deep DC load shed, and the HEP results are similar between the two. We expected that both actions would be performed inside under emergency lighting conditions, because in both cases, you're in a station blackout.

CHAIR DIMITRIJEVIC: Question.

MS. KICHLINE: Go ahead.

CHAIR DIMITRIJEVIC: And wasn't some type of analysis between your -- you know, the 1st, 99th, and the 50th, did you have experts guessing a specific range or it's based on variation between those six experts?

MS. KICHLINE: No, that was the experts' estimates.

CHAIR DIMITRIJEVIC: So you asked experts to estimate your 99 and -- okay.

MS. KICHLINE: Yes.

CHAIR DIMITRIJEVIC: What did the experts actually estimate?

MS. KICHLINE: Yes, we asked the experts to provide the 1st, the 50th, and the 99th percentile results, so they gave us all three.

CHAIR DIMITRIJEVIC: Assuming what distribution?

MS. KICHLINE: We did not ask them to give us a distribution, and so it's not fitted to a distribution, we just asked them specifically to find -- to tell us the range they thought that the HEP would be in.

CHAIR DIMITRIJEVIC: And so those numbers which you present to us, are those mean values of six experts?

MS. KICHLINE: Yes.

CHAIR DIMITRIJEVIC: So mean values for 99 and mean values for 50 percentile?

MS. KICHLINE: I believe so, but, Jing, can you confirm that the 1st and the 99th are also mean values?

MS. XING: Yes, the numbers shown here, every number is a mean value of all the expert data. Let's say the 1 percentile is the mean value of all the experts' 1 percentile, so the 50th and the 99th.

When we asked the expert to give the 1 and the 99th, we asked them not just to give the -- their estimated number, but they had to come up with their justification, like, what makes you change from the mean value to 99 percentile or what would make you change to the lower end.

Those were documented in the report. Done.

MEMBER BALLINGER: This is Ron Ballinger. And I'm a little bit of a HEP heretic, I guess. The 99th percentile -- and I confess that I read the report, but when you get to page 530 --

(Laughter.)

MS. XING: Thank you.

MEMBER BALLINGER: Anyway, there's a big difference -- and I'm sitting here alive because of that difference -- between when you have a drill where you pretty much know that you're sitting alongside the pier, and if you screw up, nothing's going to happen that's going to go wrong, and have the actual scenario happen when you're at sea, you find out pretty quickly who remembers things and who does not remember, and who freezes and who doesn't.

And so my question is have you got a fudge factor that you can apply that goes between the answer that you're getting here and the answer that you might get under actual, in Walt's terms, zero dark thirty circumstances, where you're actually having the problem? Is that where the 99 percent comes from, do you think?

It's kind of important.

MS. XING: Yes. That's how, based on experts, talk of their thinking process, that's where they put the 99th percentile. They think all the -- what they were aware of, they can think of the bad situations happen, such as declare ELAP, even if it appears just a decision, but they would consider, if I don't have all the people on-site, then what's the point I declare ELAP after I declare that people have to perform the action. I don't have people do the -- perform those actions yet, so that may delay their decision declaring ELAP.

So the high range, the high numbers, the 99th percentile, reflected that line of consideration.

MEMBER REMPE: So I have a --

MEMBER BALLINGER: Okay. I guess it varies. The factor I'm looking at is between -- varies between 2 and about 5. Okay. Thanks.

MEMBER REMPE: So I have a question based on what Xing said in her response, do you have the numeric average of what the experts provided or did you go back and do what was shown on Slide 4, where you integrate beliefs, where you take the justification provided by each expert, and you try to reach a consensus value?

Because Dennis Bley has beat it into me over the years that you just don't take the average number and plop it in the table, and I know those numbers are in your report too, but I didn't see it, and maybe I missed it, because it was a lot of pages, some discussion about some effort to come to consensus among the experts.

MS. KICHLINE: So I can take that, Xing.

MS. XING: Yes, go ahead.

MS. KICHLINE: During the expert solicitation, during those two and a half days, that's where we tried to come to some consensus. So we discussed -- each of those HFEs, we discussed them in detail with all of the experts. We went around and each expert got to talk about what their estimate is and why they thought that their estimate should be what it is, and then they all came together to discuss what they thought was good justifications.

And in that discussion, we -- I don't know if I want to say, often, but we sometimes had, you know, people get convinced. And they said, you know, when I turn in my finals, answers, I'm going to have final answers that are different from my preliminary answers because I now have a better understanding of the situation and what the other experts were contributing.

MEMBER REMPE: So that's what you should do, again, is that in the report and I missed it, because there were a lot of reports to read for this meeting, and so I skimmed some sections, or if it's not in the report, I'd suggest that it be mentioned, because you have that in the flow diagram, what the process was, but to provide more confidence in the results.

MS. XING: Thank you. I think it's -- you're, right, it's in the flow diagram. I agree that we need to put an emphasis to make this clear.

MEMBER REMPE: Thank you.

MS. XING: Yes, my sense is they have a consensus on the scenario, what happened, what could happen, however, we did not ask them to have a consensus on the numbers they come up with.

MEMBER REMPE: I wouldn't expect that, but they need to understand if one expert's dramatically different than the other, because the one expert may have considered something that the other one didn't mention, and what Michelle said is exactly what should happen, that they understand some things that they might have missed.

MS. XING: Yes. So I can give you an example here, for example, experts spend a lot of time talking about the frequency of FLEX training. At the end, the consensus was -- or their estimation based on the assumption the frequency is every four years, some expert, so that's a consensus, but when come to the HEP estimation, some expert believe that's good enough, some experts had a different belief. So that, we accept the fact. Thank you.

CHAIR DIMITRIJEVIC: So you didn't have here, the underlying PRA scenarios, right, because not too many plants already put the FLEX in their PRAs, right?

MS. KICHLINE: We do --

CHAIR DIMITRIJEVIC: Did you have underlying the PRA scenarios?

MS. KICHLINE: Yes, in the 2018 expert elicitation, we did not talk about PRA at all. We just gave them the scenarios, and the descriptions, and we did not talk about any -- we really didn't talk about anything related to PRA, other than the fact that we were going to be requesting HEPs.

CHAIR DIMITRIJEVIC: Okay. But you not discuss a lot of importance, for example, the ELAP declaration, if you have -- if you declare ELAP, is that good for the plant response or not necessarily good, if you don't need to declare ELAP? I mean, you have to have a procedure or something to help you declare ELAP.

MS. KICHLINE: Yes.

CHAIR DIMITRIJEVIC: When you declare ELAP, you were going to get, for example, this load shed, which will shed equipment, which maybe you don't want to shed to respond to some accident, so when should you declare ELAP, you are entering some less desirable state of the plant.

MS. KICHLINE: So the scenario mentions -- the scenario descriptions that we gave them outline what the -- kind of what the -- what has occurred and what successes and failures they've had, kind of like an event tree, or fault tree, would, so the scenario description gets you to the point where you need to declare the ELAP, and therefore, it's a good thing that you declare it.

CHAIR DIMITRIJEVIC: All right. But you may hesitate to do that because it's not clear, like, for example, it is clear in your FLEX designated, because you have a, probably, seismic event, and it's not clear that you're not going to recover your off-site power in the next couple hours, right?

But in non-FLEX equipment, your off-site power can come back in two hours and maybe the generator will not fail, so I mean, the question is, then you are not -- then they can hesitate to -- it's a different scenario. That's why I'm asking this, you know, how did you choose scenarios.

MS. KICHLINE: And that is exactly why the ELAP declaration was higher in the non-FLEX scenario, because we -- I'm going to talk about it a little bit, actually. I'd rather wait until the next slide to get into that detail, but I did want to note one more thing on here, was that, you'll see that there's blank spots for the decide task, under the FLEX scenario, and that was because the way that the FLEX procedures are setup, that the ELAP declaration is actually the way that you decide to do those other tasks.

So once the ELAP is declared, you implement the FLEX support guidelines, and those additional things all happen, kind of, automatically, and so you didn't need to do the decide part.

And just what you were talking about is, in the non-FLEX scenario, there was a task in there to decide that you need to do it, because in the sunny-day SBO, there's no actual trigger, because you're not declaring an ELAP yet, to do the decision to transport and connect the equipment, because we had a two-phase non-FLEX scenario, where you start with a loss of off-site power, but then you stage the equipment, but then it progresses into a station blackout, and you need to declare an ELAP.

CHAIR DIMITRIJEVIC: And do they have a different crew for this FLEX, is that you assume, the different -- that you will have operators doing regular stuff and then you will have a FLEX crew running around getting equipment ready?

MS. KICHLINE: No, it's all the same -- we all assume the same, like, minimum shift staffing.

CHAIR DIMITRIJEVIC: All right. Well, then this will also have a much more impact on, you know, progress of accident, so it will be much more interesting to see how that fits in the total, you know, PRA model. Okay. All right. Thanks.

MS. KICHLINE: All right. So continuing on, I want to compare the action for the operators failing to declare an ELAP in the 2018 expert elicitation with the work that was done later in 2019, to try to showcase how their different, and you're going to get more discussion about the 2019 workshop from Carmen and Susan after my presentation.

But so basically, in 2018 the -- as I said before -- something is wrong. Sorry, I'm having technical difficulties on my end. There we go. All right. So the HFE to declare an ELAP was evaluated in both of those efforts. In the 2018 expert elicitation, the HFE to declare an ELAP was evaluated for two scenarios, like I said, the non-FLEX and the FLEX scenario.

In both of those scenarios, information about when AC power would be restored was uncertain. That was our given. The procedural direction that we used in the 2018 expert elicitation said that if AC power is not restored to the emergency 4kV busses within 60 minutes, and it's not expected to be back within four hours, then you declare an ELAP within 60 minutes.

And so that is the -- it's going to be similar to one of the cases that we used in 2019. In 2019, we only evaluated the ELAP for one scenario, and that was a beyond-design-basis seismic event. That occurs at a BWR from 100 percent power, 1 EDG is out of service, the other EDG fails to start due to damage from the seismic event, resulting in an SBO.

So that scenario is similar to the FLEX scenario from 2018. So the 2018 and 2019, one of the scenarios are similar. They are not the same, because in 2018, we actually defined the PIFs and we had many of them, there were 12 PIFs, and I don't remember exactly how many, but many of them were said to be impacted, either low, moderate, or high.

In 2019, they didn't define the impact of the PIFs. In 2019, the experts defined what they thought the impact was. And so in 2019, they did three cases for this FLEX scenario. The first was where the ELAP is clearly defined. The procedure says that the ELAP exists when it is expected that no 4kV bus will be re-powered within one hour. And we assumed in that case, we told the experts, that diagnosis would be obvious.

In the second case, we gave them the procedural direction that is more similar to the 2018 evaluation, where you must declare an ELAP within an hour if AC power can't be restored within four.

And in Case 2, we said the diagnosis is still obvious, that you -- it's going to be pretty easy to tell that you're not going to get power back in four hours.

For Case 3, this is the one that's really the only one that's similar to 2018, because it used this same wording that required judgment, but we also said that it's not obvious whether power can be restored within four hours.

And this slide shows a comparison of the results between 2018 and 2019, and I've highlighted the two results that are kind of similar. I mean, not results that are similar, the two scenarios and HFE combinations that were similar, as I just described, which is, the 2018 FLEX scenario was similar, but not the same as the 2019 Case 3.

And you'll see that the range that we got for the HEP estimates in 2019 would encompass the average result that we got in 2018, so they're not, you know, completely different, whereas, if you looked at the results outside of that, you might think that they don't make any sense at all.

Any questions before I move on, on those -- that comparison?

CHAIR DIMITRIJEVIC: I actually did want to get that, what you just said, so the difference -- looking at this case throughout -- this is the -- these numbers, the Case 1, Case 2, and Case 3, what do they -- do they represent these same, the declaring the ELAP?

MS. KICHLINE: Yes, so these were -- both the results for the operator fails to declare ELAP, the first -- the top one is the two scenarios that we looked at in 2018, and the bottom one are the three cases that they looked at in 2019 using IDHEAS.

CHAIR DIMITRIJEVIC: And when you say it was below E2 to lower E to minus 1, that mean between

1 percentile and 99 percentile, is that what you're talking about?

MS. KICHLINE: 0.1 to 0.01. It might have been, at low -- I considered anything low that was, like, 0.2, 0.3.

CHAIR DIMITRIJEVIC: No, no, I know what the low is, but I don't understand what 2. You have a two brackets, one is low E minus 2 and one is low E minus 1.

MS. KICHLINE: Oh.

CHAIR DIMITRIJEVIC: These are 99 and 1, what do those two blocks --

MS. KICHLINE: So in 2019, we did not present those results as a mean. The results are only presented for the individual --

CHAIR DIMITRIJEVIC: So this your Case 3, which is most similar to Scenario 1, right, from 2018, you have a low E minus 1, but 0.66 is not low E minus 1.

MS. KICHLINE: The yellow ones are the ones that are the most comparable.

CHAIR DIMITRIJEVIC: Yes, but Case 3 is not comparable with the FLEX, it's comparable with the non-FLEX scenario.

MS. KICHLINE: No, in 2019, Case 3 was a

FLEX scenario.

CHAIR DIMITRIJEVIC: Well, you said in your slide that Case 3 is wording from Case 2, but it's not obvious whether the power can be restored within four hours, right?

MS. KICHLINE: Yes, that is the procedural direction, but it was only looked at for one scenario description.

CHAIR DIMITRIJEVIC: All right. Okay. In my mind, that's non-FLEX because you know that you don't really know do you have a FLEX situation or not, so I mean, that's why I sort of like, it was, you know, trying to see some differences.

MS. COOPER: So, Michelle, maybe I can clear that up.

MS. KICHLINE: Sure.

MS. COOPER: This is Susan. So Case 3 for the FLEX scenario that looked at -- that was looked at for the FLEX HRA using IDHEAS-ECA was still a beyond-design-basis event. The less obvious whether power could be restored was -- we had some descriptions that we worked with with the HRA analysts to understand that, and it more had to do with whether damage was obvious and widespread or if it was, you know, seemed like there were pockets of damage here or there, as opposed to a very widespread severe event.

It was still beyond-design-basis event for the plant site, it was just supposed to represent a situation where you might not know what's going on off-site with respect to power restoration, it's just not as obvious.

It's different than, you know, on your own site, you're getting reports from various places around the site saying, you've got this damage, we've got that damage, so on, and so forth, so that's the difference between Case 1 and 2, and then Case 3 being less obvious.

Still FLEX, it's just a different kind of event, you know, I can't remember specifically what we were talking about, I don't think we identified a specific type of event, but the event that we looked at specifically, as is at the top of this slide, was a seismic event.

CHAIR DIMITRIJEVIC: Okay.

MS. COOPER: Thanks.

MS. KICHLINE: Any other questions on that? All right. I'll proceed to the next --

MEMBER KIRCHNER: It's more an observation.

MS. KICHLINE: Oh, go ahead.

MEMBER KIRCHNER: From these exercises, does it suggest anything about modifying tech specs to declare an ELAP? I mean, why would you waste hours and hours of time? Yes, you're probably trying to diagnose the situation, and so on, and so forth, but this would be extremely difficult to do under the circumstances of a beyond-design-basis seismic event.

So why would you not have in tech spec space -- you went beyond your design basis on a seismic event and immediately declare ELAP?

MS. KICHLINE: So you don't want to declare an ELAP if you don't have to --

MEMBER KIRCHNER: No, I understand that. Of course, but, you know, now you're beyond design basis event and you've lost power. I think that's your scenario, right?

MS. KICHLINE: Correct.

MEMBER KIRCHNER: You've lost off-site power.

MS. KICHLINE: Yes.

MEMBER KIRCHNER: My takeaway would be under those two conditions, you probably would want to go to ELAP as soon as possible, assuming -- unless your diesel generators or your -- or some of the more modern plants now will go to turbine-fired backup, and it's an alternate power supply, but no, it's an observation, not a question.

MS. KICHLINE: Okay. So I don't -- you're not looking for an answer?

MEMBER KIRCHNER: You don't have to answer it, but --

MS. KICHLINE: Okay. I do have a little bit of insight there, I think, that might help, is, you know, when we talked about this, part of the reason there is reluctance to declare an ELAP is because once you declare an ELAP, you're going to do a deep DC load shed, and that isn't so that you can -- you have an extended period of time in which you will be able to control the plant, but still have time to actually get your FLEX strategies in place.

MEMBER KIRCHNER: Yes, no, Vesna went through that. Yes, there are a lot of reasons why you don't want to be premature in doing that.

MS. KICHLINE: Yes, and so we --

MEMBER KIRCHNER: But the scenario that you described is a rather -- I'm feeling there shouldn't be a lot of room for human error in this particular decision --

MS. KICHLINE: Okay. Well, we tried to --

MEMBER KIRCHNER: -- given the scenario

being postulated.

MS. KICHLINE: -- encompass what the actual procedural guidance is out there, and there are some plants that have guidance that just specifically says, if you don't have power back within an hour, declare an ELAP, and there are other people out there, other licensees, who wanted to give themselves more flexibility.

And so they said if you don't have power back within an hour, but you don't think you're going to get it back in four, declare an ELAP. And so with that flexibility, you know, they have reasons for the fact that they wanted the extra flexibility to not declare an ELAP, so that they could have more time to, you know, troubleshoot their EDGs, but it also gives you the ability to make the wrong decision.

MEMBER KIRCHNER: Yes, so this is -- no, again, these are more observations that demonstrate that your work is useful in a way that you're probably not thinking about. I'm thinking differently. I'm thinking, okay, now I go and look at PRA space and say, okay, do I really want to wait much longer to, you know, shed load, et cetera?

And so the melding of what you're doing with a full scope PRA then, becomes a very useful exercise, and it will be plant-specific, for sure, but just playing a guessing game for three hours, as to whether we should declare ELAP, doesn't give me a lot of confidence, at least for the kind of, really, you know, beyond design basis kind of event that you started with for your scenario.

MS. COOPER: Michelle, if I could just add something, this is Susan, Michelle's actually -- there -- correct, there are still variation across U.S. plants so far as the way ELAP is defined and how it's supported in procedures.

However, there was some indication in the 2019 effort that industry had already made changes with that in mind. For the two plant sites that we visited, both of them had explicit guidance that was improved over what might have -- we might have thought -- we might have seen in 2018.

Those plants that still have some more leeway in their guidance are typically those that have very long battery lives. So those plants that have the shorter battery lives have made changes to their procedures, and in some cases they've pre-staged equipment also, recognizing that they aren't going to have enough time to do the full deployment.

So I think there are already changes that are being made, and some of that was reflected in what we found and what we represented in the 2019 effort.

MEMBER KIRCHNER: That's good. That shows value in your work, probably not where you were thinking it would prove of use, and I think that quite good, actually.

MS. XING: Thank you.

MS. KICHLINE: All right. So that leads into, you know, what did -- what were some of the insights that the experts gave us? And so the first one is that it's kind of easy to fail FLEX, because there's a lot of strategies and if you fail any one of them, you really can fail FLEX.

So all of those items I had up there, you know, those five AGPs, HFEs, you really need to do each one, right? So in a PRA, you're going to need the FLEX strategy to supply AC power with a portable generator, but you're also going to need the portable pump and you're going to need to declare the ELAP.

And so when we asked the experts, you know, what do you think -- when you sum up everything, what do you think that the failure probability could be? And they gave us, you know, estimates in the 30 to 60 percent range when you combined everything.

So they really did -- now, again, most --

a lot of these people were not PRA or HRA experts, but they really did think that, you know, implementing FLEX was going to be something that was not easy.

They also noted that the decision to declare ELAP, really, it did drive the HEP results for both the FLEX and non-FLEX scenario, so training and procedure improvements that can be done in that area, would help with that, and I think I do include it later, that just like Susan said, in the 2019 expert workshop for IDHEAS, we did see that training has improved on declaring an ELAP and procedural direction, at least some plants, has improved.

And so I think -- you know, I presented these results at the RIC in 2019, and a lot of people had, kind of, a hard spot with that, but I think that it helped, you know, realize that these are some key areas that need to be looked at, and it's definitely something that has been looked it, and I think has improved.

All right. So some of the additional insights was that for -- as far as performance influencing factors, they thought that training, scenario familiarity, and procedural direction were the most significant performance influencing factors that really affected their HEP estimates.

But again, they thought that these things would improve over time as training on FLEX is standardized, and they noted that, you know, if the equipment is used or staged for defense in-depth, which some plants have been doing, which is bringing it out when they're doing maintenance on other things, that they thought that that hands-on experience would help, and I think that is being done.

And that the -- I talked about the procedure improvements already, and that we confirmed that that was the case, I think, in 2019.

So then I want to note a couple of limitations on the expert elicitation. So one is that the HEP estimates from the expert elicitation are only valid for the specific contents under -- context under which they were evaluated.

And like I think I said before, that the FLEX and non-FLEX scenarios that evaluated, were intended to be very challenging, and both of those scenarios, we defined them with multiple PIFs that were negatively impacted.

And so we did define those scenarios to be challenging. And we -- one of the limitations is that we did not consider the impact of time or the ability to recovery -- to recover on the HEP estimates, and that could be significant, especially for the non-FLEX scenario, because the timeline you're looking at is built off of having to do debris removal in a FLEX scenario.

But in a non-FLEX scenario, you won't have debris removal, and if you did, it would be much less, and therefore, we would expect there'd be a lot more time to recover, and that could definitely impact the HEP results.

In addition, when we looked at these, we defined what the scenarios based -- the scenarios and the actions, based on the minimum required set of FLEX procedures that were written to implement the orders. So the people that we had on the team had written the -- you know, done the inspections and seen how they -- FLEX was originally implemented, and there have been changes since FLEX was originally implemented.

When they originally implemented it, nobody was putting FLEX into their emergency operating procedures. We know now that it is being added to emergency operating procedures. And so that's an example of one of the changes that have been made.

So in summary, I want to leave you with the fact that, you know, we have been considering plant-specific FLEX information as needed to support the agency's regulatory response. We're crediting it when we need to credit it, but that if we enhance the HRA for FLEX and we get more equipment performance data, and operating experience, that just makes our results better, so that our FLEX PRA results will be more realistic.

And that we also think that enhanced use in staging of the FLEX equipment will increase familiarity with FLEX, it can help with improving procedures, and getting improved FLEX HEPs. That is the end of my presentation.

CHAIR DIMITRIJEVIC: Thank you, Michelle. Anymore questions?

MEMBER BROWN: Yes. This is Charlie. I guess I've been listening to this analytical expert elicitation discussion with interest, you know, and I'm much more of a hands-on person, from my background, because we actually trained on this kind of stuff all the time, actually hook stuff up. Why hasn't the NRC put in place direct observations of declarations of need for these scenarios to actually occur in some of the plants and had people on station to actually evaluate the performance so you have real-time data, as opposed to plucks from the air that you're dealing with right now in this whole -- with the expert elicitation drill?

MS. KICHLINE: I mean, I can't talk to why, you know, the orders were written the way they were and we decided to inspect things the way that we did. My only counter to that would be, even if we went out and we, you know, inspected -- you know, we did, like, a drill and we had every single one go out and say, go ahead, run all this stuff out, and let's see how it works, that's still going to be very limited data, because we're finding --

MEMBER BROWN: Not if you go to the point of hooking stuff up.

MEMBER KIRCHNER: Yes, the third bullet, I think, Charlie, is the operative one. I'm with you. If you really hook it up and you load it, which is what --

MS. KICHLINE: So they --

MEMBER KIRCHNER: -- we did, Charlie, and I'm sure you did in NR, then you knew that your backup, the equivalent of what would be called FLEX equipment, was going to be serviceable, and this was done, in my experience, on a frequent basis.

Now, for an actual commercial plant, you probably aren't going to be able to do it unless you're in a shutdown mode or refueling mode, but this third bullet would really inform your HEP and PRA results. They would be invaluable, I think.

MS. KICHLINE: And we have not required anyone to actually hook it up to operate equipment. The closest, I believe, even in the -- I know we accepted an application for a diesel outage in which they staged their FLEX equipment, or actually, not exactly their FLEX equipment, but it's similar to the FLEX equipment, but they were not required to actually hook it up to the plant and confirm that it would work.

They can confirm that it works by hooking, like, the diesels up to a load bank, but not hooking things up to actual plant equipment.

MEMBER KIRCHNER: Yes, that's a completely different thing, because a load bank is a passive dump. If you hook up to the plant, you have to sync with whatever power is still available in the plant. There are all kinds of complexities that go way beyond just demonstrating that the diesel can take a load.

MS. KICHLINE: Hence, some of the issues that we have had in the information notice.

MEMBER BROWN: Have you ever -- have we had experiences where -- let's see, how long ago were the FLEX approaches -- I've forgotten how many years ago, was it four, five, six years ago, when they were supposed to have all this stuff in place?

MS. KICHLINE: I want to say, like, 2016.

MEMBER BROWN: Okay. Four years ago. I was off by a year. Have we had any circumstances where plants have had to call on the actual ELAP and hook up FLEX equipment in real time?

MS. KICHLINE: No.

MEMBER BROWN: No? And that just emphasizes the fact that unless you take this Bullet 3 approach, and I admit, you can't -- it's not like the Navy plants. I mean, we trained like crazy on those. We'd take out of service and into service, trip off turbine generators, loss of loads, hook up -- you know, open and close valves, that's part of the normal things, and they would do that either quarterly, or semi-annually, or annually, depending on what the circumstances were, at almost every submarine and every aircraft carrier.

But we knew the fittings would fit, we knew the -- and sometimes we had circumstances where something didn't quite come out right, and your procedures get very well defined and refined as to who's supposed to do what, and without that, this is -- I just don't think you make much progress, particularly in the light of, you've never ever -- nobody's ever gone through a complete setup, it sounds like.

And they have to do it during a refueling outage or whatever, but you certainly have opportunities to run that drill and have each licensee demonstrate in two or three plants that they can actually accomplish it, maybe even in every plant.

And then you know when their outages are coming, you just roar in and declare they're going to go do it. You're the regulator and you got to make sure this stuff is safe.

MEMBER BALLINGER: This is Ron. I'm going to reinforce that Item Number 3, I mean, in effect, even an expert, in quotes, solicitation, amounts to a bunch of assumptions. With Item Number 3, you have a falsifiable contention here. You can find out what the difference is between the right answer and the assumed answer.

And until you do that, everything you have is really, you know, based on a lot of assumptions, and maybe these 99 percent, or 95 percent, things are correct, but until you actually try it, you just really don't know, and you might actually be surprised in the, sort of, information sense of the word.

MS. COOPER: This is Susan, Office of Research, just wanted to add something and probably, Michelle can add something more, so in looking at the information that was used for the 2019 FLEX HRA effort, I did look at two plant-specific final integrated plans, including their FLEX validation.

And in the requirements for the FLEX validation, which comes from NEI 12-06, someone can correct me later on that, they have to identify which actions are time-sensitive actions, and for everything that's identified as a time-sensitive action, they had to do a demonstration.

There was a phasing -- different phases, you know, whether it was within the first, I want to say, 12 hours, or maybe the first 6 hours, then 6 to 12, 12 or -- I can't remember what the breakdown is, but that also changed the fidelity of what the demonstration required.

At the highest level, they would do multiple operators performing the same action and taking their times. So there is some aspect of demonstration that's required for some of these actions, especially those that are time sensitive.

Now, I think we've already pointed out that there are going to be some limitations to performing all of the steps that might get you hooked up to the plant because it's still operating, so, you know, obviously, some things that are different there, but that's -- we've lived with that so far in other PRA hazard space.

You can't -- you know, there are a lot of things you can't do. All of the actual manipulations for a field operator, whether it's internal events PRA, whether it's a fire PRA, or whatever, there's some things that you just can't do out in the plant because it's operating at that time.

But there is some -- for some of the more -- like I said, what they call time-sensitive actions, there are demonstrations that are required.

MEMBER KIRCHNER: Yes, my observation on that, Susan, is they're more -- those time demonstrations had more focus on moving the equipment from its storage to its deployment location than -- and admittedly, if you have a lot of physical site damage, that certainly is of concern, but they haven't gone the next step, which is what your Bullet 3 here would do.

And actually, you know, they could sync the -- it'd take some skill to do it, but it's done routinely. Charlie's experience, and Ron's, and mine are very similar. We, once a week, fired up all the diesel generators on the Savannah and we synced them with the main load.

So the plant's operating, and we sync them, and we put power on -- we put load on them, and likewise, you know, probably, the equivalent of the FLEX equipment then would be the emergency diesel generator, which was, you know, your last stand, so to speak, for power, other than your battery power, for the controls of the reactor itself.

And we did the same. We synced it with the grid onboard and took load to demonstrate that it actually was going to function. I think they could do that with the FLEX equipment, not necessarily pumping water, that's a little bit -- that one's a little different, but, you know, when you look at the three things that were on the proceeding slides, it's -- pumping water into a tank is probably the easiest.

Syncing connecting power and taking load is probably the most difficult. So that's based on my own limited experience, so just, again, in the vein of observations, I would just concur with Charlie and Ron, and I think if you had actual familiarity, you know, those plants that are doing it for defense in-depth should be commended, and anything you can gain from how they've staged and operated the equipment to improve your own estimates, and then also feed that back, eventually, to the PRA, would be extraordinarily useful. End of observations.

MEMBER BROWN: You can also hookup hoses, but you don't have to put water any place. You just don't operate the last valves. And so you can go almost through the entire process where you have an open tank that you're going to be pumping stuff into, you can hook that up, like Walt said, and pump water if you want, but you can still complete most of the process without impacting the plant itself.

And it's just invaluable to know that all your connections work, that something hasn't gulled a connection because somebody tried to hook something else up or hit it, tons of things can happen if you don't periodically try it.

And that way you also get a good feel for how long does this really take to do certain things. Lighting off a diesel is not as simple as it sounds.

MEMBER BALLINGER: There's another aspect to this, and that is that when you -- a lot of times, when you do the actual event, or the actual process, you discover that, well, you know, two refuelings ago, somebody did some maintenance on this thing and this piece of it hasn't been exercised, and all of sudden you start doing this scenario, you discover that some things don't work.

The diesel doesn't start, cooler's got a leak, something, and so you expose the so-called unknown unknowns, which are hopefully in the PRA, but that's different than actually experiencing them.

MEMBER KIRCHNER: Yes, and there's a lot of equipment downstream of the connections. I had looked at this carefully on some of our site visits, so yes, you see, for example, for the AC power, you see where they're going to open up the ports and connect the three large cables from their transportable diesel, but on the other side of the wall are circuit breakers.

And instrumentation and you need all that as well, and so exercising -- you know, it's not just the diesel startup probability, there are circuit breakers and instrumentation on the other side of the wall that the operators need to be familiar with and be able to operate to actually connect that diesel that's sitting out there in the parking lot outside the reactor building.

CHAIR DIMITRIJEVIC: I just want to bring something to your attention, this is a completely new equipment and wasn't credited in most of the PRAs, you know? I mean, we didn't have it up until, like, a couple years ago, so the thing -- I mean, you know, every plant has an emergency diesel generator, station blackout, diesel generators, everything which is normally exercised.

This equipment isn't credited at all, it's credited in very small recovery value of, I don't know, 50 percent chances to save the plant or something, so we are not yet there. We will use this in verified modeling. This is just an exercise of it, so that's why they don't have a PRA models we can apply in here, so we will see, because there will be some industry presentation and I'm looking forward to it.

Okay. So --

MR. CHEOK: I want to chime in real quickly. This is Mike Cheok from the Office of Research. So that was a good discussion on, you know, whether we require, you know, Item 3 from this slide or not, you know, for a lot of reasons.

You know, there was no specific requirement for it, but, you know, we -- the staff and licensees are starting to credit FLEX equipment, you know, in the plant safety in terms of licensing activities, of plant oversight, in terms of the significance determination process, or something.

So in that case, when we model the FLEX equipment in our PRAs, what we will do is, we will give very specific credit, depending on what the licensees do in terms of the equipment, their training, or something, so what we say is, we will give the appropriate credit for this equipment, depending on things like, you know, what they do in Item 3, or how they keep the equipment reliable, or something.

So we are -- the staff and the licensees are moving in this direction. We have the equipment, we have FLEX equipment modeled in our PRA models, and, you know, the credit for this equipment and for the human actions, you're, is going to be dependent on what the plant itself does in terms of maintaining the equipment, or maintaining the training, or incorporating the procedures into their plants.

CHAIR DIMITRIJEVIC: Okay. Thank you. I also want to mention to the members that in the additional slide to this presentation, there is some interesting human error rates and insights from other industries. I know that Ron will definitely enjoy the ones from the airplane industry.

So take a look in that. It's in the backup slides to this presentation. Okay. So who will be -- so next, we will discuss how the IDHEAS-ECA was used to estimate or, you know, calculate those FLEX HEPs. Who will be presenting this?

MS. COOPER: So Carmen should be bringing up her slides. This is Susan Cooper.

CHAIR DIMITRIJEVIC: Okay.

MS. COOPER: And I'm going to get us started while she's getting organized here, so good afternoon, everyone, officially. Susan Cooper. I'm a senior reliability and risk engineer in the Office of Research. I was the technical lead for this project of FLEX HRA using IDHEAS-ECA.

And Carmen Franklin, the project manager, is going to start off the presentation and I'm going to pick it up again when we start talking about scenario development. So it looks like Carmen's all set. Go ahead, Carmen.

MS. FRANKLIN: Thanks, Susan. So today's agenda, I will discuss the objectives for this FLEX HRA effort. I'm going to provide a summary of the technical approach that we used, highlight the project key resources that helped this project be a success, and then Susan will discuss the project key scopes and limitations, the three scenarios that were developed and evaluated, the results, the insights, lessons learned, and provide some potential next steps for this work.

Slide 3. So the objectives for this project were built on previous FLEX-HRA efforts that were completed in the past. Specific objectives for this project included performing an HRA PRA for FLEX and non-FLEX scenarios using FLEX strategies and/or the equipment.

And we also wanted to actually pilot IDHEAS-ECA, so specifically, with IDHEAS-ECA, we wanted to assess the human failure events in the FLEX and non-FLEX scenarios, and we also wanted to evaluate the ECA quantification tool and make sure that we provided feedback to its developers for further improvements.

Slide 4. The underlying objectives were developed to address lessons learned from previous HRA efforts that had been done. We knew that in order to design more detailed scenarios that we would need to have a better understanding of the FLEX operations.

So therefore, we specifically wanted to develop a set of credible HRA PRA scenarios that used FLEX equipment and from that, we wanted to develop a detailed qualitative HRA analysis.

We wanted to facilitate a workshop to discuss results among analysts and obtain feedback from both NRC and industry HRA analysts for insights and lessons learned.

All right. Slide 5. So to make sure that we would be able to obtain the level of detail needed for this project, we wanted -- well, we took a more extensive approach, so the first bullet pretty much is consistent with the approach taken to perform a traditional HRA to support PRA.

So which is to identify and collect the information on the FLEX strategies, the equipment, and the associated operator actions.

The remaining bullets were different from the typical HRA PRA approach, given that we wanted to identify a group of HRA analysts, FLEX and operational experts to represent both NRC and industry, and once those teams were developed, we then had the FLEX and operational experts assist in developing the credible HRA PRA scenarios that use FLEX equipment.

And I would just like to mention that this project, we were working on a very compressed scheduled, so we were very diligent with the project planning and scheduling. So we had weekly meetings with each team, starting off with the FLEX and operation experts.

So the first weekly meetings focused on that particular group while we gathered information and developed the scenarios, and then we began our weekly meetings with the HRA analysts, and so with that team, we had regular meetings to make sure that they were prepared on the IDHEAS-ECA and the tool.

And we also had regular reoccurring weekly meetings with the owners' group representatives, just to make sure that we touched bases on the project status and that we were communicating any updates to move the project forward.

All right. Slide 6. So once the scenarios were developed to a certain point, we began having, like I said, the weekly meetings with the HRA analysts to begin their activities in preparation for evaluation, to include identifying and defining the human failure event associated with the -- with using FLEX equipment.

They also developed the qualitative analysis for each human failure event. They were also attending the IDHEAS-ECA training on the tool and then they were also participating in the three-day workshop to evaluate those scenarios.

And so just to give you some insight on the workshop structure, it was hosted at the NRC's Professional Development Center early December 2019, and so in attendance, we had our HRA analysts, we had the IDHEAS-ECA developers, the technical support staff from NRC and industry, and we had two of our FLEX and operational experts attend as well.

And so pretty much the structure and the agenda flow as we went through each scenario's qualitative information, and then including the performance influencing factor and discussing the performance influencing factor attributes that were selected, and then immediately discussing that scenario, we would then apply the scenario in the tool to get the quantitative results.

And then concluding the workshop, we conducted a survey to capture the IDHEAS-ECA experience that they had, and any ideas for updates and improvements.

So Slide 7. So there were several key resources that we used for this project. Prior to the project starting, NRC staff, we re-familiarized ourselves with the expert elicitation project and the report that was completed in 2018, in addition to EPRI FLEX HRA report that was also completed in 2018, I think, in November.

So by using the existing MOU between EPRI and the NRC's Office of Research, EPRI was able to facilitate bringing on the involvement with key industry counterparts, so EPRI provided us, also, with a SharePoint access, which included -- I'm sorry. Technical difficulties on my end. Sorry.

They also included a SharePoint site that included plant-specific procedures, they also provided some industry reports that were related to the implementation of FLEX, training documents, and other plant-specific documentations that were very helpful for this project.

So therefore, having EPRI involved allowed us to have access to very key pieces of information that we might not have had otherwise without the MOUs. Also, very early on in the project, NRC attended and hosted a FLEX overview meeting, August 2019, that was led by industry.

A major resource of information also came from our two plant site visits. These visits helped the HRA analysts gain a clearer understanding of FLEX and how the power plants were actually implementing FLEX and its equipment, and we were also very evicted to have operational experts who provided a wealth of knowledge continuing throughout the project, not just at the beginning, but also during the plant site visits and through the life of the project to help keep that information going and keep it flowing.

All right. Slide 8. So the most important key resources, of course, were the actual project team members that represented several different roles and had different expertise. So starting off with the technical support staff, their role was pretty much, we had a continuous engagement with the project members.

They provided the technical support and the guidance on previous HRA efforts that had been done, and was able to share lessons learned from that, and the PWR and BWR Owners' Group representatives, they provided an oversight perspective of the FLEX programs and their statuses with their respective fleets.

And that was pretty much just to ensure that the appropriate FLEX activities were being captured and considered during this project. And then the owners' group also, I want to mention, they were also key with helping identify the plants that we actually went to visit.

The FLEX and operational experts, this

team, they provided plant-specific and the realistically related FLEX feedback that we wanted and a development in the refinement of the scenarios.

So this group had a rich understanding of FLEX, of the equipment, its operation, mitigation strategies, and so forth, that were being used in the non-FLEX scenarios, which also really helped the HRA analysts during the workshop.

And so lastly, we have the HRA analysts, and they were responsible for performing the preliminary HRA assessment of the scenarios. They also assessed the human failure events and they were also responsible for performing NHRA quantification using the method and the tool.

And so next, we'll have Susan talk about the key scope and limitations that we had in this project.

MS. COOPER: Thank you, Carmen. I seem to have an echo here. I'll step away and maybe it will go away.

Anyway, we're on Slide 9. Susan Cooper, Office of Research. I just want to quickly more reiterate that there were scope issues and limitations that principally were driven by the project schedule.

Carmen mentioned that we had the FLEX

overview meeting, which sort of started the project off and the interaction between the NRC and industry. That was in the first week of August 2019. I think we had our HRA analyst team and most of our FLEX and operational experts team put together sometime in the September timeframe.

We had our HRA kickoff meeting in early September. We had our plant visits in mid-to-late September and first of October. We had our scenarios developed by Thanksgiving week, and the first week of December we had the workshop and did the quantification. So that was a pretty quick turnaround for what we -- what we needed to accomplish.

So just on this slide I want to reiterate there were no existing PRAs that were available to help us develop these scenarios, and that also meant that there were -- we didn't have access to any more realistic engineering calculations that could support what the HRA or PRA success criteria might be, so we had to make some assumptions.

We didn't develop the PRA, of course, but we tried to make sure that it was -- what the scenario development that we had was consistent, as best we could.

And I mentioned earlier in response to one of the questions that we did use some of the information developed by plants in order to implement the FLEX strategies, in particular the FLEX validation times. If there were time-sensitive actions where they did demonstrations, we did use that information.

And then I'd also point out that, you know, the analysts still had their own jobs. So they were not able to -- you know, once we got past that workshop, we didn't -- they didn't have too much time. Let me also reiterate from some of the discussions this morning the application of IDHEAS-ECA, and this particular effort did not include dependency of recovery.

The recovery approach was pretty much hot off the press when we got to the workshop. The analysts hadn't had a chance to digest that or figure out how to apply that, so that was not exercised. And as Sean Peters indicated this morning, the dependency approach for IDHEAS-ECA, is just now getting finished or getting into its first draft.

The other thing is you'll -- there is -- James Chang talked this morning about the IDHEAS-ECA tool, and they showed some things about how you could do some calculations of a contribution from time, timing, and we did apply that approach to -- for a couple of the different HFEs. There wasn't a significant contribution in those particular cases, so that was not captured in the results that we put in the report. So I just wanted to point those out.

Also, since -- as I mentioned earlier and we'll see in the next flew slides. Since the FLEX scenario that we picked was a seismic event, we generally didn't need to be concerned about environmental factors when we were doing the HRA quantification.

All right. Next slide, please. Carmen, Slide 10.

So, as Carmen indicated, the real objective and the predominant effort in this particular project was to develop scenarios that had more detail than maybe previous efforts had had. We wanted to make sure it was representative of a real PRA, a credible scenario, and we wanted to make sure we reflected the understanding that we got from plant site visits and from discussions with FLEX and operations experts. And it needed to be understood and accepted by all of the HRA analysts.

So I actually developed the scenarios, working with the FLEX experts, and then we had many conversations with the HRA analysts and they reviewed that material. And it was basically my job to make sure that we had scenarios that the HRA analysts felt were adequate for quantification.

So as mentioned before, the FLEX and operational experts provided us inputs throughout the project. This was pretty key. I mean, certainly, getting information from them and phone calls was good, but having them along with us when we went to the plant site visits, we were able to get some insights on maybe the history behind why people -- why FLEX was implemented in one way or another, and also get some insights about the variations across the U.S., you know, plants to plant.

And then we also had a few of those experts with us during the quantification workshop, and that was a specific request of mine. I wanted to make sure that when we got to the workshop, we finally got to doing the quantification, that if something came up that seemed to be a gap or something missing in the scenario development, that those FLEX experts could provide us with at least a credible assumption, even if we didn't have plant-specific information.

So I wanted to make sure that we maintained the integrity of the credible scenarios to the end.

Next slide, please.

So this particular effort we developed three different scenarios, each with associated human failure events. There was a classic FLEX scenario that was for a BRW. There were two non-FLEX scenarios, both for PRWs, and one of the non-FLEX scenarios it was for a loss of all feedwater. And the second one was for a station blackout with pre-staged FLEX-plus diesel generators.

And when we get to that -- if we get to that scenario -- it's in the backup slides -- I can explain more about what FLEX-plus diesel generators are.

Because, as I mentioned before, we didn't have PRAs available to this project, we had to do some of that work ourselves to make sure that the whole scenario made sense from a PRA perspective. And most of the information, except for what we might have needed additionally from FLEX experts, was given -- were given to the HRA analysts, like I said, around Thanksgiving time, which was like a week before the workshop.

But we had substantial interactions prior to that point in time with other drafts of the scenarios, scenario descriptions for the HRA analysts to review, and provide comments and requests for more information.

Next slide, please.

So the descriptions of the scenarios included several different pieces of key information. There are assumptions, both general assumptions that applied to all three scenarios, and then assumptions that applied only to specific scenarios. We gave a high-level description.

In some cases, we had an example event tree and a fault tree, and we borrowed those from other efforts, like from the SPAR models or whatever, revised them as needed.

We always had some kind of timeline, could be a scenario -- what they call a scenario script. We had FLEX scenario scripts from the two different plants that we visited. For the non-FLEX scenarios, we at least had a timeline or a procedure path with some estimated timing, and then we identified the relevant procedures, which would include both EOPs and FLEX support guidelines.

Various timing information -- in some cases, it might align with what a typical PRA scenario might have, but then there would be some specific times that would be related to FLEX or FLEX equipment.

Of course, we need to identify those key operator actions and the associated human failure events, and then those human failure events had descriptions as well that would get into things that related to PIFs. In some cases, there were some variations that we addressed in the HRA quantification using IDHEAS-ECA, but for the most part the variations that we identified we were not able to pursue in the interest of schedule.

And I'd just like to reiterate that some of the information assumptions and scenario-specific information was very important. And we only focused on the FLEX-related actions, even if the PRA scenario included actions either upstream or downstream of the FLEX action.

Next slide, please, Slide 13.

So we're about to get into talking about the scenarios themselves and the quantification results, so I'll go over, you know, some of the key details and what the human failure events were, some key assumptions, and the results. I just --

CHAIR DIMITRIJEVIC: Susan?

MS. COOPER: Yes.

CHAIR DIMITRIJEVIC: Maybe this would be good -- because next slide we will go through FLEX and maybe this will be -- maybe this is a good place to make a break. What do you think? Susan? Did we lose, Susan?

MS. COOPER: No, I'm sorry. I muted myself somehow without knowing it.

CHAIR DIMITRIJEVIC: Okay. Well, I was thinking that this could -- because we want to -- we have -- we are taking break in the middle of this presentation, and I thought maybe this would be good place to take a break, because this is just before we go to specific like scenarios for BWR. What do you think?

MS. COOPER: Can I just say something real quick about the plant --

CHAIR DIMITRIJEVIC: Okay. Sure.

MS. COOPER: -- site visits? Because I think I'd like -- it's kind of connected with some of the discussions earlier.

CHAIR DIMITRIJEVIC: Okay.

MS. COOPER: So there were a number of reasons why the plant site visits were really important. We mentioned already that, you know, over time it appears that industry has done some things to improve, for example, their procedural support for the decision to declare ELAP, and so we were able to get that update.

But, you know, anyone who has done HRA -- and, you know, we've got some various folks on the committee with operations background, it's important to see things and not just hear them. And so it was good to hear from the FLEX experts as to what we would expect.

It was good to hear from the plant-specific training department folks and their presentations, but there was really nothing to replace doing walkdowns with either an equipment operator or an SRO and -- because you could -- you could sense from them what their comfort level is.

And, you know, I went into these site visits with not much expectation because I have done some walkdowns and some site visits for the Level 3 PRA that Office of Research does where we were looking at EDMGs and the (b)(5)(B) equipment. And that was very -- not well supported, and it was a challenge to figure out ways to credit that.

So FLEX is very different, and we saw that and I heard that. The connections are standardized across the industry. You know, the color coding makes sense. The hard cards for operating the equipment are there, and we walked through those.

And there is just -- there was just a world of difference between talking to the operators that conducted our walkdowns and what I got from a field operator at the reference plan for EDMGs who expressed concerns about not having enough training. So I think that was very important.

And then the fact that in the report -- I can't remember whether it's in the main body or on the appendices -- we identify everyone who went on the different plant site visits. Almost all of the HRA analysts had a chance to go and visit a plant site, and then I circulated notes from each plant site, first to the FLEX experts for corrections on details, and then I circulated to the HRA analyst, and we discussed that, too.

So it was very important, and I'm glad that that ended up being part of the project, and I think, again, getting the industry involved through the EPRI MOU was key to being -- making that happen.

So now I can -- now I'm okay. I can -- we can take a break.

CHAIR DIMITRIJEVIC: Okay. Thank you, Susan. Excellent.

So we will take a break, a 15-minute break here, so let's be back at 15 plus, so that's at 23, so

4:23. Okay? 4:23 we will get back to discuss specific FLEX scenarios.

Thank you. We will start with Slide 14. All right. See you then.

(Whereupon, the above-entitled matter went off the record at 4:08 p.m. and resumed at 4:23 p.m.)

CHAIR DIMITRIJEVIC: Okay. Our 15 minutes has expired. Susan, are you ready to continue?

MS. COOPER: Yes, I am. Thank you, Vesna.

CHAIR DIMITRIJEVIC: Okay. Excellent. Okay. So let's continue with the FLEX scenarios. Thank you, Susan.

MS. COOPER: Thank you. Yes. Slide 14. We'll start talking about the FLEX scenario first. This FLEX scenario was for a BWR. The draft report has several pages of description for this scenario. I'm going to try to just pluck out a few things that are key.

It's definitely a design basis external event, and a particular case that we looked at was a seismic event with no debris removal required. There are a number of key pieces of information and/or assumptions that define this scenario. One of them is that one of the emergency diesel generators is out of service for maintenance at the start of this event, and of course one of -- the other one then fails after the initiating event.

And we've already talked some about the importance of procedural guidance for such an event, and that was very important, and we indicated that actually both sides that we visited last fall had procedures that seemed to have embraced better formatting and content support for, for example, the decision to declare ELAP.

That was important, but understanding how the training worked with the procedures was also important. For the BWR plant site visit, we actually got a chance to watch a simulator exercise for a seismic event, beyond design basis external event. So it's always good to actually see the plug-and-play version of operator response.

There were some other important things that came out of the plant site visits. You know, consensus on the details of how the response would work, we got some good feedback there. An example that we had a lot of discussion on was, you know, how many times will the field operator try to start a failed EDG, or how many times is the control room going to ask them to go do that. And we got straight -- quick, straight answers, you know, on that.

You can always tell the difference between something that has already been put into your plans versus trying to troubleshoot on the spot. So those also helped us get some confidence in how the operators would respond.

And then for some of the actions related to putting the FLEX equipment into service, you know, we saw walkdown and saw the standardized connections, simple-to-use FLEX equipment, and so on and so forth.

So for the FLEX scenario, there were four HFEs that we evaluated or had the HRA analyst evaluate. Operators failed to declare extended loss of AC power or ELAP. Operators failed to perform FLEX DC load shed. Operators failed to deploy a FLEX diesel generator, and operators failed to perform containment venting.

Next slide, Carmen, please.

So Slide 15, continuing on the description of the FLEX scenario. As Michelle had already discussed, there were three different cases that we evaluated for the HFE operators failed to declare ELAP.

The base case or Case 1 was for a scenario with the plant having a short battery life. Within the EOP flowchart EOPs for the BWR, there is a prominent note that defines ELAP as the extended loss of AC power exists when it is expected that no 4 kV bus will be repowered within one hour. And that was considered explicit guidance, especially supported with training.

And also, as we -- some of the discussion earlier, this particular case, there was severe and widespread damage as obvious onsite. And it makes it clear that the offsite power options are clearly unavailable.

And then the two variations, Case 2, with a longer battery life and then it has a more ambiguous procedural direction -- and as I indicated before, this is -- this seems to be consistent with what is in existence in nuclear power plants right now. Those plants that have a longer battery life may not have changed their procedural support to be like the base case, because they just have more time.

And then Case 3 is the same as Case 2 with a longer battery life and the ambiguous support, but then it's also less obvious when power might be restored.

And so here are the HEP results, by one significant digit or two more than Michelle did. You can -- this range is a range between the HRA analyst, what values have they actually provided. The draft report provides tables that show the results for each of the analysts, and that's what this -- that's what I am reporting here.

So for the base case, we have a range from 1.1 E to the minus three to 2.7 E to the minus three. And then higher -- you know, the low end, the same for the first variation, 1.1 E to the minus three, but then going up to three to the minus two for the case of the more ambiguous procedure.

And then for the Case 3, or variation 2, we have a little higher results still shown there, going all the way up to .1 for that particular case.

CHAIR DIMITRIJEVIC: A question, Susan.

MS. COOPER: Yes.

CHAIR DIMITRIJEVIC: Are those analysts from the different plants?

MS. COOPER: I'm sorry. Could you say that again, Vesna?

CHAIR DIMITRIJEVIC: Okay. So you have here the different results, because you have different people performing analysis, right?

MS. COOPER: Yes. The different -- the range that I'm showing for the HEP results are from different analysts.

CHAIR DIMITRIJEVIC: Okay. So how many analysts did you have in that day from different BWR plants?

MS. COOPER: So I don't -- I'd have to go back and look at the list. You know, and I know that, for example, the NRC analysts are not from any plant. So, I mean --

CHAIR DIMITRIJEVIC: So what did you use for procedure? I mean, exact process and just --

MS. COOPER: Oh.

CHAIR DIMITRIJEVIC: -- what are you looking, specific procedure?

MS. COOPER: So we used specifically the procedure for the BWR that we visited for the base case and --

CHAIR DIMITRIJEVIC: So it's the same BWR --

MS. COOPER: Yes.

CHAIR DIMITRIJEVIC: -- project case. Okay.

MS. COOPER: Right. So --

CHAIR DIMITRIJEVIC: Now, let me just ask you, so you were using the same methodology and same base case and so variation of this first happened only because the analysts made different assumptions. Is that true?

MS. COOPER: Well, I mean, this is an area where I haven't had a chance to dig into the results and come to any conclusions. But my recollection of how things went was that the -- some of the analysts made some different choices as to what they thought were drivers than for the HEPs. So that's where some of the variation is.

Now, you see there is not a lot of variation really in the base case, but, you know, more as you get to --

CHAIR DIMITRIJEVIC: Variation, yeah.

MS. COOPER: Yeah. Where judgment is required. So, you know, and this is an area where I think that we could -- we could look a little bit deeper into the results that we got in the workshop and also, you know, working with potential new guidance for using ECA. You know, we discussed -- when I say "we," I said I've led the discussion for the HRA analysts in the workshop, you know, going over the details of the scenario before we got into doing the quantification, then also talking about the specific HFEs and what was going on.

So, you know, I could identify where they were pattern-matching, if you will, you know, pieces of analysis, qualitative analysis, you know, coming from the plant and how we described or defined the scenario and things that were in IDHEAS-ECA.

CHAIR DIMITRIJEVIC: Well, you know, this question -- my question is because one of our concerns in the previous meetings was that this methodology would be -- could be strongly dependent on the person performing analysis and, you know, out of --

MS. COOPER: Well, I think that's --

CHAIR DIMITRIJEVIC: -- so this is very interesting to see this variation actually.

MS. COOPER: You know, I think it is always going to be dependent on the HRA analysts and their experience. What I tried to do, since I wasn't an analyst, I was just trying to make sure they had all of the tools. I tried to make sure that they had the same understanding of the scenarios in the HFEs, and that I wrote up all of those plant site notes, and I wrote up all of the scenario descriptions and HFE descriptions, so they had the same information.

So it was really a matter of how they used that information to represent what they thought they understood about the --

CHAIR DIMITRIJEVIC: That's exactly point, which you said very well, because when you have such a big variation like, you know, between 1E minus three and 1E minus one between different analysts, the point -- the question is, what is point of uncertainty analysis at all, if your result is depending on the person performing the analysis and underlying assumption. It's extremely important insight.

MS. COOPER: I agree. Unfortunately, we did not have time within that workshop to probe a lot about why people were making different choices, especially when they -- when you have a range like that. The other thing, though, is that not all of the analysts were as prepared, I guess you could say.

Some of them had actually used the IDHEAS-ECA software tool ahead of the workshop to try to figure out what -- you know, how to use it and develop some preliminary numbers. Others were developing them on the spot while we were at the workshop. So, you know, there were some differences that way as well.

MS. XING: Susan, may I make an addition here?

MS. COOPER: Sure.

MS. XING: So from -- we're looking for variation number 2 in these HEP numbers. I just look at the report last week. Two analysts select table number E minus three. So they basically selected all of the PIFs and no impact. And the analysts -- three analysts showed -- gave a range in the E minus one. They all select PIF -- the information uncertainty -- information is uncertain.

So that -- I think that's one way we can -- I think IDHEAS ECA helps is that we still get this difference, but we can't say where the analysts make a difference.

CHAIR DIMITRIJEVIC: You would not have a different analyst performing the analysis for different plants. So you know it would be -- well, there may be -- I understand what you're saying. We have a tool which, you know, help us to see why there is a difference. But, you know, to see why do we have difference between different plants, that would not be used, you know.

So it's interesting. I mean, I just wanted to point this out, because that was one of our concerns, how dependent on the analyst is this method. So, okay. Well, thanks. We can continue.

MS. COOPER: Okay. Well, why don't we go to the next slide, Slide 16. Now we're going to look at another one of -- another HFE within the FLEX scenario. This one is for failing to performing FLEX DC load shed.

As Michelle mentioned earlier, this is a different load shed than what operators typically perform in their station blackout procedure. This would be more load shed. There are differences between plants, so far as how many more loads they need to shed. So that's definitely going to be a variation between plants.

But for what we evaluated, which was in line with the BWR plant that we visited, there were very few manipulations required, and they were mostly in the same place. What we observed in the walkdown is that there were blue FLEX tags on the electrical cabinets that identified specifically which breakers needed to be -- needed to be manipulated. There was a self-checking mechanism within the procedure, and so forth.

So as, you know, the overall valuation that all of us who went on that particular plant site was that this action is not only similar to the station blackout load shed, but because there are fewer manipulations and you've got those FLEX tags, you could argue it should be even more reliable for those reasons, but there wasn't any way to represent that.

But, in any case, the last bullet at the bottom shows the range of values that the different analysts provided for this particular action. It goes from 2E to the minus three to 6E to the minus three.

And I'll pause to see if anyone wants to comment on that. Okay. If not, let's move on.

Slide 17. Another HFE for the FLEX scenario. This is for failing to deploy the FLEX diesel generator. Here we identified two critical tasks using IDHEAS-ECA: one, failure to transport; and, two, failure to connect and start.

You know, some of the key information that we walked down when we went to the plant sites and looked at the FLEX building and looked at the equipment, the hard cards, interviewed people, and so forth, that we understood that information. We also looked at the color-coded and standardized connections, you know, various places around the plant. The specific FLEX diesel generator that we saw was a pushbutton operation, very simple.

And then we -- I hadn't had occasion to learn about the systematic approach to training, but I learned some more about that as a result of these plant site visits and talking with field operators and trying to understand a different kind of action that's simpler and doesn't require as much training, and that's per the systematic approach to training -- identifying -- going through a process of identifying what kind of content and frequency of training is actually required.

And then the bottom of the slide, again, shows the HEP ranges for the analysts, failure to transport 1E to the minus three to 3E to the minus three, and then failing to connect and load that ranges from 1E to the minus three to 1.2E to the minus two. So a bigger range on the failure to connect and load.

CHAIR DIMITRIJEVIC: So, and then the time components here, the time --

MS. COOPER: I'm sorry?

CHAIR DIMITRIJEVIC: Is there a time component available here? Time it takes. Did you take into account time it takes to perform this action versus available time?

MS. COOPER: I do not remember. One thing I will say, though, you know, the -- there were some interesting things to learn about the -- what FLEX calls success criterion versus what PRA might call FLEX success criterion.

For example, in going back to the previous HFE, the FLEX DC load shed, the purpose of that action is to make -- mostly to make sure that loads don't start, because most of them aren't running at the time and would drain down the battery.

So there are a lot of things that are being -- you know, breakers that have been manipulated for loads that are actually not -- you know, not on. They're not operating.

So it's not really clear whether missing one or two is really a failure. And then also we learned that there's some different approaches for doing battery life calculations, some of which will be more realistic than others. So that's one example of a success criteria mismatched between FLEX, I would say, and PRA.

I would say the same thing is for the FLEX diesel generator. Based on the two plant site visits and talking with FLEX experts, my understanding is the main reason why you need the driver for the timing on success in FLEX-based for the FLEX diesel generator is to make sure you've got electric power for the instruments in the control room to keep your turbine-driven pump going, whether it be a RCIC pump or an aux feed pump.

And you want to have the indications in the control room to help make sure that that turbine-driven pump continues.

CHAIR DIMITRIJEVIC: Yes. Often you need the DC power to keep those valves bringing steam to the turbine open. So DC power is definitely necessary for this pump. So that's -- available time is depending on battery life.

MS. COOPER: Right.

CHAIR DIMITRIJEVIC: Right. And also, but there is definitely time needed to do transport, right?

MS. COOPER: Yeah.

CHAIR DIMITRIJEVIC: So this -- I think the time has to be big factor here, because what else -- why would you otherwise fail to transport? Because you already have diagnosis. You already declare elapse, so you know you have to transport, so why would the transport fail? Otherwise, it is not time dependent.

MS. COOPER: Gosh, I'm having trouble remembering what we -- I'm sorry, I just don't remember what kind of factors we looked at for the failure to transport. But I don't believe it was related to timing, is my recollection, because I don't think that ever ended up being a contributor.

So I'm sorry, I -- I'm going to have to

get back to you on that and take a look more deeply at the report to see what was driving that. But I don't think it was time.

MS. FRANKLIN: It wasn't time, Susan. This is Carmen.

MS. COOPER: No.

MS. FRANKLIN: It wasn't time. We didn't look at time.

MR. SCHULTZ: This isn't the numbers -- this is Steve Schultz. The numbers don't look like time was a consideration.

MS. FRANKLIN: No, I don't -- no.

MS. XING: Yeah. This is Jing. I may not remember correctly. Last week when I looked most of the base PRA for this execution would be E minus four. And some panelists selected a lower level complexity because it takes many steps. And some analysts selected -- said it's an environmental factor. So those drive the HEP slightly higher than the minimal for transportation.

MS. KICHLINE: We also talked about you have to -- in some cases, you have to hook up the trailer to the truck, and then you need to get the truck out of the building, and you need to drive it through a couple of gates.

And so there is a lot of things, you know, that you have to do that's associated with driving the truck and hooking up the trailer and getting it to its location, like backing up. In one case, you know, you have to get it into a certain spot.

MS. XING: Yes, Michelle. But those were the --

CHAIR DIMITRIJEVIC: Well, maybe it's --

(Simultaneous speaking.)

MS. XING: -- not 2019. I think that the 2019 scenario assumed this is -- those are -- have no impact at all.

MS. COOPER: Yeah. I think the main -- the main driver was -- as I'm just looking at the tables, was a scenario from the familiarity -- as Jing was saying, there is going to be a floor coming from that base HEP. That's the driver for the transport number.

CHAIR DIMITRIJEVIC: Okay.

MS. COOPER: I can get back to you on that, but that's all I --

CHAIR DIMITRIJEVIC: That's okay. I mean, I can check if you have more details in the report. I was just curious what is -- because if you have unlimited time, obviously, you are going to get that diesel generator there. I mean, so I was just trying to see what your --

MS. COOPER: Well, yeah. And the timing -- the time is, you know, after any kind of debris removal would be done. So, in the particular case that we had with the BWR, there was two hours for debris removal.

However, with the seismic event that we had, we didn't -- that wasn't going to be needed, you know, so I think -- and I think they estimated an hour or the -- the final integrated plan for FLEX was an hour for the transport and for the connect.

CHAIR DIMITRIJEVIC: Okay. Okay. Let's keep moving, so we will --

MS. COOPER: Okay.

CHAIR DIMITRIJEVIC: -- we can finish today. All right.

MS. COOPER: Next slide, Carmen, please.

All right. So we're going to change gears and talk a little bit about one of the non-FLEX scenarios. The second non-FLEX scenario is in the backup slides.

But, anyway, both of them are for PWRs. The one we're going to talk about right now is one for loss of all feedwater. And we worked with members of industry to develop this one particular plant, had done some procedure modifications to address this event.

There is quite a lot of information and some assumptions that make up this particular scenario. Some of the key things are, first, we are going to have an initiating event following a loss of feedwater, but one of the feedwater pumps is unavailable -- aux feed pumps is going to be unavailable due to the maintenance.

And the second one is going to run for an hour and then fail. That's one of the really key things.

And this particular -- the way this particular scenario works is that success is getting the FLEX pump deployed and operating before you reach the feed-and-bleed criteria. And the way to support this particular action is to modify the loss of heat sink procedure, FR-H.1, and then to make sure that it's supported in training, such as simulator training.

The specific procedure guidance that the analysts used in their qualification was just to be salient and unambiguous. In particular, we wanted to indicate that the instructions were not going to be put in notes or cautions, and you wouldn't skip any steps. And so there is one HFE, and that is operators failing to initiate use of a FLEX pump.

And we wanted to focus on the cognitive portion only, since the transport and connection would be, you know, similar or the same to what you would do for a FLEX scenario.

Next slide, please, Carmen.

So the HEP results for this particular HFE is -- are shown there at the top, 1.7E to the minus three to 1.6E to the minus two. And I want to note that the actual FR-H.1 modification was a bit different than what we chose to analyze.

The wording was -- well, first of all, it was in a caution prior to I think Step 3 in FR-H.1, and it said something to the effect "If at any time it has been determined that restoration of feed flow to any steam generator is untimely or maybe ineffective in heat sink restoration, then the AF -- aux feed crosstie should be implemented per step 5," which is a couple of steps later.

And then that particular step also had -- said something about the shift supervisor making a judgment about whether or not you could -- feed flow is going to be restored in a timely fashion.

So the analysts -- and that included both the industry and the NRC analysts -- preferred to evaluate a case that didn't have some of this more flexible, maybe more ambiguous instructions. That doesn't mean we couldn't have evaluated it, but it probably would -- it probably would have involved some higher HEPs, and we probably would have needed some more plant-specific information.

If I had been doing this for, you know, somebody, I would probably want to interview some operators or, you know, if possible, look at some of those simulator exercises that they said they had started doing. But, anyway, so we -- we did something a little bit different than what the actual plant had done.

Next slide, please.

Okay. So now I'm going to move on to talking about some of the insights and lessons learned. I'm going to do it first for FLEX scenarios, and then I'll go to non-FLEX.

The first has to do with the timelines and time validations with respect to HRA feasibility. FLEX implementation talks about feasibility also, but HRA feasibility is a bit different. It needs to fit into PRA. But for the most part, for a FLEX scenario, it seemed that the timing -- time information that was developed to validate FLEX implementation was sufficient for PRA purposes.

Part of the reason why we didn't elect to evaluate debris removal within HRA is that we decided that it was really outside of HRA. HRA is mostly intended to model -- I would say model -- operators and other folks, you know, professionals doing things that require training at a certain level.

We did talk with people about debris removal. We looked at the equipment. We walked things down. We had people that -- from the NRC that had done some of the audits, and it's -- for a variety of reasons, we put that outside of HRA.

We saw some consistent things about FLEX implementation between the two plant sites that we visited. There were some things that were a little bit different, but in our discussions with FLEX experts we did talk about variations across the industry. So it is going to be important to make sure that you represent the plant-specific implementation when you're modeling.

I mentioned earlier, for example, on FLEX DC load shed there can be big differences between plants so far as what's involved in that particular operator action. I think there is even some that don't require FLEX DC load shed at all that, you know, have really long battery lives. So that can be a very different thing to evaluate going from plant to plant.

And, you know, kind of getting back to the -- some of the questions about FLEX connections, and stuff like that, we were satisfied -- and I say "we." I'd say the HRA analysts were satisfied with how we understood, you know, how simple operating the FLEX equipment was based on those plant site visits.

But as we discussed earlier, you know, some of the recent OpE, you know, kind of raises the question as to whether or not there is something else going on there. But, you know, just in comparing what we saw for FLEX, definitely the intent to try to improve upon what was done for the EDMGs, I think that comes across loud and clear, that they definitely have done something to try to improve the situation.

Question? I thought I heard somebody. Okay. Maybe not.

All right. Next slide, please, Carmen. Slide 21.

Some more insights and lessons learned for FLEX scenarios. You know, most -- as we have been discussing, most of HRA models have been focused on in-control room licensed operator actions using EOPs. And even if it is something outside the control room, if it's within the EOPs, chances are there has been a job performance measure, or JPM, put together that would make certain that anyone who does that job can do it -- do that within a certain time period.

So there is some confidence in the reliability of those actions. So it has been a challenge for operator actions that aren't -- don't fall into that category, aren't in the control room, aren't within the EOPs that have a JPM defined.

So trying to understand some of these FLEX actions and whether or not what industry has done to try to better support those actions in the absence of being in the control room in a controlled environment, or in the absence of, you know, doing timed verifications. Everyone can do it within a certain period of time. How do you make these judgments?

And included in that is not just things like, you know, field operators now doing FLEX DC load shed as opposed to station blackout DC load shed. There are also things like the FLEX equipment transport, which doesn't require any kind of operator training at all, what's called a journeyman skill set.

So that kind of aligns us in a very -- it puts us in a different category of task and how to judge its reliability. So I think, you know, understanding the FLEX context and the role some of these things play is pretty important.

And then, of course, what are reviewers, you know, like NRC reviewers and the NRR, doing for justification of the HRA modeling and quantification?

And, in general, the HRA analysts who participated in the study thought that the results produced by IDHEAS-ECA were reasonable. So those were the insights and lessons learned from the FLEX scenarios. Slide 22 we start the non-FLEX scenarios, insights, and lessons learned.

The first thing that came across loud and clear is that non-FLEX scenarios that a utility might be motivated to try to credit are going to be very plant-specific, including what initiating event and plant's function or system are important.

So for the two non-FLEX scenarios that we addressed, the one that is in the backup slides with the FLEX diesel generator, the main reason -- one of the main reasons why that utility or that plant decided to credit their FLEX diesel generator in a station blackout scenario is because they had extra FLEX diesel generators.

They could pre-stage their FLEX-plus diesel generators for, you know, taking the place of an EDG that is out for maintenance and still have their full FLEX capability, because they had other FLEX diesel generators. Not every plant is going to have that.

For the loss of feedwater, non-FLEX scenario that I mentioned a few slides ago, that was important for that plant because they didn't have a turbine-driven aux feed pump. They only had two motor-driven aux feed pumps. There are only four plants like that in the country.

So, again, that was a very plant-specific decision based on limitations or capabilities they have.

We didn't have any PRA people working on this project. I did get some help from especially Chris Hunter from the Office of Research. He was one of our HRA analysts -- and getting some SPAR models that could help us build our scenarios.

But it was pretty clear that when you look at the FLEX implementation documentation and they talk about success that it -- that that success is not aligning with PRA and HRA -- PRA and HRA definitions of success.

So I think going forward with, you know, implementing FLEX into EOPs and crediting it in PRA, I think that's probably going to have to be looked at some more.

And for the non-FLEX scenario involving using a FLEX pump, we had to make some assumptions in the absence of thermal hydraulic calculations. We had to make up a number for how much more time did we have before the feed-and-bleed criteria were met, if we got an hour of motor-driven aux feed pump operation and then failure, in order to have enough time to deploy the FLEX pump before feed-and-bleed criteria were met.

So, you know, there are definitely going to have to be some additional things looked at. There was actually another scenario that we didn't model, didn't address, in loss of feedwater, and that was loss of both aux feed pumps at T-zero. In that particular case, there was no chance of the FLEX pump being deployed before feed and bleed, but the utility was still interested in crediting the use of FLEX pump operation just for restoration of feedwater after feed and bleed. And we don't have any kind of branch like that in a PRA that I know of, so that would be another example of where you would need some additional PRA work.

Next slide, please.

A few more insights on the non-FLEX scenarios. The FLEX timing information is not likely to be sufficient or realistic enough to demonstrate feasibility for the non-FLEX scenarios, and this is because most of the PRA scenarios, you know, time to core damage, time to feed and bleed, those times are shorter than what is, you know, assumed in most of the true FLEX scenarios.

So either you're going to have to cut like -- you know, like in the case of the loss of feedwater, you're either going to have to come up with some different branches in your event tree, or you're going to have to sharpen your pencil on some of your timing estimates or do something else, like some of the plants have done some pre-staging of FLEX equipment or something.

But, in any case, chances are the timing information that is associated with FLEX implementation is probably not realistic enough for many PRA scenarios.

And, again, the plant-specific approach to how to incorporate FLEX equipment into EOPs is going to be really important. And in both of the non-FLEX scenarios, the panel of HRA analysts who used

IDHEAS-ECA elected to evaluate a scenario that was a little bit different than what the utility had proposed.

And, you know, we already talked about the loss of feedwater scenario and how a different procedure content, formatting, and support was evaluated. And a similar sort of thing was done for the station blackout scenario where there were some differences in what we evaluated versus what the utility had done.

Next slide, please.

And I think I got ahead of my slide, because the second bullet there is talking about that. And like I said, the -- it wasn't that we couldn't evaluate the scenario that the utility had -- basically had put into place with what changes they had made to their procedures. It was more that we felt -- the analysts felt more comfortable with making some different assumptions. Chances are we would have needed more plant-specific information to evaluate the more complicated situation, and chances are that the HEPs would have been higher also.

But this is also an illustration of how feeding back HRA IDHEAS and concepts into, you know, how the utility decides to change things could be helpful, because we could -- although we didn't evaluate, you know, a specific HEP for the actual case, in both cases -- both non-FLEX scenario cases -- we're fairly certain that the HEP would be higher for the actual case versus what -- the situation the HRA analysts evaluated.

Next slide, please.

So this slide I just identified a few thoughts on what the next steps would be for some of this information. But, really, especially for this effort, we have been on a pretty fast track to get something out the door.

The draft report that was provided to the ACRS -- I'd call it Rev 0 at least -- it's had some review, but not a lot, so, you know, thinking back on this effort and what might be the next steps for IDHEAS-ECA or how better to support FLEX HRA are still kind of -- we're mulling over. We also -- I mentioned some of us -- Michelle and I, in particular, I'm remembering presented the NEI FLEX Summit. So we'll get feedback from all of these, and of course from the IDHEAS-PRA Subcommittee.

But, you know, I think that one of the things that would be very important to do would be try to capture some of the understanding that everyone got that went on those plant site visits and from the overall experience of developing the scenarios to try to capture that understanding for HRA.

And whether that gets put into new guidance or additional guidance, you know, or something else, I think somehow we need to do that.

And one question is whether we also would need to try to capture some of the variations between plants. You know, I hadn't gone on any of the -- any of the other plant site visits. So I don't know if the two plants that we visited were model plants or if they were representative plants, so it's hard to say. But those are just some of the -- some thoughts about what we might do next and where we are in the process of discussing that.

So, with that, I conclude my presentation, unless there are any questions.

CHAIR DIMITRIJEVIC: Well, I think we might actually -- you make most conclusions on the FLEX point of view, but actually some of those conclusions -- actually, it will be valuable to see these conclusions more concentrated on that IDHEAS methodology, because that's going to be sort of like today here to -- to learn.

And so, you know, some of them are

applicable today, but how the methodology -- how well did methodology work for this? Also, you had the richness of the -- that you have expert panel elicitation numbers, and then you actually use some, you know, state-of-art methodology to calculate those human error probabilities. And there is not any good agreement between those.

And so the conclusions which we can make about our -- you know, because we are here to develop methodology to calculate and estimate the APGs. And, you know, FLEX has other issues, you know, PRA, the things like how it will be incorporated in the risk model.

But here there are some conclusions based on this experience as related to the limits on methodology, pluses on methodology, and things like that could be valuable. That's just my insight on that. So you know what I meant? Just concentrate more how did this methodology work there? What were issues? Why there are difference in analysts? Why there is a difference what expert opinion was versus what we see? Things like that, so --

MS. COOPER: Yeah. I agree. And I'm glad to hear that you think that's a good next step. I think the various members of the team for the different parts of IDHEAS-ECA and IDHEAS-G, and so -- IDHEAS data have all been working on our separate deliverables trying to meet a deadline and haven't really had a chance to come together and talk about some of these things.

However, I think at least for the context of FLEX that there could be, you know, some additional guidance to HRA analysts on how to interpret -- you know, interpret FLEX contexts and operator actions.

I mean, one of the points I have been trying to make with various people is that, you know, the practice of HRA, you know, you have to collect the information that you need to know, and that's an art, to be able to get that from people at the plant site, and you have to use the tool.

But there is actually another step, and that's the interpretation of the operational information into the language of the tool. And there is actually evidence that this is -- this is a pretty common problem. I mean, I think Sean Peters mentioned this morning and maybe -- and I think maybe Jing did also -- the HRA benchmarking efforts that were done, you know, a few years back. There was the international HRA benchmarking, and then there was the U.S. HRA benchmarking.

And in the -- I remember very specifically in the international benchmarking there were two different teams that were using SPAR-H. And for a steam generator tube rupture example, for a Westinghouse PWR who wasn't up-to-date procedures that used level for steam generator tube rupture indication instead were using radiation alarms and they failed the radiation alarm.

The two different teams used -- had the same information, but there were two different ways to represent a problem with that alarm within SPAR-H. And they both had to do with missing or ambiguous information, and the difference between picking those two different things within SPAR-H was a factor of 50.

But everyone had the same qualitative understanding, but trying to map it to the method was where it kind of fell apart. So that's why I say, you know, guidance maybe specifically for -- you know, for like IDHEAS-ECA, for FLEX -- the FLEX context, could be helpful to support that interpretation step.

Everybody -- you know, in this particular case, you know, for the FLEX HRA, using IDHEAS ECA, I tried to eliminate any -- you know, any differences between analysts and understanding the situation, the context, and the operator actions.

So, but that interpretation step is still there. You know how do you map what you understand operationally to that, the language of the tool?

MEMBER PETERS: Hi, Vesna. This is Sean Peters again. I just wanted to weigh in one thing with respect to variability. That was a big concern when we went through the international and U.S. benchmarking studies, because when we ran through the scenarios -- and I'll have Susan or Jing correct me, or James correct me, if I'm wrong here -- but from my memory, we were getting around three orders of magnitude variability for each scenario analyzed amongst the different analysts. It was really based upon how they -- they input their particular methods into the scenarios.

And so what we were finding here -- I'm actually quite pleased that we're looking at about one order of magnitude difference on these FLEX scenarios. And the reason I'm looking at that as a big positive is because one of the big changes we wanted to make to HRA was to reduce that variability.

So pulling it down a couple orders of magnitude, obviously, we're not comparing -- we're kind of comparing apples and oranges here. But that capability to pare it down to roughly one order of magnitude is a big step forward for us.

MS. COOPER: I agree, Sean. Getting it to within an order of magnitude is a big, big step.

MS. XING: Susan, I'd like -- this is Jing. I'd like to make some addition to your comment. And I really appreciate the 2019 report that documented every HRA analysts' selection of PRA attribute.

As I looked through them, I think of two things. One, as you already said, we need to give HRA analysts some guidance -- better guidance, more guidance, on how they should map certain contexts to PIF selection, especially those -- the base PIF that can easily get you order of magnitude difference.

Taking the example of the major difference in declared ELAP variation, the message was clear. Already told analysts that it's an ambiguous situation. And the one PIF attribute specifically for -- use the same time if the information is ambiguous. Still, the analysts did not select -- two analysts did not select that PIF, and I compared it to my meeting notes.

Those were the -- those analysts -- those two analysts had a strong belief from their plant visit -- they got from their plant visit. I think they also documented it in the report that they talked to these operators. Every operator said they would declare ELAP.

So this is the case that HRA analysts' personal belief in something overrided you assess extra information. So I'm thinking that the future effort in addition to the guidance for the method, we should also develop, first, guidance on the HRA practice.

MS. COOPER: I agree, Jing. I guess the other thing is that -- and I had some discussion with Mary Presley about this a few weeks ago. Oftentimes in HRA, especially if they are looking at a relatively novel situation, and you get the opportunity to spend time with operators and understand how they are going to do the job, especially if it's like a simulator exercise, and you sort of see, okay, so that's how it works.

But there is often some -- I don't know, I can't remember the term I used with Mary, but there is just some kind of untangible thing that helps you understand that this is really going to work.

And, in some cases for these FLEX actions, there are some additional details or things that the utilities have done to support the action that I might put in the category of compensating factors, which aren't necessarily easy to represent within an HRA method.

You know, for example, I'm going to go back to the FLEX DC load shed. The fact that -- you know, that the label specifically for FLEX were there in one of the plants. The other plant they had a -- their procedure mimicked the electrical cabinet in the layout of the breakers. And they used bolding for those that needed to be changed and other ways to label the ones that weren't to be changed.

And the whole procedure was organized so you could do a pretty effective self-check. But there wasn't really a good way to represent that in the HRA. So, you know, the ability to weigh in compensating factors that might not be explicitly addressed by the HRA method is another challenge, and I think that may be something that will come up with some of the non-FLEX applications and FLEX equipment coming up.

MEMBER REMPE: So I'm trying to understand what I'm hearing from everyone. It sounds like IDHEAS has helped because you can get some insights on why the analysts have different values. But I'm thinking I'm hearing Susan say you need another box that they can add compensating factors or contributing factors that they can't just check things that are in the software where the analysts would also add some notes.

So, again, I think you're always going to have difference of opinions with experts. And you try to reduce variability by having all of these different things for them to check, but maybe there is other -- a category of other that needs to be added to the software, so that if someone looks at the analysis they can understand differences. Is that a way you can quantify and implement something to address this lesson?

MS. XING: This is Jing. Susan, I put my comment here for Joy's question. Yes. The method itself, IDHEAS is it requires analysts to first do a thorough qualitative analysis. The method includes five worksheets, just like work some -- and you need to assess the context and put your justification, what context, how the context transformed to the PIFs.

And that also allows you to justify what Susan said, if you think their compensating strategy put there justifies your PIF selection. And my understanding, this 2019 effort was focused on testing the software. So most analysts did not use worksheet data to do that amount of analysis. That could be -- and also, we got feedback from the analysts that it's too tedious going through those worksheets.

So just as a suggestion, the IDHEAS team is thinking in the future we should incorporate this worksheet into the software, like adding box allows analyst to put a justification, including compensation factors.

MEMBER REMPE: It's too complicated, but you want to have something else. Is that what I'm hearing back from you, Jing? Because the analysts are saying this is already too much effort. We just want to do the analysis, but --

MS. XING: Yeah.

MEMBER REMPE: -- on the other hand, I'm hearing that something else is needed to just -- again, you want to document why people had different values for their results.

CHAIR DIMITRIJEVIC: Joy, and everybody, let's stop this discussion this moment, and we can come back when we have a staff committee discussion on our agenda. I would like to be sort of -- put this back to the members of public who would like to speak.

So I would like to move us, so that we are not totally out of the whack with our agenda. So, and then we will have -- after public comments we will have another, you know, chance to discuss the things.

So I propose that we move now to the industry feedback on using IDHEAS and ECA. I think it's also related to the FLEX.

Michelle, who -- is this Frank and Roy will be giving presentation?

MR. ARNER: Okay. So Michelle -- okay. Michelle was slated first, but we can -- we can go with Roy.

CHAIR DIMITRIJEVIC: Okay.

MR. LINTHICUM: Oh, no. That's okay. Go ahead. Go ahead. Michelle can go first.

CHAIR DIMITRIJEVIC: Well, whatever decides, go ahead.

MS. KICHLINE: All right. Well, then I'm ready to. Let me see if I can share my screen. Did that work? Did I steal the screen from Roy?

MR. LINTHICUM: Yeah, you did. You did.

CHAIR DIMITRIJEVIC: Yeah. It works.

MS. KICHLINE: All right. I was successful. It doesn't show me that you guys can see my screen, but you can?

MR. ARNER: We can see it, yes.

MS. KICHLINE: Okay. All right. So I'm Michelle Kichline again, Senior Reliability and Risk Analyst in NRR, and I'm going to talk about some of our user feedback.

First, I'm going to tell you where did we get the user feedback from. Well, James and I -- James Chang and I gave the senior reactor analyst two training sessions. They were informal training sessions at our counterpart meetings.

We also, in NRR, have been piloting the use of IDHEAS-ECA for human error probabilities in detailed risk evaluations that are part of the significance determination process. And then, in Research, they're piloting the use of IDHEAS-ECA for the accident sequence precursor program.

So during the training sessions that we had, we got a couple of comments from the people we were training, and one of the great things was that they thought that it was very easy to understand. They thought it was easy to use the tool itself and to look at the failure modes, mechanisms, the PIFs, the PIF attributes, and how to check all of the boxes.

They also appreciated that the direction we gave them was that they could analyze human failure events at the same level they did in SPAR-H. So one of the differences between SPAR-H I think and industry methods is that SPAR-H would leave the human failure event as a whole and not break it up into a lot of critical tasks.

So in IDHEAS-ECA, we don't have to break down -- you had to break it down into critical tasks, but only such that you aren't going to have any overlap in your critical tasks. So it's not a deep breakdown like some other methods.

But at the time, they did also comment that, hey, there wasn't enough -- there wasn't information on dependency and recovery. And so I know we have a dependency model now. That's something that we'll need to provide some training on, on how that would be used and how we're going to calculate recovery.

Now, some of the users that used it for SDP and ASP also agreed the user interface was very easy to use. They thought the results that they got were reasonable. They were comparable to what they would have -- I don't want to say gotten from SPAR-H. But if they had inferred through SPAR-H what they should probably get, then they thought that comparing SPAR-H and IDHEAS was reasonable.

They thought there were a lot more choices in IDHEAS-ECA, and so they thought their result was more accurate, because they were getting to actually pick the things that they thought were important as attributes, whereas in SPAR-H they just have to kind of figure out which of the, you know, items they go in, because there is not very many choices.

One of the negative things, though, is that the comment -- feedback on the timing module, the calculating piece of T, right, it's confusing for users who aren't familiar with distributions that much. So the timing part asks you to come up with a mean, a standard deviation, and a distribution for your time available and time required, or, alternatively, you can just have, you know, one -- a straight line.

So that's a little confusing, and so I think they asked for more guidance on how you would determine if you have a normal or a log normal distribution for the time available and time required.

And then, lastly, was some of the feedback from the workshop attendees. So they did -- after the workshop, they submitted worksheets or -- I don't want to say worksheets, sorry. Summary feedback forms, basically. And they -- thankfully, all of the users at the workshop agreed that the interface was very easy to use, and they thought they were getting reasonable results.

They liked the ability to document their results in the tool, but they would have liked it to be expanded. As Jing was saying, they didn't really want to have to fill out all of those worksheets.

Now, in other methods, they have to do that anyway, but they just found that it was so much easier that they wanted to be able to do that qualitative analysis and document it in the tool would it have been nice.

They also -- we also had some issues during the workshop with how exactly you would calculate the impact of time and how you would choose distributions for your time HEP. They also really liked that there were some little pop-ups telling you what a PIF was, like defining this PIF. But they thought that that information should be expanded, such that if they wanted more detailed information they could maybe click on it and it would take them right to the description of what is scenario familiarity, a more detailed discussion.

And then they requested more information on how to break down an HFE into its critical tasks. And I think that was -- you know, I think personally it's because it's a little different than how they do it in other methods. And so they wanted a little more information on that.

So, to summarize, all of the users thought the interface was easy to use and understand. Both -- all the industry and our NRC users have liked the way the tool works and have found that it provides reasonable results. And then the NRC people have said that, you know, they like the more detailed PIF options. Especially for actions outside the control room, they think they are giving -- it's giving them better results than they were getting in SPAR-H.

That's all I had. I think now Frank Arner was -- he is a Senior Reactor Analyst in Region I. He was going to give you a little more personal information, since he has actually used it in a couple of cases.

MR. ARNER: Yeah. Hi. I'm Frank Arner, SRA from Region I. Really enjoyed this process, being involved in this. I think the team did a great job in getting us prepared, showing us, teaching us how this works. We didn't have a lot of time to come up to speed, but it really isn't that tough to come up to speed. Sometimes the variability you might get from HRA analysts could just be the knowledge of the situations and FLEX in general.

I was fortunate to lead probably over half of the TI-191 inspections for FLEX in Region I, so I'm very familiar with FLEX. I'm familiar with the timelines and, of course, the plant in Region I that we looked at.

A lot of good comments so far by ACRS, which are right on the market. Dependency questions, pre-initiator event error questions, and of course the effect of diesel generator loading, and what is that going to do with respect to evaluating human errors.

That is one of the things which we evaluated as Suzanne went through was diesel generator -- FLEX diesel generator deployment, hooking it up, starting, but we really didn't evaluate the loading piece, and that has always been one of my main concerns, as I've been involved in not only this but also in the equipment reliability data as well. So I won't get that tangled into this conversation.

But like the members from ACRS talked about, it's a much different situation when you're starting equipment with inductive loads and having to stay below, you know, certain current draws and things like that where you could trip equipment off. In fact, one of our inspections when we did this, we found one of the amptector settings not set correctly.

So, no, many of the plants have not ever connected to the plant and process equipment and have run the equipment. So it is something to think about, and it's something that we would -- we evaluated.

So, anyway, I wanted to just check this against what -- what we do as SRAs is we do SDPs, and I've been involved in several of these over the last couple of years. Three or four years ago, we didn't have a FLEX event tree. So kind of what we just kind of made up is like a box at the end of our sequence for SBO, and we'd give a credit for FLEX.

We might assign that credit .1, but, really, we didn't have a whole lot of fault trees and everything built behind that. But since then we do have FLEX modeled in the SPAR models.

I think it's fairly well modeled, and it was interesting because I was able to take this new tool and actually look back at an SDP I used a couple of years ago at one of the plants where a diesel failed and fire was a huge contributor, where you have a switchgear fire with a high-energy arc fault and it took out a lot of things.

And so the licensee had a third party do a very extensive calculation on what would be the FLEX generator human error probability to, you know, deploy it, start it, load it, and they came out to .1.

So using this tool, believe it or not,

when I went back and used it to just kind of validate that or verify it, you're right. The deployment of the FLEX generator is really not a big contributor typically in a sunny-day FLEX event like that where you have that big fire. It's a small contributor.

The real contributor is, you know, hooking it up and then starting it. There is a lot of -- a lot of steps, but then loading it. And the loading piece, again, is where you need a lot of communication, where you're loading one piece of the equipment at a time, and you're trying to make sure that, you know, you don't overload it or trip it out based on the loads that you're trying to get energized up there.

So I got -- when I did that -- and we do factor in time. I heard that question. I didn't want to interrupt anybody during the whole course of these conversations. But if you know FLEX, the FLEX strategies, you know they have about seven hours available because of the battery life for the deep load shedding.

And typically, you know, to deploy the generator out there, to hook up the cables, to make sure you've got it all hooked up correctly, started, I mean, you might be looking at four to five hours.

So you have a mean time there, you have an available time of seven, and then you can kind of figure out -- you can estimate a standard deviation of what different crews might take.

I use a simple rule called the range rule, which is just the span divided by four. It's a simple estimate of standard deviation, and it works out pretty well for a normal distribution. So the contribution there was something like 1-1/2 E to the minus two compared to the whole .1. So not a huge contributor, but it's still there.

So that gave me some confidence, you know, that, hey, look, these added PIFs and CFMs really, you know, might be able to be used, you know, for something like this. I think, you know, declaring an ELAP is a big deal with respect to how the procedures are written. If a plant has a declaration of ELAP, which is a hard stop, you have one hour and if you -- and in one hour you will declare ELAP, the error is not going to be that great because, you know, talking to the operators and everything, they have to follow that procedure.

In this plant that we evaluated, it said if no AC power is expected within one hour, you know, then you would declare ELAP. Now, this plant does have an SBO type of source, which is expected to be able to be, you know, assessed within one hour. So it would be very tight.

So a lot of, you know, HRA -- the different HRA analysts here might have looked at that and said there is a lot of uncertainty, and that sort of thing, and that might explain some of the differences. The plants that say, hey, declare an ELAP, you know, declare within one hour. If not expected to get it back in four hours, now we're talking a whole different story.

Now I have maybe an SBO diesel. I might be able to get it back in two hours. Maybe it's possible, not a lot of damage, so, you know, I'm going to really consider that, because do I want to go on FLEX, or do I want to use the in-plant equipment that has been proven for 40 years, tested, load tested, you know, versus going to FLEX.

So, you know, that can bring some uncertainty, but that -- so if something is written like that, you get four hours' leeway, I came out with like a calculation of like 6E to the minus two versus like a 6E to the minus three for a one-hour hard stop.

Now I'm not going to say what's better, if you have that written in there to have four hours' flexibility or one hour, because is that better? Because what if it's just a fuse that's blown? What if you can get it in an hour and a half?

I think maybe you would rather run your diesels that were in place than have to transfer to all your -- you know, people over to a FLEX strategy, where really -- we really haven't hooked it up to the equipment in the plant in all cases and verified it.

So a lot of things to think about, but I think that kind of explains -- you've really got to be familiar with the FLEX strategies, and maybe that explains some of the differences and where we came out. And I do -- I think IDHEAS really brings out a lot of different PIFs.

And with regard to FLEX, I heard dependency brought up. Just for everybody's information, in our current FLEX trees, for our SPAR models, you know, you really -- in the FLEX event tree, you don't really have two different operator errors matched up. What I mean by that is, if you fail to declare ELAP, you go to core damage. If you fail -- if you're successful with that, and you fail to line up a diesel -- a FLEX diesel generator, and load it, you go to core damage.

So there's really not two different

operator failures where you typically look at that dependency. It would almost have to go back to a pre, you know, SBO available piece of equipment, like a hydro plant or something like that, if you failed that and then went into FLEX.

But so I don't think dependency was a real big factor with that regard for FLEX. Now, it would be for other scenarios where FLEX is going to be used for other scenarios, non-ELAP type of things. So that will have to be looked at. But those are the main points I wanted to bring out. I think ACRS hit on some really good topics, like I said, pre-initiators.

There has been a lot of issues where batteries have not been charged up. They go out to start the generator; it doesn't start. Well, that's because the battery wasn't hooked up correctly. So is that a fail to start? Maybe it's not being considered wrong, because they can start it and jump it.

Our take on that would be, well, you couldn't do that in an event, because you might not have a truck there to start it, to jumper it. So there's a lot of good conversations. The owners' group is doing a great job. Roy's group -- I think they're going to -- they're doing a lot of good work on FLEX data.

So that's about all I've got to say. I think it's a good tool. I bounced it off of SPAR-H and other methods, and it's -- so far, I've been pleased.

Thank you.

CHAIR DIMITRIJEVIC: So is anybody else planning to talk?

MEMBER PETERS: Yeah. We're waiting for Roy's presentation.

MR. LINTHICUM: Okay. Okay. Can you see my slides?

MEMBER PETERS: Yes.

CHAIR DIMITRIJEVIC: Yes.

MR. LINTHICUM: All right. Thank you. So I guess I'm last, and I'll just introduce myself. My name is Roy Linthicum. I'm Chairman of the Risk Management Committee for the PWR Owners' Group. And I'm actually employed by Exelon, who has allowed me to actually work full-time to support the Risk Management Committee.

I'm going on to Slide 2.

So I'm going to talk about some of the insights that we got, first of all, from supporting the IDHEAS-ECA development. It actually turned out that when we were asked to support this effort, we were actually working on a -- not a similar effort but an effort to look at how we can risk-inform the EOP structure for the PWR plants.

We actually just -- the stars aligned, and actually the meeting that was talked about, you know, where we had the initial workshop was actually the day after we had our workshop on risk-informing the EOP. So we got a lot of insights from both of those efforts.

I'm also going to be talking about the -- some benchmarking we did and the scope of our benchmarking and the results and conclusions that we had from looking and using IDHEAS-ECA.

So moving on to Slide 3, as far as supporting the development of IDHEAS-ECA, we felt really realistic modeling of any HRA -- and this isn't necessarily limited to FLEX -- does require walkdowns and observations. You can't have an analyst really sitting, you know, on a desk and try to figure out what needs to be done, especially for actions that are outside the control room.

Just as important, though, is you really need to know how EOPs are used, and you need to read the EOPs with an operator's mindset, including, you know, the conduct of operations for that plant that really defines, you know, what the different action words within EOP mean. So you actually get the full meaning and the full use and how the operators would actually proceed.

And to do that you really do need to spend a lot of time with operations personnel doing operator interviews. And then -- for risk-significant actions, you know, you really need to have well-defined scenarios, so you can get realistic values. And when I say "risk-significant," I mean in a perfect world, with unlimited resources, we like to look at every action, every possible scenario.

But that's -- you know, I think everyone knows that's not possible, so we tend to take some bounding work and some average results. But for those actions that tend to be risk-significant, you need to spend the extra time and effort.

Going to go on to Slide 4.

So the scope of our benchmarking that we did, we actually looked at five FLEX actions. I won't read these here. I'll go through each one of them briefly. But it was important to us that we wanted to remove, you know, the analyst variability. So what we did is we actually wanted to benchmark IDHEAS-ECA against the HRA calculator, which is the predominant tool that the industry uses in PRA modeling.

So we wanted to use the same analyst, using the same scenario, the same set of assumptions, and the same boundary conditions, and apply that to both IDHEAS-ECA and the HRA calculator, so we could understand the differences.

And that understanding is important to us in the industry for two reasons. I know Frank mentioned, you know, the significance determination process. And when you get into discussions, you know, between the utility and the NRC regarding the significance determination results, almost all the time it comes down to either common cause or human reliability analysis, and the assumptions and the results that are driven by the tools.

So it's very important that we understand those differences, so we can have valid conversations.

Also, though, we also wanted to see if there were any insights we could gain from a different method, you know, that we could, you know, work with EPRI to develop the HRA calculator to see if we can make improvements there in our tool that we use with them, within the industry.

I'll move on to Slide 5.

So the first one we looked at was

declaration of ELAP. As Frank mentioned, you know, there is a lot of plant-to-plant variability there. We saw in this case that IDHEAS-ECA gave us significantly lower failure probabilities. I would note this is a case where the plant -- this particular plant has a time requirement for the declaration of ELAP. This is a specific requirement for when they need to declare it, if they haven't had power restored.

And we saw that in this case IDHEAS-ECA cognitive model we feel is a better reflection of the current state of operator training and practices than the information we were getting out of the HRA calculation, which was giving us roughly a 4E to the minus two failure probability for something that should be fairly simple and straightforward in this case.

Moving on to Slide 6, we also did look at the ECA load shed. This is a case where there are quite a few breaker manipulations. Once again, you can see in this case the HRA calculator is giving very adverse results, and that's driven by the methodology and the HRA calculator, you know, aggregates all of the individual circuit failure manipulations. And that number goes up substantially if you have a substantial number of results.

But it was also mentioned, you know, as we implemented FLEX at the plants there are a lot of human performance tools that were put in place that help ensure you get the right breakers, and then they help -- you know, help in the human performance area.

So in this case we also felt IDHEAS-ECA -- that it uses more of a critical task when a cognitive failure model provides more realistic values, especially when the number of the task is high. And, once again, we think that's a better representation of actual operations performance.

Moving on to Slide 7, so we actually looked at FLEX deployment. Now, this particular plant, the FLEX pump is permanently installed, so there is no actual movement of the pump that is needed. The only thing that is needed to deploy the FLEX pump is hooking up the hoses, which all have quick disconnects some valve manipulations.

Once again, we were getting some what we would consider adverse results from the HRA calculator, and what we considered more representative, more realistic values coming out of the IDHEAS-ECA.

Moving on to Slide 8, this is a case -- we looked at low pressure injection. This would be actually initiating a pump, and this is a case we felt neither method actually was realistic. In this case, we were getting some adverse -- what we consider very adverse values for initiating a low pressure pump, but also we felt that the HRA calculator was giving us, you know, a number below 1E to the minus four for that action, is also unrealistically optimistic.

We haven't identified -- and we're still working on figuring out what's driving those differences. We do think that's an area that we need to look at in more detail.

And then the last one we looked at was refueling the FLEX diesel generator, and this is a case where we think the HRA calculator is probably the more realistic one, and the IDHEAS-ECA, once again, may be overly optimistic in this case.

From Slide 10, some additional insights we had. Once again, we did use significant input from operations personnel to support NRC Research's development of IDHEAS-ECA, and that use does, we think, do a better job of reflecting operational practices and training.

It has actually improved I think the understanding of the HRA analysts, both from the NRC and the industry side, about how EOPs are really used and how to interpret those. And we also had a lot of discussion about simultaneous procedure use. I know we had discussions with the ACRS and the industry on simultaneous procedure use several years ago when we were talking about FLEX.

But the operators are pretty well versed in using simultaneous procedures, and we do feel that that -- some of that information has been accurately reflected in IDHEAS-ECA.

We did note, you know, the current version of the tool that we have does not include treatment of dependencies. We do recognize that, you know, that is under development to be put into the tool. I would agree with Frank as -- you know, for using it, from a FLEX perspective, there is not, I would say, much that you would have in the way of dependencies.

But taking a more broader use and using this for other operator actions or other uses of FLEX, we do think, you know, the treatment of dependencies is something that does need to be included, and we do understand that is being added into the tool.

Now, we also felt we needed some additional guidance on the treatment of recovery. That scenario we felt is probably too subjective.

Some better guidance would help us provide more consistent results as far as the treatment of recovery is concerned.

And then my last slide, know, our conclusions, we do feel IDHEAS-ECA is a significant step forward getting realistic human error probabilities. You know, the current tools that, you know, we have been using, you know, really uses decades-old methods and data.

Now, IDHEAS-ECA, as you heard earlier today, has been updated with more recent data. I think that's an important use, because as we have improved both EOPs, as well as operator training, I think operators are both better trained and have better tools to reduce the numbers of errors they make.

We do think some better guidance on the use of the tools -- I don't know why I said "tools" in this case. It's not just IDHEAS-ECA, but also the HRA calculator, particularly in how to apply it to FLEX equipment will help provide more realistic values.

And as we move forward, we really want to reduce any disagreement we have in regulatory applications, whether it be in license amendment requests or a significance determination process evaluation.

We spent -- so to avoid a lot of that discussion, it comes down to differences in methodologies. And if we can align and get the methodologies getting similar numbers, I think that will be a big resource reduction on both sides.

I also -- I already mentioned the current version doesn't include the treatment of dependencies, if you want to include that. And we are still looking at some of the significant differences between the two tools, and we expect to have our work wrapped up in the next couple of weeks, and we'll be providing some additional insight, both to NRC Research as well as to EPRI, on ways we feel we can improve both tools.

And with that, that concludes my presentation.

CHAIR DIMITRIJEVIC: Okay. Thank you, Roy.

Members, any questions for Roy, Frank, or Michelle on the use of feedback?

MEMBER REMPE: I guess I have one. Oh, go ahead.

CHAIR DIMITRIJEVIC: Okay.

MEMBER REMPE: Okay. I have one, but I heard another voice. This is Joy. On Roy's last slide, he is saying basically that they need better guidance on both tools, and they are still investigating the differences. But is there enough documentation in what was done that they can investigate the differences in the results?

Because one of them you said, "Well, we're still looking into it." And one of them you said, "Both of these values seem" -- or, no, you said IDHEAS may be too optimistic on refueling FLEX diesel generator.

MR. LINTHICUM: Right. So I think there is enough information. It just takes time to delve into this. I mean, both sets of tools are -- you know, are very complex. I mean, you know, fortunately, from a user's perspective, they both have pretty good user interfaces. But, you know, to actually delve into what's driving some of those differences, it just takes some time and effort to drill down and identify those. I do believe we'll get there and we can provide that feedback. It's just going to take us a little bit more time.

MEMBER REMPE: Great. Thank you.

MR. SCHULTZ: Roy, this is Steve Schultz. You also mentioned that the version -- the IDHEAS version that is currently being evaluated has got more modern data set in it. Is that in comparison to the EPRI methodology?

MR. LINTHICUM: That's correct, yes.

MR. SCHULTZ: And, if so, is there an intention then to find a way to update the EPRI methodology to match the database that IDHEAS has been able to create or utilize it?

MR. LINTHICUM: So we are working, and we have initiated discussions with EPRI, who owns the tool, and they are investigating, you know, what it would take to update, you know, either the methodology, the data, or both. I can't speak for EPRI's specific plans. At this moment, I think they're still under development.

I would suspect we wouldn't use identical data sets at the end, but at least if we can get both tools using, you know, more recent data reflective of current performance, I think that will help bridge the gap.

MR. SCHULTZ: Thank you.

CHAIR DIMITRIJEVIC: Okay. If we don't have more discussion at this moment, I propose that we open public line, and --

MS. XING: Vesna, there is one more presentation.

CHAIR DIMITRIJEVIC: Oh. It --

MEMBER PETERS: Can anybody hear me?

CHAIR DIMITRIJEVIC: Yes, I can hear you. Sorry, I completely jumped over this number 13. Yes, please, future work.

MEMBER PETERS: I'll try to wrap it up very quickly, Vesna. Thank you.

CHAIR DIMITRIJEVIC: Okay.

MEMBER PETERS: This is Sean Peters again, Branch Chief for Human Factors and Reliability Branch and Research. So I'm just going to talk a little bit about our path forward, what we're planning to do. So we're planning to take the feedback we get from the ACRS and do a final publication of our IDHEAS-G methodology. This would be our Rev 0.

We're always up for making future revisions, you know, once we get more information back. But we need to get something out there that states, "Yes, this is an approach forward for the NRC."

We are also, as Roy is going to be giving us feedback from the PWR Owners' Group and Exelon, we're going to be getting feedback from other people on the -- internal to the NRC on IDHEAS-ECA. And, of course, we're updating, as we told you, dependency, recovery, timing. We are also working on integrating this with SAPHIRE and SPAR models.

And so our plan is to take all of that information and then make a publication of a revision to IDHEAS-ECA to increase these -- or to improve the methodology overall. So IDHEAS data, we're going to be filling in some of the gaps over the next year, including the timing analysis and some of the other places where there may be more holes in the data.

We're talking about a peer review. It's a high likelihood that we'll be doing that based upon our earlier discussions and looking at publishing this into, again, another Rev 0 form. And then, going back, we talked about periodic revisions to the methodology.

Other HRA work that's going on simultaneously, we did allude that we were on minimum joint human error probabilities. This is where we talked about -- where we multiplied multiple human failures against each other, and you can get ridiculously low numbers that are -- can be below astronomical event levels. So we have -- we're working on some scientific basis behind that to try to provide a technical basis for what those should be set for.

Also, I updated here in bold with an exclamation point, data is crucial to our overall program. I told you a little bit about what -- the other things that we have going on with respect to the data work we have, and we are seeking out both U.S. and international partners to further that data structure, so we can fill in these gaps in human reliability.

And, finally, a wish list of things that we are seeing coming down the pike. There is a lot of interest in physical and cyber security right now, especially trying to develop risk models for that. So that's something that we're seeing coming down the pike. It's being led by industry.

And then, of course, the last two, which are always the holy grail, which is incorporating errors of commission and organizational factors, trying to improve the state of practice for those into our HRA. And when you have all of that together, what that will really give us is kind of a full picture of full site risk with respect to the human element. So these are the areas that we're working on.

So I'm going to my last slide, which is number -- Slide Number 12.

And so we think we have, as far as the

IDHEAS program, a complete and practical HRA method, it can always be improved. We already stated the areas where we think we can improve the methodology, but we know it's an improvement to our current state of practice at the NRC.

So currently we are utilizing the SPAR-H method, and we know that we've improved on that state of practice in several areas. Because it's human-centered, scientific, and data-based, this can be applied to all of our domains, not just our typical domain that we use SPAR-H for, SPAR-H was built for in control room at power applications using highly set procedures.

So this methodology can be utilized for medical applications, fuel cycle facility applications, spent fuel transportation. It can be used across the entire realm of NRC applications.

And our programs establish that we can continuously update this based upon our user feedback and more data we apply. So the big question is, from our perspective in Research, we think we have achieved the intent of SRM M06-1020. And now, from our perspective, we're going to continue to go down this path, and I think that we're in a good place.

So the question that has to be kicked back to the ACRS is: what does the ACRS want to do with that SRM? My personal recommendation would be I think we have enough here to say -- you know, to at least write a letter to the Commission from the ACRS that we think we're going down a good path, and we can close out the SRM. But that's something we'll have to kick to the ACRS, because, as I said at the very beginning of the presentation, this is an SRM that was directed to the ACRS. It was not directed to Research.

So we've done a lot in our power to get us to that state of closure, but the final say will have to come from the ACRS.

And, with that, I want to thank all of our presenters. I really appreciate it. I really -- and thanks to folks not under my direct command, like Michelle and Frank and Roy, for coming here and giving us their time. And, again, thank you to the ACRS for giving us the time for this presentation.

CHAIR DIMITRIJEVIC: Thank you, Sean. We also thank everybody who took time to give this presentation to us. It's a huge and complex project, and it took a lot of effort to put all of this together. So we appreciate that.

Okay. Anybody has comments in this moment? Or I propose that we open the public line.

And if Mr. Stetkar is still there, that we give him a chance to present his comments.

MR. STETKAR: Hello?

OPERATOR: The public bridge line is open for comments.

CHAIR DIMITRIJEVIC: Okay. Mr. Stetkar, are you still there with us?

MR. STETKAR: This is John Stetkar. And all of my audio cut out, so I don't know whether you can hear me.

CHAIR DIMITRIJEVIC: We can hear you. Can you hear us? Obviously, we have some audio problem.

MR. STETKAR: Can you hear me? Okay. Good. Thanks. Some feedback was good.

I'm assuming you can hear me. So I am a former member of the ACRS, and of course today I am speaking as a member of the public. I'm going to limit my comments to the IDHEAS general methodology in NUREG-2198. I'm going to submit more detailed written comments on that report.

Unfortunately, I have not yet finished studying the other reports that were discussed today, and I plan to submit written comments on them as soon as I finish all of my homework.

MS. LUI: John?

MR. STETKAR: Yes.

MS. LUI: John? Hi. This is Chris Lui. Sorry. Your audio now is not coming through into the meeting. Okay? So --

PARTICIPANT: It is coming into the meeting.

MS. LUI: It is not, okay?

PARTICIPANT: Hey, Chris?

MS. LUI: Therefore, just hold off. I am sorry. Okay? All we heard -- the last thing we heard was all of your audio is cut off, and that was the last thing we heard.

MR. STETKAR: Yeah. And I -- you know, all of the feedback from the meeting to me was also cut off. Everything went dead.

MS. LUI: Hmm. Okay. So --

MR. STETKAR: It was apparently a two-way problem.

MS. LUI: Right. So just stay there for a little bit. Let's see as we're --

MR. STETKAR: Okay. Just --

MS. LUI: -- trying to fix it. Okay?

MR. STETKAR: Yeah. Just let me know when you think you have it fixed, and maybe --

MS. LUI: Okay.

MR. STETKAR: Okay.

MS. LUI: All right. Hold on.

MEMBER PETERS: Yeah. I hear it, too, Chris. This is Sean Peters. I hear --

CHAIR DIMITRIJEVIC: Right.

MEMBER PETERS: -- John. We've heard everything he said.

CHAIR DIMITRIJEVIC: Yeah, everything.

MS. LUI: All right. Great. So it seems that it's fixed now. Great.

MEMBER PETERS: We've heard everything he said up to this point, so keep progressing, John.

MR. STETKAR: All righty, then. Regarding the general methodology, NUREG-2198, in general, I think the report is, from my perspective, nearly ready for final publication. I only wanted today to highlight a couple of my most important concerns.

The first one is that I remain concerned about the lack of technical justification for the quantification model, in particular equations 4.6 and 4.7. In particular, I don't know why the primary influence on human performance is determined by the three specific performance influencing factors while the other 17 factors are treated as a cumulative modifier.

I also don't understand why the assumed linear summation of those performance influencing factor weights is justified, at least from the information in 2198.

From today's discussion of the IDHEAS data report, it seems that that report may provide the technical basis for the model. So I really look forward to studying it. And, as I said, I have not yet read it.

Unfortunately, again, from the perspective of NUREG-2198, neither of the examples in Appendix M demonstrates how the cognitive contribution to the human error probability is quantified. So analysts using the generic methodology, or trying to understand the generic methodology, don't really have an instructional example of how that model is applied in practice. So that's one comment.

Speaking of Appendix M, I think there are still a couple of errors in the uncertainty distributions in both examples, and I've tried to elaborate on them in my written comments.

If my calculations are correct -- and they may not be -- those errors should be corrected. I think that's really important, because explicit use of the time uncertainty analysis to quantify a contribution to the overall human error probability is a rather new concept to many analysts. And because of that, I think it's very important that the examples of that process demonstrate a realistic evaluation of the uncertainties, and the distribution math should be rigorously correct. So that's a second comment.

Third comment is -- and I mentioned this I think last year -- is I continue to think that it would be really useful for NUREG-2109 to provide nominal evaluation scales for the states of each of the 20 performance-influencing factors, with examples that illustrate a few applicable conditions for those states.

As has been mentioned a few times today, one of the major objectives of the IDHEAS methodology is to reduce human reliability analysis variability. I think a consistent set of guidelines for assessing the performance-influencing factor states in the general methodology would help to reduce analyst-to-analyst variability in that very important element of the process.

And Susan Cooper I think alluded to part of this need in her comments on what she termed mapping the available information into the language of the tool. I know that would take a little bit of work, but I think it would be really useful in the general methodology rather than specific applications.

And as a final comment, I really like the conceptual construct of the dependency model in Appendix K. I understand why it's difficult for NUREG-2198, at least in its current form, to provide examples of how that model is applied.

I hope that either a future update of the general methodology report or perhaps a companion report that explicitly focuses on dependency analysis provides some clear examples of how that methodology is used in practice.

And, with that, I will turn myself off. Thank you very much.

CHAIR DIMITRIJEVIC: Thank you, John. Thank you very much. Is there any other member of the public which would like to make a comment in this time? Okay. Hearing none, then we can I guess close the public line again and have our discussion in this moment.

Okay. Is there any other ACRS members which would like to make a comment in this time?

MEMBER KIRCHNER: Yes, Vesna. This is Walt again.

CHAIR DIMITRIJEVIC: Okay. Thank you.

MEMBER KIRCHNER: I have commented too much, but I'll -- I've been really -- I thank everyone for the presentations, first of all, and indulging all of my comments and questions. I am thinking about this ELAP decision, and I'm thinking about this framework.

The ELAP decision is a little -- it's -- how should I say it? It's an elevated decision in that it's like a strategic decision. You know, it has analogies with the military operations, and you are dealing with a lot of uncertainty. So when you use the framework where you do detection, understanding, and then decision-making, there are -- if you're in a beyond design basis accident situation like the seismic event that was hypothesized, their situational awareness is extraordinarily difficult.

And this kind of methodology, although it provides a nice framework, in a sense that decision is almost like a strategic decision; hence, my comparison to a military kind of decision-making process. And I don't know how well -- I would expect that would have lots of variability, and I wouldn't expect that to get washed out from one analyst to the next.

So, as John just alluded to, you know, guidelines for things like the PIFs and such for nominal values, but I wouldn't expect good agreement on such a high-level decision where there is so much uncertainty. You know what I'm trying to get at where you don't -- it's a little bit different than being in the control room and looking at the indicators that you have there, detecting what the problem is, understanding, and then making a decision.

It's just at such a high level it seems to me that one shouldn't expect -- I would expect large variability in that first step. And then, once we got to the actual FLEX equipment, then one would hope to have, as some of the presenters just showed, much better agreement. That's my observation.

CHAIR DIMITRIJEVIC: Thank you. Thank you, Walt.

Anybody else would like to make an observation in this moment? Joy, we interrupted you once because we were in hurry to try to finish and get to the comments. Did you get everything you -- all answers you wanted in that time?

MEMBER REMPE: Well, I stated the question. I'm not sure I truly got any answer on what exactly would be needed. I heard something from Jing, but I'm not sure -- it helped to hear what Roy said. If Susan wants to add anything else, that would be of interest to me.

MS. COOPER: I'm sorry, Joy. This is Susan. I don't remember the question anymore.

MEMBER REMPE: Well, you and Jing were talking about -- and I'd have to pull up your slides, so this is from memory, about your suggestion about mapping as well as guidance and what would -- one of our goals that I understood from following this IDHEAS over time has been you want to reduce variability, but even if you can't reduce the variability, do you have enough information to understand why people are coming up with different values?

And you had mentioned about compensating factors, and is there enough -- are there enough places in the software for analysts to document what they need? Or if something is just a little -- you know, something else needed that ought to be included in the software to help address this concern. Is that a fair way of trying to say what I was trying to say earlier?

MS. COOPER: Sure. I mean, I guess -- I think that as PRA and HRA continue to be expanded into more and more contexts that they are going to -- there is going to be more and more things that you could imagine adding to the -- to the method. So I'm not sure you could ever have -- say there's a static way to address this. So there may be other ways to address it.

But is there something that we've learned already with FLEX that can be added? I think it would be worth looking at it. It sounds like what Roy is doing could be useful feedback there. It looks like he is doing a pretty good -- pretty deep dive there.

I said I had not really tried to evaluate that. Sounds like Jing is looking at the results from our workshop.

So, I mean, I think if there's something we can do in the near term, I think we could do it. And I think there are also some things with the software tool that can be helpful. I mean, I think James did a fantastic job putting together something easy to use and basically an alpha version of a piece of software, not even a beta version -- alpha.

But, you know, just to make sure that the analysts look at all of the factors, you know, I don't have any specific documentation, but I kind of got the impression that even though the HRA analysts in the NRC's workshop had the same information, that they sort of caught on one PIF maybe that they -- that kind of appealed to them, and they may not have looked in all cases, you know, down further the list and the expanded list to see if there was something else that they might add.

So, I mean, I think just presentation within the software could address that potential problem. But I think the best plan, in addition to seeing if there is anything we already know that we can add, would be to have some way to maintain some flexibility for context that haven't imagined yet.

MEMBER REMPE: Okay. Thank you.

MS. COOPER: Sure.

CHAIR DIMITRIJEVIC: Thank you, Susan. Yes, that was actually well said.

Any other members who would like to make comments in this time? Okay. We are a little tired, but we can --

MR. SCHULTZ: Excuse me. Vesna?

CHAIR DIMITRIJEVIC: Yes.

MR. SCHULTZ: Vesna, this is Steve Schultz. I have a comment or a question -- and a question that follows on to Joy's comments and what -- some of what John Stetkar said as well.

I understand the goal -- the goal of the overall methodology is to develop a system, a method, as Sean called it this morning, to allow for the human error probability to be developed by an analyst. And each and every analyst, from the workshop at least, was expected to do its -- do his or her best to come up with the response, the methodology application, and then we compared the results of one analyst to another and found the range, and so forth.

Susan, the thing that seems to be missing here is I know that there was some collaboration between analysts in terms of discussions and training before, and so on and so forth. But one of the things that is extremely useful in application of PRA in general is internal review of analysts' work, peer review of PRA analyses and results.

And all of that really wasn't discussed here, the after-effects of the workshop, although it was noted what the variation was from analyst to analyst. The follow-on discussions, which could have deeply investigated why there were differences, and perhaps changed analysts' impression of what should be done in the application of the methodology, that seems to be missing here so far, I guess in Rev 0.

MS. COOPER: Yeah. We didn't -- that was not part of the effort, because the software interface is easy to use. Even within the workshop, analysts were able to see what their results were after they made PIF choices and CFM choices, and so on and so forth.

So they were able to see that, and we did have some discussion among ourselves about that. But you're correct that there was not any kind of formal review of any kind as part of this effort. Yes, it wasn't part of this.

MR. SCHULTZ: That's fine. The other question I had, you mentioned -- or the other comment I had is you mentioned scenario development. And have you utilized, in scenario development, especially in the FLEX area, that which is developed for emergency drills and event valuations that are done by utilities commonly, severe accident management exercises, and so forth, over the years?

MS. COOPER: That didn't play a role in what we did for FLEX, except that, at least from -- as I mentioned earlier this afternoon, for myself, I was familiar with the initial development of the SAMGs and the range of content and approaches to implementing them across the plants, and also some aspects of how EDMGs might have been created within the SAMGs. But that was part of a different effort that I have supported, and that's the Level 3 PRA project that the Office of Research is doing.

So with respect to this project, you know, I had that perspective as a comparison point. It was also clear from talking with the various FLEX experts who accompanied us on the plant site visits and provided input to the scenarios that they had that experience in mind also and wanted to do better.

But other than that, there wasn't a role with respect to SAMGs. Does that answer your question?

MR. SCHULTZ: Yes, it does. I'm just -- I'm glad that, as you describe what you did in terms of developing the overall workshop and the lead-in to the overall plan and program, if you talked to the right people and looked at the right things.

The other comment I had was with regard to -- I know it's not -- it's not real data, and we don't necessarily want to find all of the real data, but the emergency exercises and severe accident management exercises, they are done routinely. In terms of getting information about success with regard to decision-making in emergency situations, obviously, they are mock emergency situations, but there is data out there from those exercises that might be able to be used.

And you could certainly come up with an

interface between what is developed from the modeling and exercises and get some value out of making comparisons between the analysts and the actual activities that occur during an emergency exercise.

MS. COOPER: I agree. I think any kind of data like that would be useful. And we've had some discussion about wanting some more information about how some of the ex-control room actions in the FLEX scenarios are using FLEX equipment. We could get more information that way.

You know, beyond what we've discussed, like for FLEX validation, I'm not aware of anything. I do know that years ago, you know, the first generation of SAMGs and trying to use EDMGs that there were -- there was at least one plant, the reference plant, that we were modeling had started to do some what they called mini drills using SAMGs and implementing EDMGs.

And they were actually -- on at least one occasion by that point in time, had involved the field operators, and the field operator I interviewed thought that was tremendously helpful to him and wanted to see more of that. So if any of that is going on, especially using FLEX equipment, that would be good. But I'm not aware of anything like that right now.

MR. SCHULTZ: Okay. Thank you.

MS. COOPER: Thank you.

CHAIR DIMITRIJEVIC: Thank you, Steve.

Anybody else? Okay. Then I would like to say something, even I don't get involved in this very late. When I started reviewing this method, I asked myself a couple -- you know, the questions which I always kept in mind were, first, will this evaluation HFE be more comprehensive? And the answer to this is definitely yes.

Is it more complex involving than current methods? Yes.

Is documentation likely to be better? My answer to this is maybe, but I believe it's probably better.

I quantify AGP slightly to be more accurate. My answer to this is no way to know. With the PRA designs benefit from this matter, and my answer to this is probably not because this application would not reduce uncertainties in the risk results. And that's about all the things which I want to say.

My other question: could the industry, in general, benefit from this method? And my answer is still maybe to this, and I'm still thinking about this.

But one of the things which I want to point this out, I don't know because considering these human factors, there is very famous -- that German psychologist called Gerd Gigerenzer. I don't know if you are familiar with his book, because he is the Director of the Harding Center for Risk Literacy or Max Planck Institute.

And he is -- he devoted so much years of his work to see how uncertainty interacts with the decision-making. And he is the famous author of the phrase which says less is more. And his sentence in this sense goes that using less information can produce better outcome than complex model depending on numerous assumptions. And I think that this is very important to keep in mind whenever we do discuss this.

Also, we make more complex, bring more information, and we just increase uncertainties, and benefits of this may not be high. Actually, it may be an opposite way.

So whatever -- we have been on this journey together, ACRS and NRC staff obviously, for a very long time. So we are where we are. We have a very complex model with richness of information, which brought so many things especially through the data provides a very comprehensive model.

However, with all of this information you needed to make decision, we have introduced so many new sources of uncertainties. So the thing is, what I was going to say, since this is -- I mean, and we can ask ourselves are we basically done, because Sean started presentation today, and we responded to us SRM but proposing that the model, you know, and the -- proposing the guidance and model and all specific concerns this way can be used.

Obviously, this development is not finished, because we still have -- you know, you are still working with dependencies, recoveries, integration with SPAR, joint AGBs, and all of the work that's remaining, details of this, maybe we should really try to keep those simple, as simple as we can based on what we learned from this very complex model.

And even Susan is saying that some of the simple versions were used in the FLEX. And if we can base on what we learned, that will -- the simple version with this -- you know, don't rely on this future number of assumptions and can make analysts make the decision much faster based on what we have learned of this very comprehensive model.

I think we can benefit from that, so, you know, if we can introduce some of those, keep things simple and less is more philosophy in completing details of this project, I think we could benefit from this.

So this is, you know, how I feel in this moment about that, but as was said, we have to discuss -- this is personal opinion, it is all of our opinions, you know, about that we definitely need to discuss, as a full committee, do we feel that we have -- we are ready to close this SRM, and do we think that we have good enough guidance, good enough to, you know, provide the general application in this HRA model. So --

MEMBER PETERS: Vesna, this is Sean Peters again. I would like to just step in a little bit. There are several different types of uncertainty, and one type of uncertainty is completeness uncertainty, right? So you wouldn't put together a PRA model that just ignored the diesel generators or ignored offsite power, because you could, and it would make the method simpler, it would make the model simpler, but you would have this massive completeness uncertainty that you're ignoring.

And that was the problem that we had with some of our older methods, that they didn't account for some of the factors that actually played a part in the human behavior.

And so what I am trying to say is with this methodology, we've tackled that completeness uncertainty and drove down that uncertainty. And what we found by implementing it is it's not significantly more complex to use than existing models. It just allows you to -- because what was a complexity in SPAR-H was, how do I actually characterize this in the limited set of PIFs that I have? Because this may not apply to stress. I don't know, right?

Trying to fit what you understand from your human behavior into that SPAR model is a difficult process because it doesn't model that. So with -- I think the step we made forward here is we've reduced completeness uncertainty, and we've allowed the actual -- the actual drivers of human performance that people can identify in their qualitative analysis. We have a check button for that, and that lets them put that into the model.

So that's all I'd want to say about uncertainty.

CHAIR DIMITRIJEVIC: Okay. That's true. There is some -- that is the truth that there is something, so maybe this will reduce completeness uncertainty.

However, there is definitely -- I mean, the things which are brought here that they have to estimate the time, you know, the time curves in order to get this evaluation integral, they had to divide the tasks on exactly, you know, if you divide the tasks in different way, you will get a different result.

There are so many, I don't -- I really sort of appreciate all of this work very much. D Don't get me wrong. It's a long journey and exactly the richness of information. But, however, I think it can definitely be -- if we want to look into separate dependencies, and you start looking in the -- first, has it satisfied those three, then does it satisfy the extent of the PIFs, you have to make so many decisions, and the nature of the decisions and assumptions in this analysis that you definitely increase uncertainty.

You saw that we got the results based on the analyses which are way out of any uncertainty they included in there. That doesn't make sense. It's not really -- you know, so the goods and the -- which I just want to say now, and if you are doing -- looking at dependency, which is sort of high, medium, and low, and then you have two numbers, three numbers, was that different? Would that produce a bunch of different results? I'm not sure. That's what I think is there.

So I just want to say whenever we can see that we already have a model which we -- everybody felt is going to give them better results. This I don't know, but it could be used to learn something from it.

MEMBER PETERS: I just want to add in that we didn't originally have a dependency model in the methodology, nor that time uncertainty distribution, and both of those pieces were added at the behest of members of the ACRS. We spent a significant time developing them.

CHAIR DIMITRIJEVIC: No, no, no. They have to be there. There is no doubt about that. Don't say --

MEMBER PETERS: No, no. We were intending to use old dependency models, and I think that at the time the ACRS did not believe that we should be using those because they didn't see as much of a technical basis behind them.

So, for our perspective, I think we could go back the other way, but, again, it's just -- it's a --

CHAIR DIMITRIJEVIC: Okay. I'm not proposing to go back, but to use this model whenever we can to keep things more straightforward without making numerous assumptions.

Well, this show I feel. I have -- I was always feeling like that. You know, I always thought unfortunately we can make things as complex as we want, and, actually, it takes much more effort to, you know, keep them simple. So it may not be able to be done. I'm not saying anything. That's just my personal opinion in this moment.

So, okay. My members of the committee may feel completely different way. So, okay, so if we don't have any other comments, I think we have been only late 36 minutes, so it's not so bad.

MS. LUI: That's not -- this topic is currently scheduled to come back to a full committee in November.

CHAIR DIMITRIJEVIC: Okay.

MS. LUI: If the members feel that the staff should come back to brief the full committee in November, I'm sure that the staff will appreciate you letting the members -- let them know what to focus on, because we have a lot of material today, and during a full committee not going to have the luxury of the time as we have today.

Therefore, I think that any kind of indication about whether to return in November, and if to return in November, where to focus.

CHAIR DIMITRIJEVIC: Okay. Christiana, I am just standing up for Dennis. This is his subcommittee. I am relatively new to all of this. This is going in the last, like, you know, more than decade.

So I think that Dennis should be one to make the call when he returns.

MEMBER REMPE: As another member, I would second what Vesna is saying, because there has been so much material. And trying to figure out how to concentrate it for a full committee meeting I think takes a little more thought, and we do have time before November to ponder this and provide some more comprehensive guidance. Just another member's thought.

MEMBER PETTI: Yeah, I agree with both of you. It's going to have to be executive summary level, and there is so much to cover. I think we need to think about it a little bit.

MS. LUI: I just tried to be practical

that the November full committee will be the first full week in November, and we are sort of towards the tail end of September. For the staff to be able to pull together a quality presentation, and also supply any additional information, they will also need time to prepare.

Therefore, I think that we may have to revisit whether November is realistic for the staff to come back.

MEMBER REMPE: That is another point, but why don't we give ourselves a couple of weeks to decide that.

CHAIR DIMITRIJEVIC: Well, I don't know how is -- how fast the staff moving on this future work. If there is nothing happening, then we don't really need them. They already gave us excellent presentations today, so if there is not any future developments, then I don't think we will need much more than what they already presented. So --

MEMBER PETERS: I don't think we'll have many future developments in the next two weeks, just to be funny about it.

CHAIR DIMITRIJEVIC: All right. Okay. Okay. Yeah. It's actually a month. All right. So --

MEMBER PETERS: Yeah. We just have to get you them 30 days in advance, so any -- any new developments.

CHAIR DIMITRIJEVIC: All right. Okay. I don't think that there were -- if ye have a presentation for the full committee in November, it will be just some short recapture what was said here. Chris, I don't think you will require for much preparation for staff.

Are we ready to make a decision in November? I think that should be Dennis' call.

MS. LUI: So, Sean, I just want to make sure that we understand the timeline here, to decide whether this will come into November's full committee meeting. A decision will have to be made during the -- during the P&P discussion in October?

MEMBER PETERS: Yes. That's what I heard the committee saying, that they believe that Dennis needs to be involved, and some of the decision-making on what should be presented, if they come to the committee in November. And so when we can, we'll talk to Dennis about that.

And also, if they are pushed back from November, that's not a problem because the November schedule is very packed.

So, at this point, I think when we can we'll talk to Dennis. I want to thank the staff for their presentation. Please stay in touch with Christiana. If you do -- well, whenever you do make a presentation, just be aware that it's going to be significantly abbreviated from anything that was given today.

The committee is lately asking for its full committee presentations to be, you know, much, much shorter than was presented to any of the subcommittees, not just for this one but for all of them.

Chris, does that answer your question?

MS. LUI: Yeah. We can talk about a timeline in a little bit more detail later on.

MEMBER PETERS: Sure.

MS. LUI: But I just want people to be generally -- generally be aware that things have to happen in sequence.

MEMBER PETERS: Yep.

Back to you, Vesna, or --

CHAIR DIMITRIJEVIC: Okay. Well, Chris, are you -- are we okay then? In this moment, do we need some other information?

MS. LUI: No, I think that -- I think that we understand that you will be -- will be a decision by the October P&P discussion.

CHAIR DIMITRIJEVIC: Okay. Sounds good. In that case, I wish everybody nice evening or afternoon. So thank you for the very productive meeting and the great presentations. And I feel that we had a good discussion on the topic.

So, okay. Bye, everybody. Have a nice evening.

(Whereupon, the above-entitled matter went off the record at 6:41 p.m.)

The Integrated Human Event Analysis System (IDHEAS) Program Introduction

Sean E. Peters

Advisory Committee on Reactor Safeguards Reliability and PRA Subcommittee Meeting

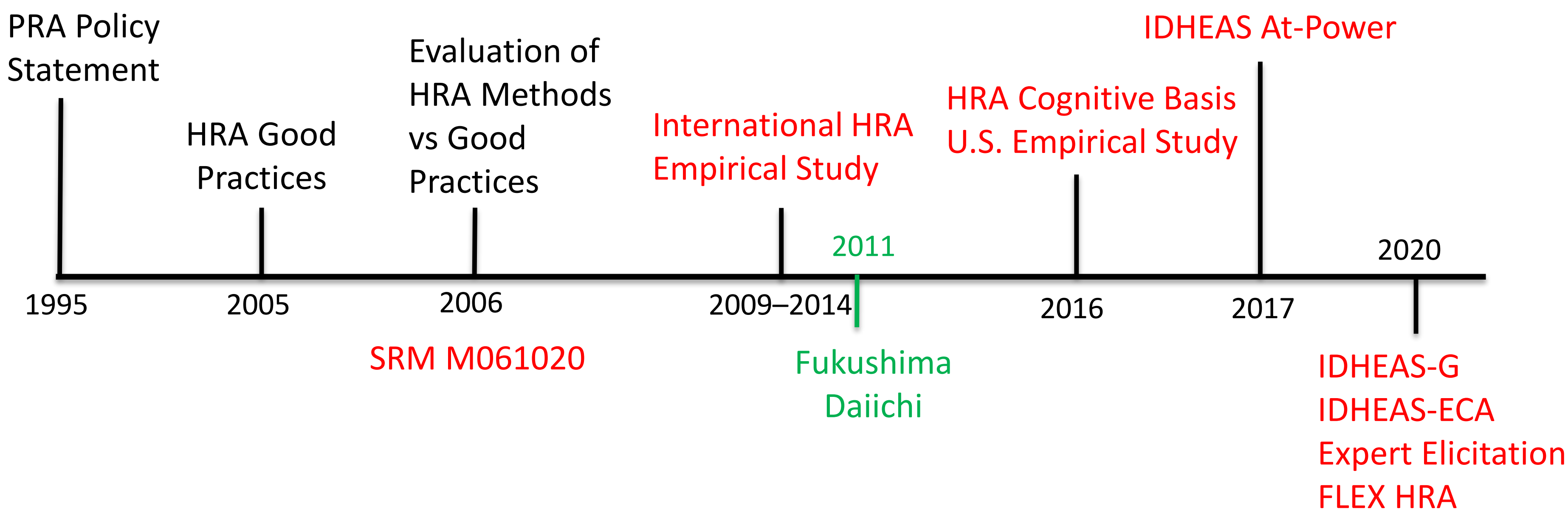
September 23, 2020

Why are we here?

SRM-M061020

The Committee should work with the staff and external stakeholders to evaluate the different Human Reliability models in an effort to **propose either a single model for the agency to use or guidance on which model(s) should to be used in specific circumstances**.

Timeline of HRA Development



Timeline References

- PRA Policy Statement " (60 FR 42622) – “The use of PRA technology should be increased in all regulatory matters to the extent supported by the state of the art in PRA methods and data, and in a manner that complements the NRC's deterministic approach and supports the NRC's traditional defense-in-depth philosophy.”
- NUREG-1792 - Good Practices for Implementing [HRA] (ML051160213)
- NUREG-1842 - Evaluation of [HRA] Methods Against Good Practices (ML063200058)
- NUREG/IA-0216 - International HRA Empirical Study (ML093380283, ML11250A010, ML14358A254)
- NUREG-2127 - The International HRA Empirical Study: Lessons Learned from Comparing HRA Methods Predictions to HAMMLAB Simulator Data (ML14227A197)
- NUREG-2114 - Cognitive Basis for [HRA] (ML16014A045)
- NUREG-2156 - The U.S. HRA Empirical Study (ML16179A124)
- NUREG-2199, Vol. 1 - [IDHEAS] for [NPP] Internal Events At-Power Application (ML17073A041)
- RIL 2020–02, Integrated Human Event Analysis System for Event and Condition Assessment (IDHEAS-ECA) (ML20016A481)

IDHEAS Development Process

- US and International Benchmarking Projects – determined existing methods' strengths and weaknesses
- Cognitive Basis Report
  – Extensive Literature Review, Scientific Basis for Structure
- IDHEAS at-Power
  – Industry/NRC Collaboration – goal of reducing variability
- Fukushima

Development Process (cont.)

- IDHEAS-G
  - Guidance for developing application-specific HRA methods or tools
  - Framework to generalize and integrate human error data
  - Structure to analyze human events and identify human failures and root causes
- IDHEAS-ECA
  - Built from IDHEAS-G to handle all NRC applications
  - Can be used for in/ex control room activities and other nuclear/non-nuclear domains (human centered method)
  - Quantification model and software tool included

Development Process (cont.)

- IDHEAS-Data
  - Data basis for IDHEAS quantification
  - Constantly evolving and tied to NRC data collection activities
    - Scenario Authoring, Characterization, and Debriefing Application – SACADA
    - NRC's Human Performance Test Facility
    - Halden

IDHEAS Reviews

- IDHEAS–G
  - Multiple ACRS Subcommittee reviews
  - 2 external peer reviews, 1 internal peer review
  - Tested on: Fukushima, US Benchmarking Events, Fuel Cycle Facility Events
- IDHEAS-ECA
  - Tested on FLEX Scenarios (NRC and industry studies), ASP and SDP Events
  - Currently taking user comments to incorporate into revised report/tool
- IDHEAS-DATA
  - Data review (underway), peer review possible thereafter
  - Plans for regular updates

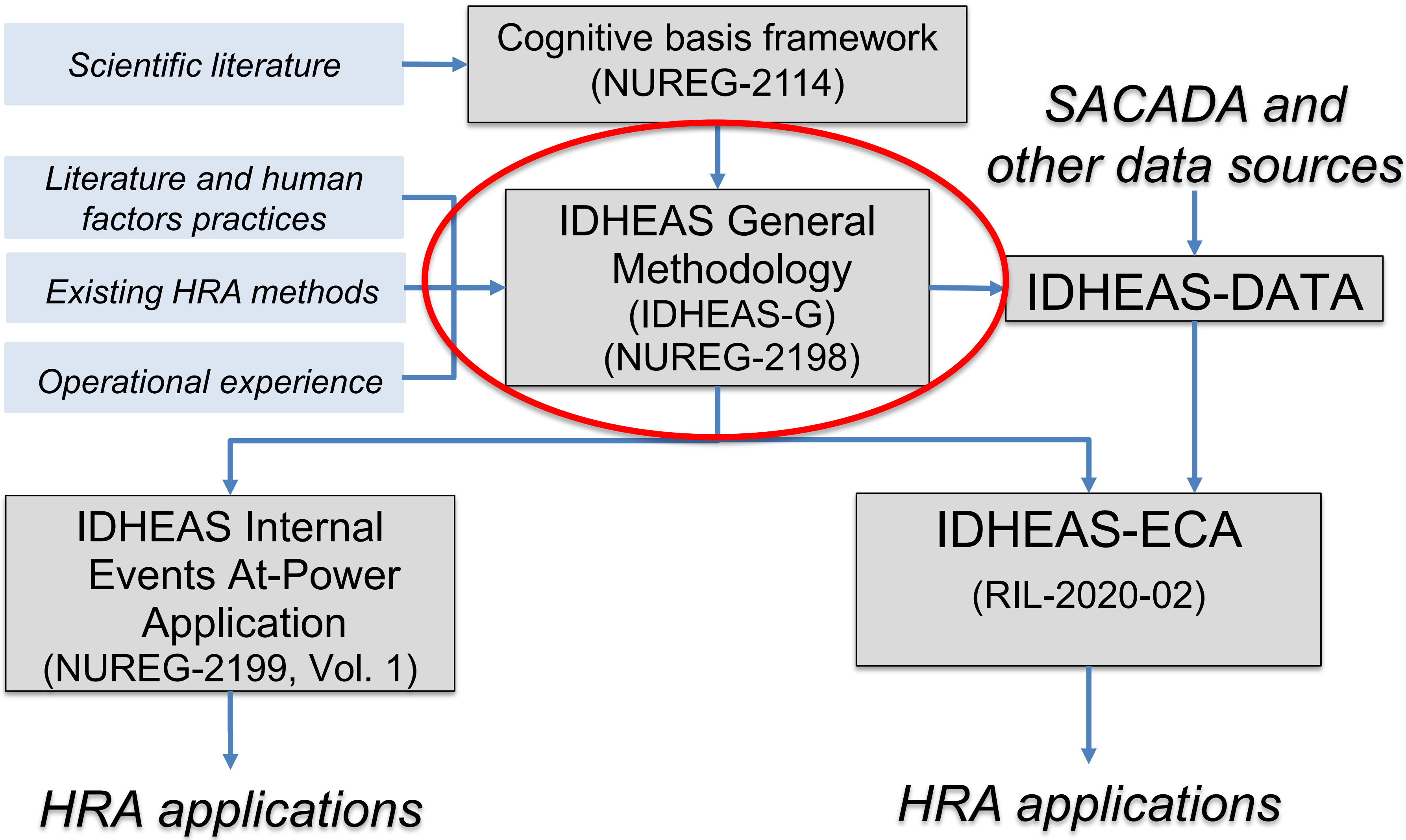
The General Methodology of an Integrated Human Event Analysis System (IDHEAS-G)

Jonathan DeJesus

Presentation to the
Advisory Committee on Reactor Safeguards
Reliability and PRA Subcommittee
September 23, 2020

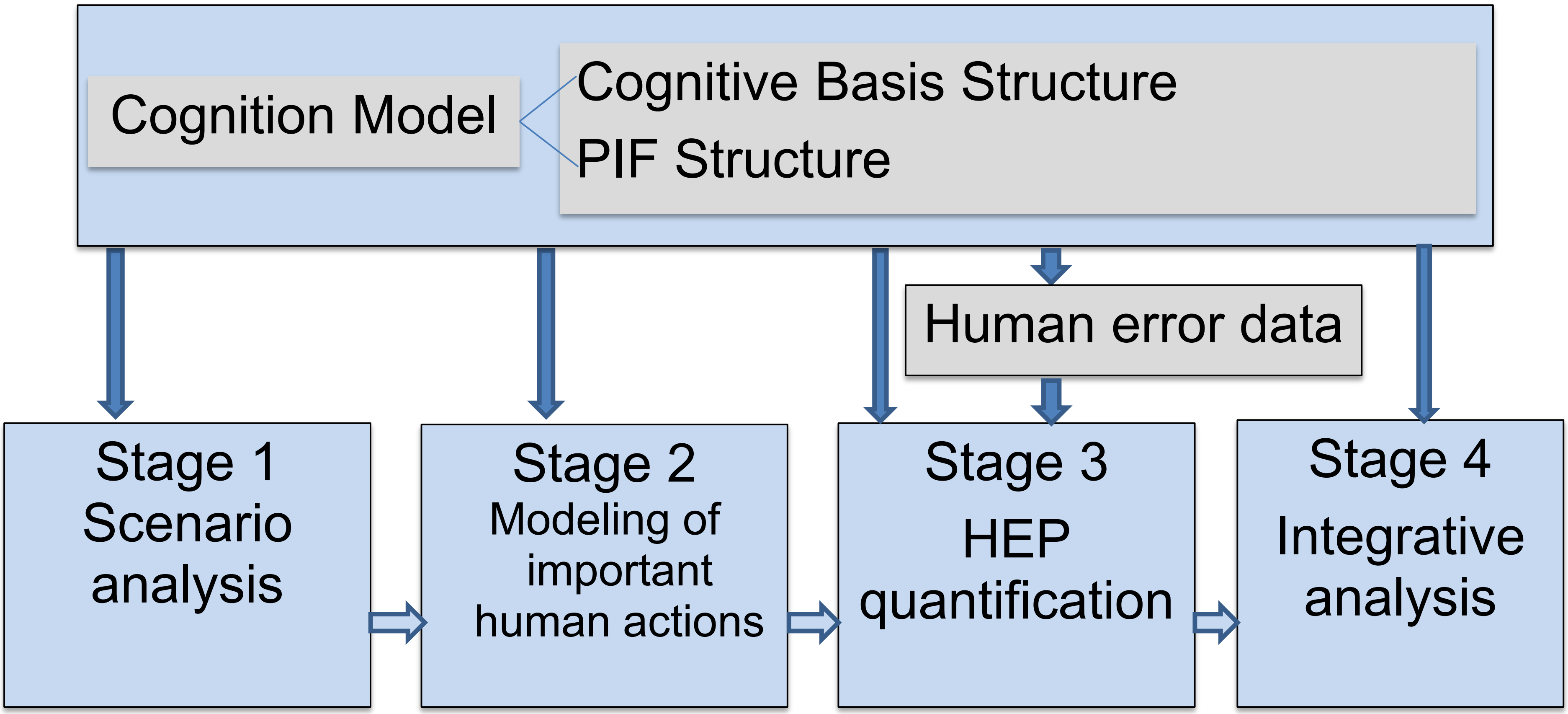
Acronyms and Terms

ACRS	Advisory Committee on Reactor Safeguards
CFM	cognitive failure mode
CT	critical task
HEP	human error probability
HFE	human failure event
HRA	human reliability analysis
HSI	human-system interface
IDHEAS	Integrated Human Event Analysis System
IDHEAS-DATA	Integrated Human Event Analysis System for Human Reliability Data
IDHEAS-ECA	Integrated Human Event Analysis System for Event and Condition Assessment
IDHEAS-G	General Methodology of an Integrated Human Event Analysis System
IHA	important human action
I&C	instrumentation and control
NRC	U.S. Nuclear Regulatory Commission
PIF	performance-influencing factor (same as performance-sharing factor (PSF))
PRA	probabilistic risk assessment
PZR	pressurizer
RHR	residual heat removal (system)
SACADA	Scenario Authoring, Characterization, and Debriefing Application
SI	safety injection
TS	Technical Specification
P_c	error probability attributed to the CFMs of all CTs of an IHA
P_t	error probability attributed to the uncertainties in T_{avail} and T_{reqd}
T_{avail}	time available
T_{reqd}	time required

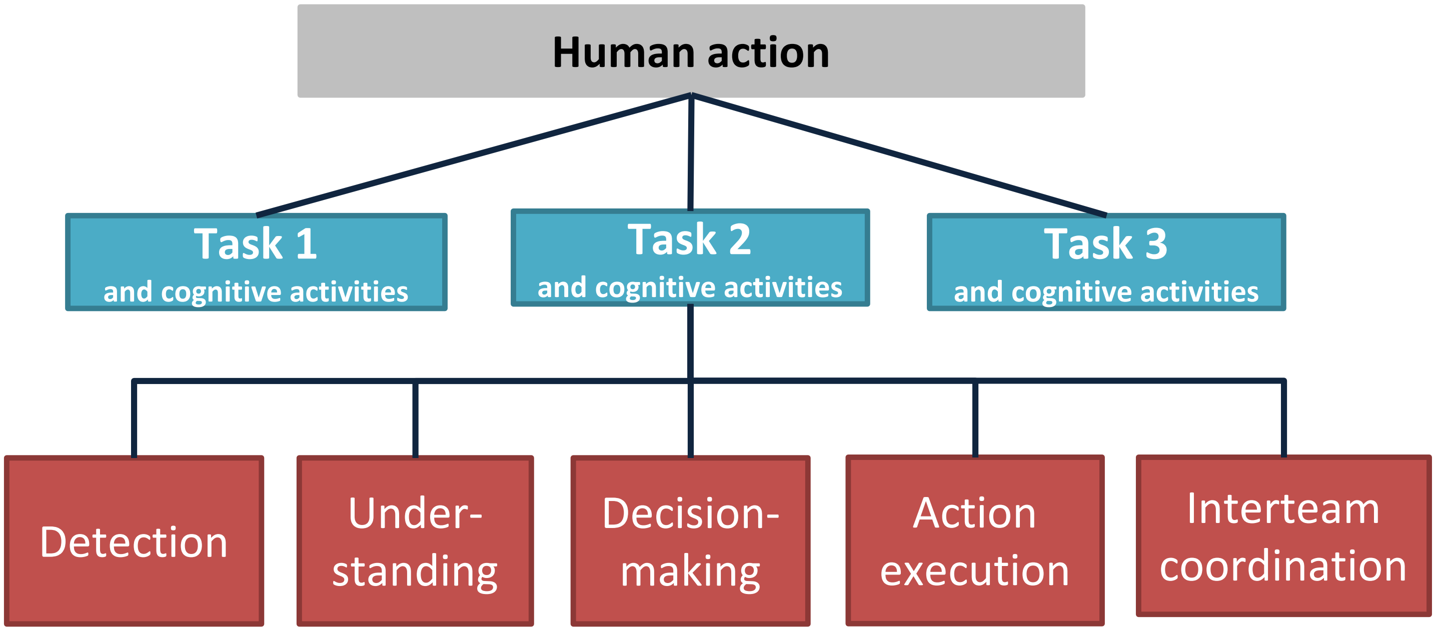


Scientific literature
Cognitive basis framework (NUREG-2114)
SACADA and other data sources
Literature and human factors practices
Existing HRA methods
Operational experience
IDHEAS General Methodology (IDHEAS-G) (NUREG-2198)
IDHEAS-DATA
IDHEAS Internal Events At-Power Application (NUREG-2199, Vol. 1)
IDHEAS-ECA (RIL-2020-02)
HRA applications
HRA applications

Overview of IDHEAS-G



Cognitive Basis Structure

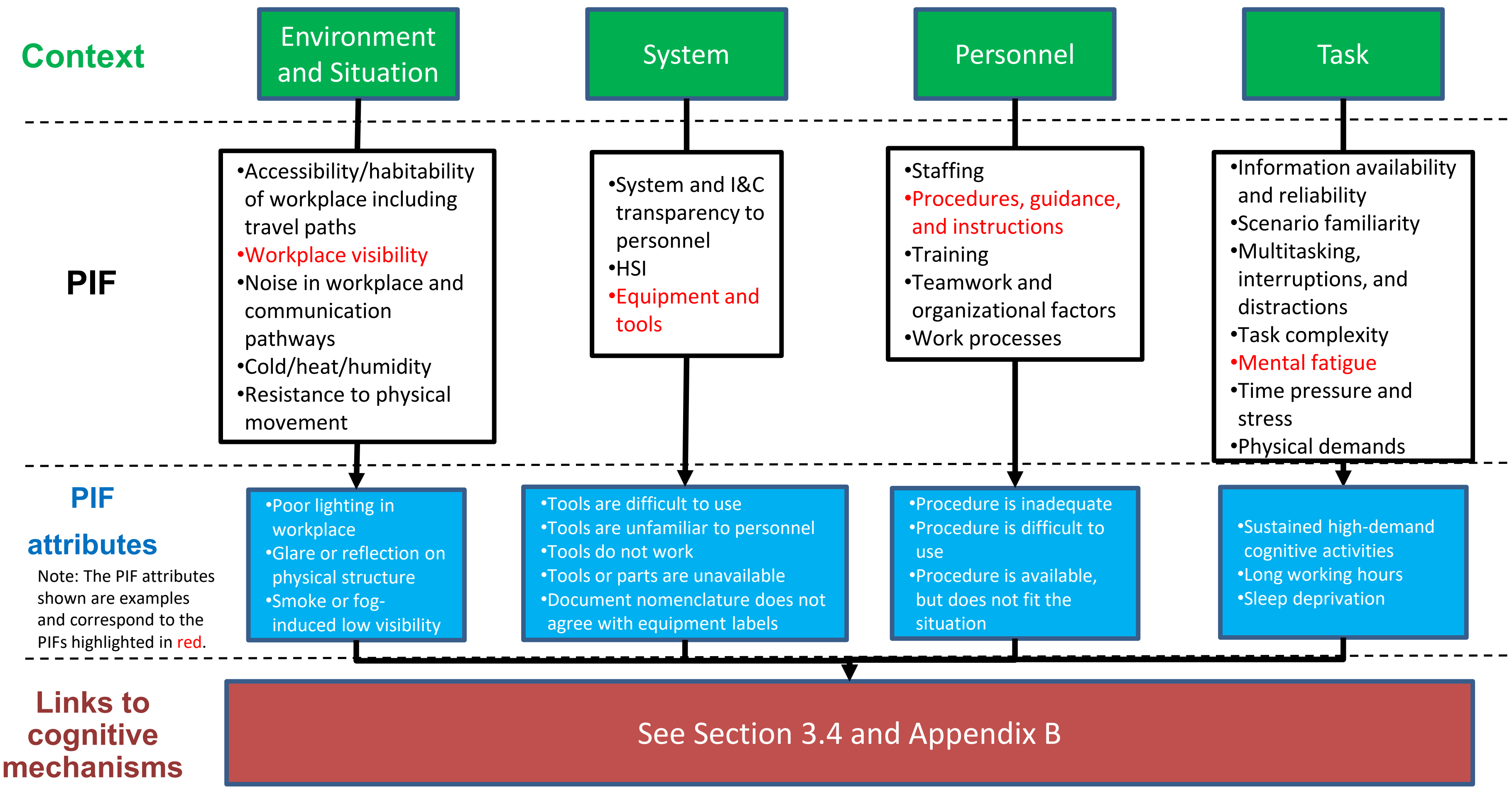


Cognitive Basis Structure—Failure of Human Actions

Macrocognitive functions — Processors — Cognitive mechanisms — PIFs

- Failure of any macrocognitive function leads to the failure of the task and the human action.
- Failure of a macrocognitive function results from errors of one or more processors.
- Errors of a processor may occur if one or more associated cognitive mechanisms do not work properly or reliably.
- PIFs affect the capacity limits of the cognitive mechanisms.

PIF Structure



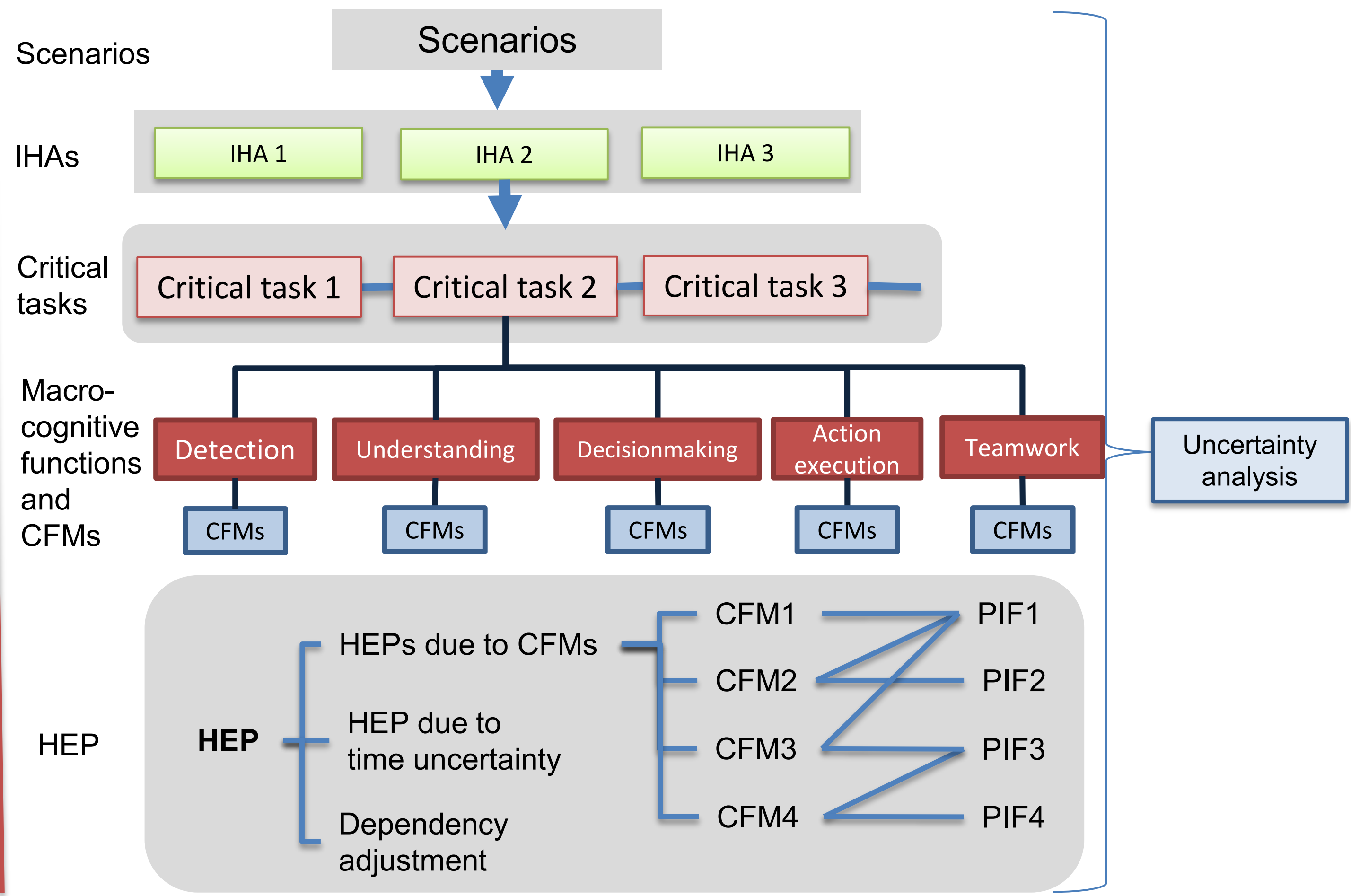
IDHEAS-G HRA Process

Stage 1: Scenario analysis
- Develop operational narrative
- Identify scenario context
- Identify important human actions

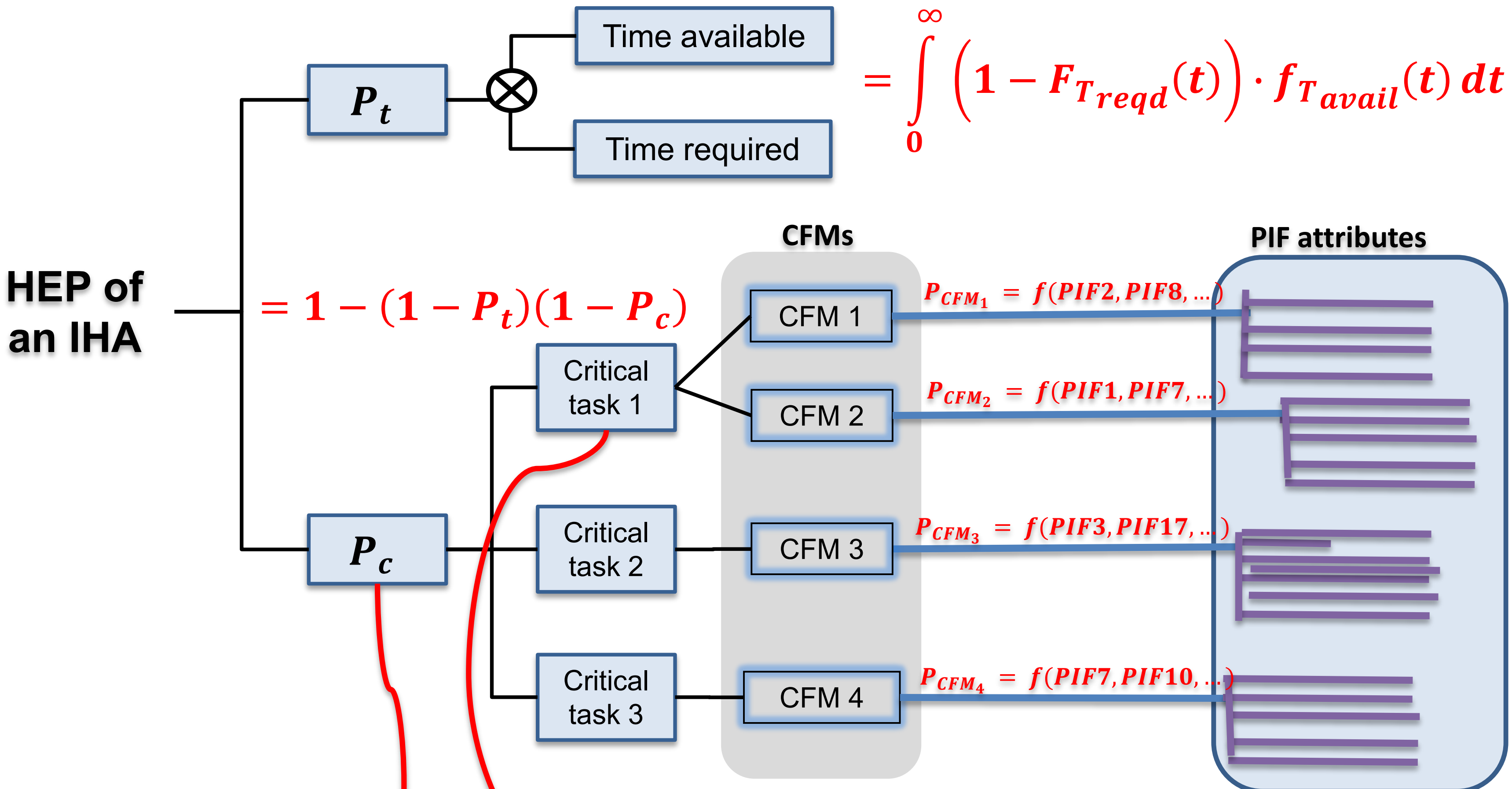
Stage 2: Modeling of important human actions
- Identify and analyze critical tasks
- Identify applicable CFMs
- Assess PIFs

Stage 3 – HEP quantification
- Estimation of P_t
- Estimation of P_c

Stage 4 – Integrative analysis
- Document uncertainties
- Assess dependencies



HEP Quantification—Overview



$$= \int_0^{\infty} \left(1 - F_{T_{reqd}}(t)\right) \cdot f_{T_{avail}}(t)\, dt$$

$$= 1 - (1 - P_t)(1 - P_c)$$

$$P_{CFM_1} = f(PIF2, PIF8, \ldots)$$

$$P_{CFM_2} = f(PIF1, PIF7, \ldots)$$

$$P_{CFM_3} = f(PIF3, PIF17, \ldots)$$

$$P_{CFM_4} = f(PIF7, PIF10, \ldots)$$

$$1 - \prod_{i=1}^{3} \left(1 - P_{CT_i}\right) =$$

$$= 1 - \prod_{i=1}^{2} \left(1 - P_{CFM_i}\right)$$

HEP Quantification—P_c

- HEP quantification model

$$P_{CFM} = \underbrace{P_{CFM_{Base}}}_{\text{HEP from Base PIFs}} \cdot \Bigg(1 + \underbrace{\sum_{i=1}^{n} (w_i - 1)}_{\text{PIF weight factors from Modification PIFs}}\Bigg) \cdot C \cdot \frac{1}{Re}$$

Recovery factor; set to 1 unless data suggest otherwise

PIF interaction factor; set to 1 with linear combination

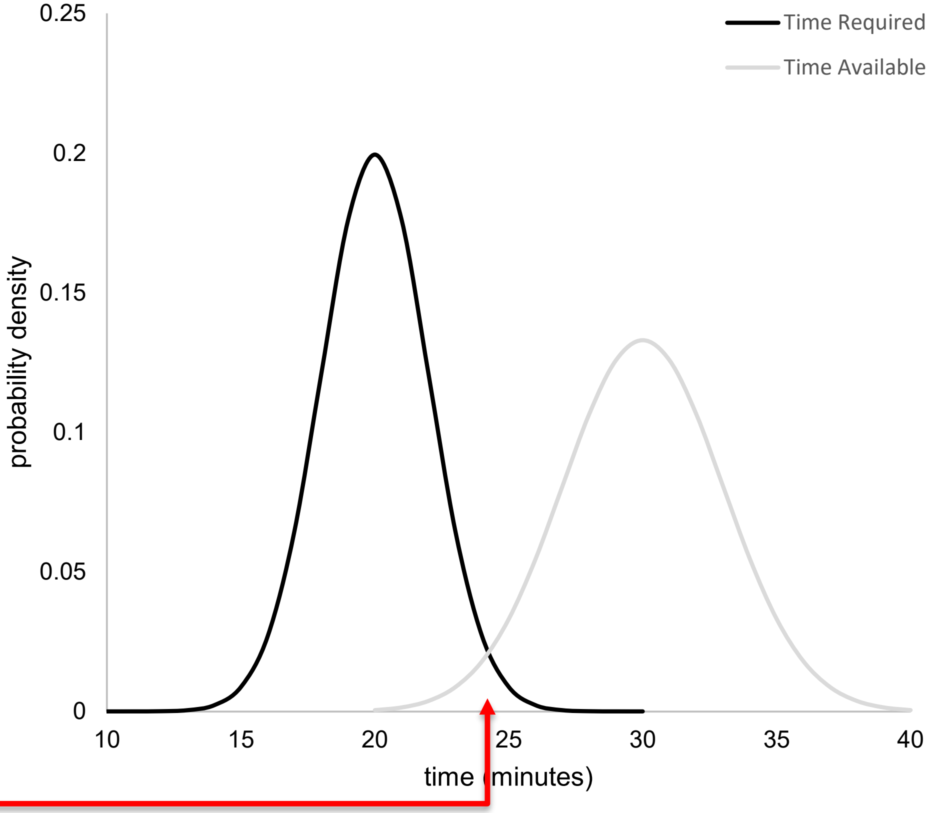
$$w_i = \frac{ER_{PIF}}{ER_{PIF_{Base}}}$$

$ER_{PIF} \equiv$ error rate at a given PIF attribute

$ER_{PIF_{Base}} \equiv$ error rate when the PIF attribute has no or low impact

HEP Quantification—P_t

- In response to ACRS comments, time uncertainty model was developed
- Convolution of time available and time required distributions
- $P_t = P(T_{reqd} > T_{avail})$
- P_t is proportional to this area



U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

IDHEAS-G Changes Since Last Meeting with ACRS Subcommittee

- Addressed ACRS (and public) comments
  - Clarified distinction between interteam and intrateam CFMs and PIFs
  - Added language so that reader can go to Chapter 4 (HRA Process) without reading Chapters 2 (Cognitive Basis Structure) and 3 (PIF Structure)
  - Added PIF attribute in PIFs *Staffing* and *Physical demands* to address personnel safety considerations
  - Each PIF has its own description table in Chapter 3
  - Added list of reviewers in Acknowledgments
  - Addressed concern with the use of "et al." in References
  - Many other editorial changes
- Proposed a dependency model (encouraged by ACRS comments) – Appendix K

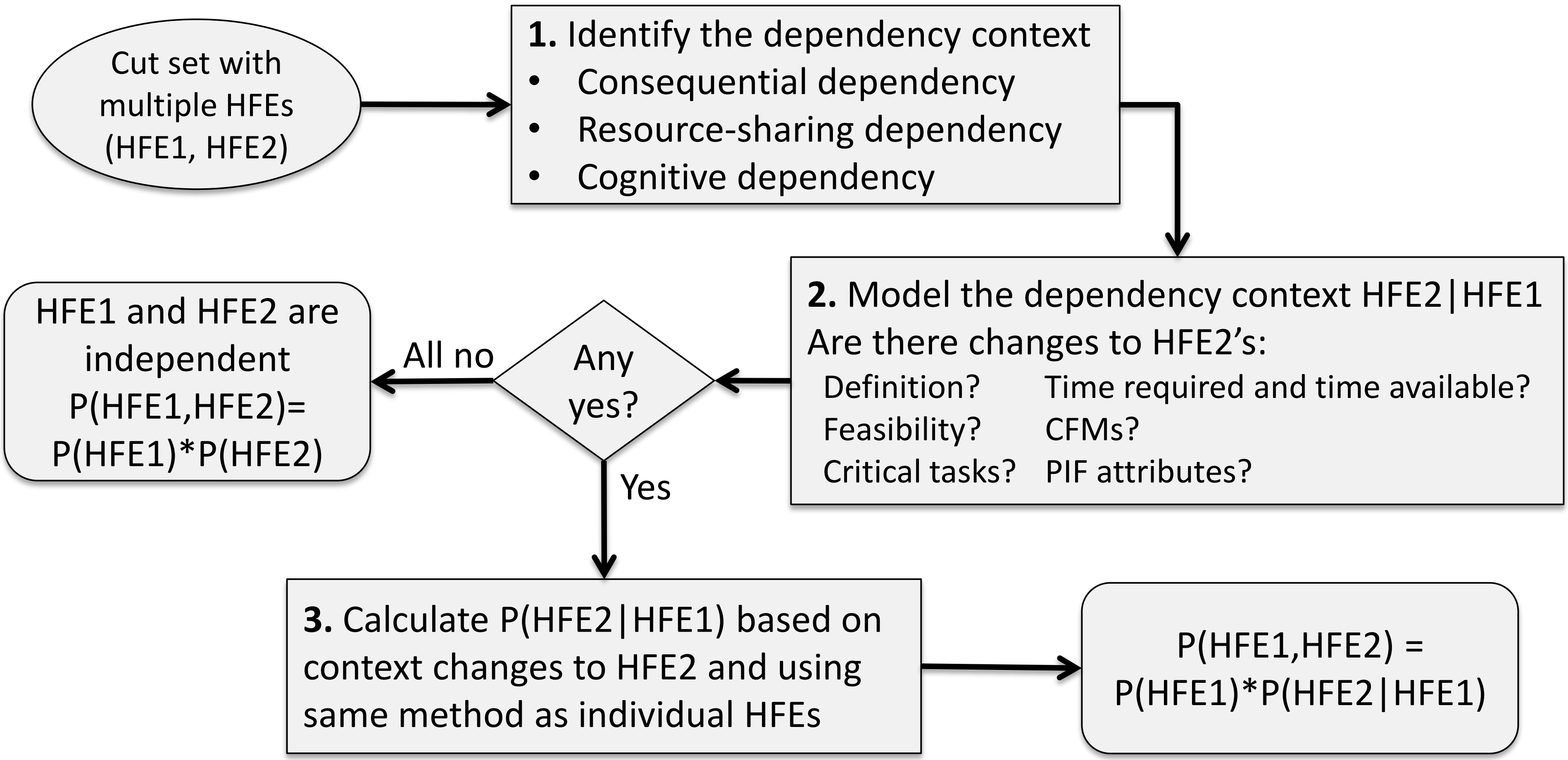
IDHEAS-G Dependency Context Categories

- Consequential dependency
  - Millstone Unit 3 (ML051860338), spurious alarms triggered an SI signal. Operator failed to control SI flow that resulted in a water-solid PZR. That, in turn, increased workload and delayed the subsequent operator actions.

- Resource-sharing dependency
  - Palo Verde (ML042220267), simultaneously perform a boron injection system testing and an atmospheric dump valve test that should be performed in sequence. The prior testing limited the charging flow and the latter testing increased letdown flow that caused high regenerative heat exchanger temperature and a pressurizer level transient above TS limits, and resulted in a loss of letdown event.

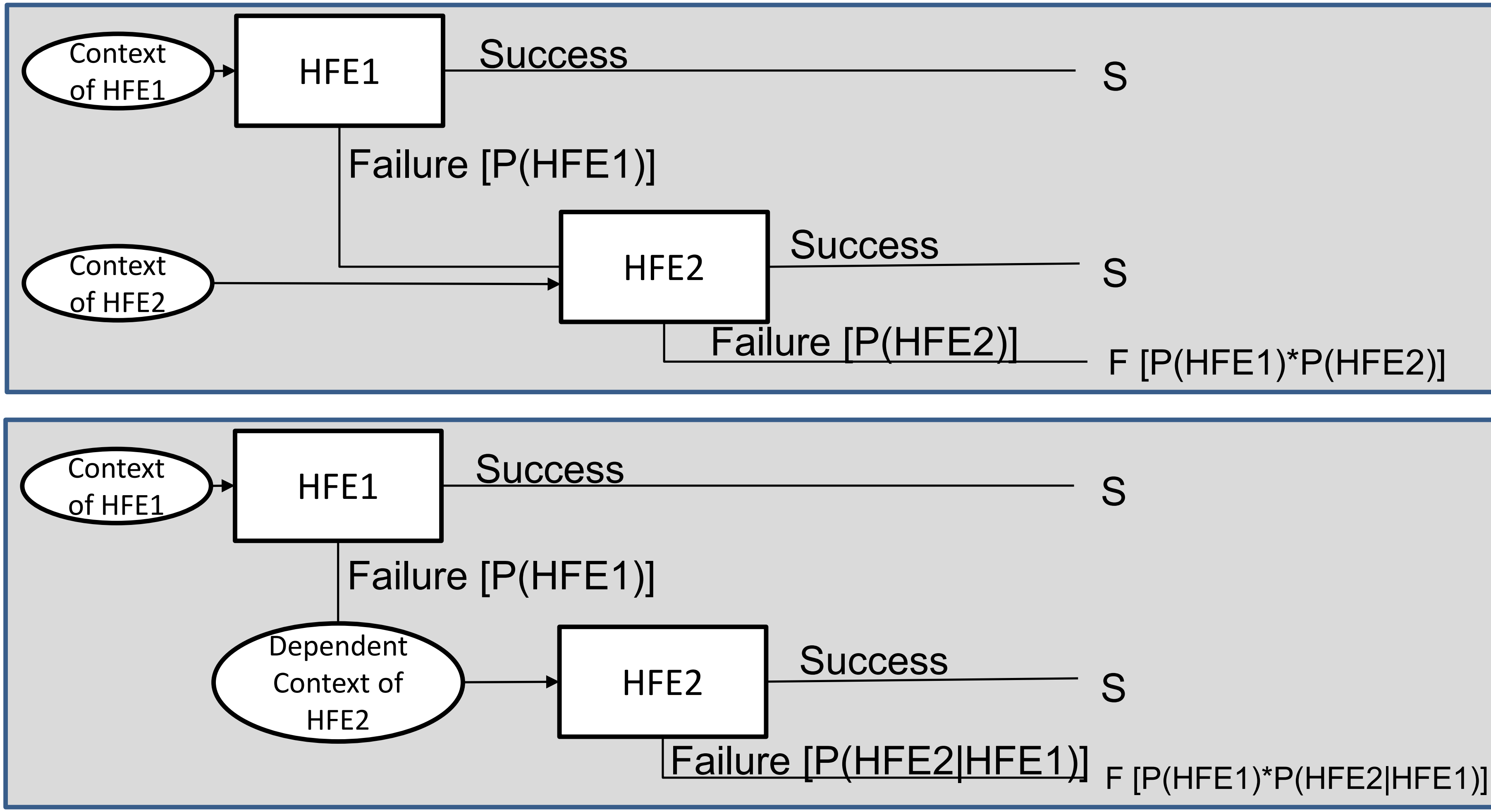
- Cognitive dependency
  - Catawba Unit 1 (1990), forgot to reopen sensing lines of three pressure sensors after maintenance work resulted in RHR over-pressurization.

IDHEAS-G Dependency Model: Process



"HFE2|HFE1" means the occurrence of event HFE2 given the occurrence of event HFE1, where HFE1 is the first event and HFE2 is the second event.

IDHEAS-G Dependency Model: Illustration



S = success
F = failure

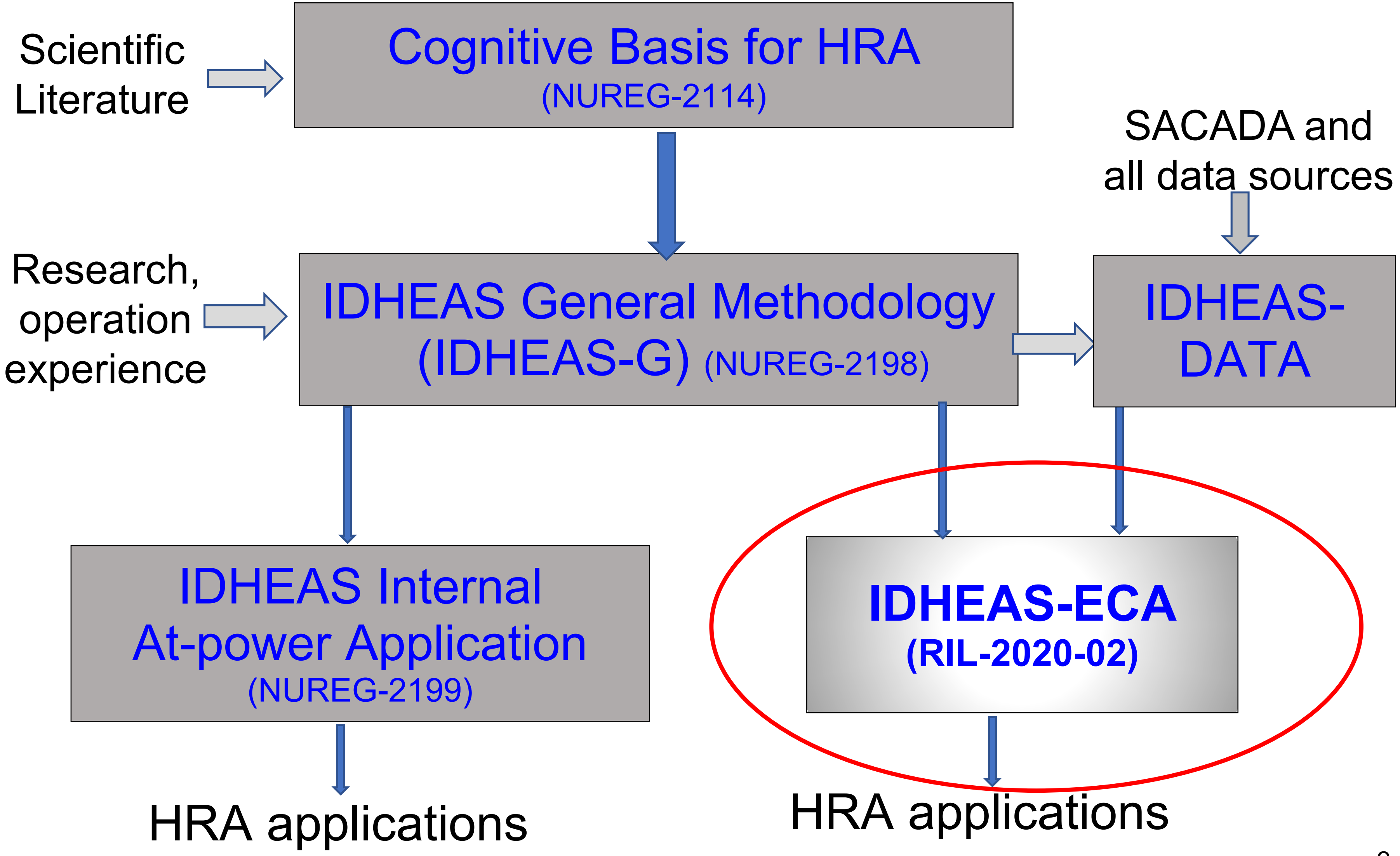
IDHEAS-ECA

Y. James Chang

RES/DRA/HFRB

Presented at the ACRS Subcommittee Meeting

9/23/2020


Scientific Literature
Cognitive Basis for HRA
(NUREG-2114)
SACADA and all data sources
Research, operation experience
IDHEAS General Methodology
(IDHEAS-G) (NUREG-2198)
IDHEAS-DATA
IDHEAS Internal At-power Application
(NUREG-2199)
IDHEAS-ECA
(RIL-2020-02)
HRA applications
HRA applications

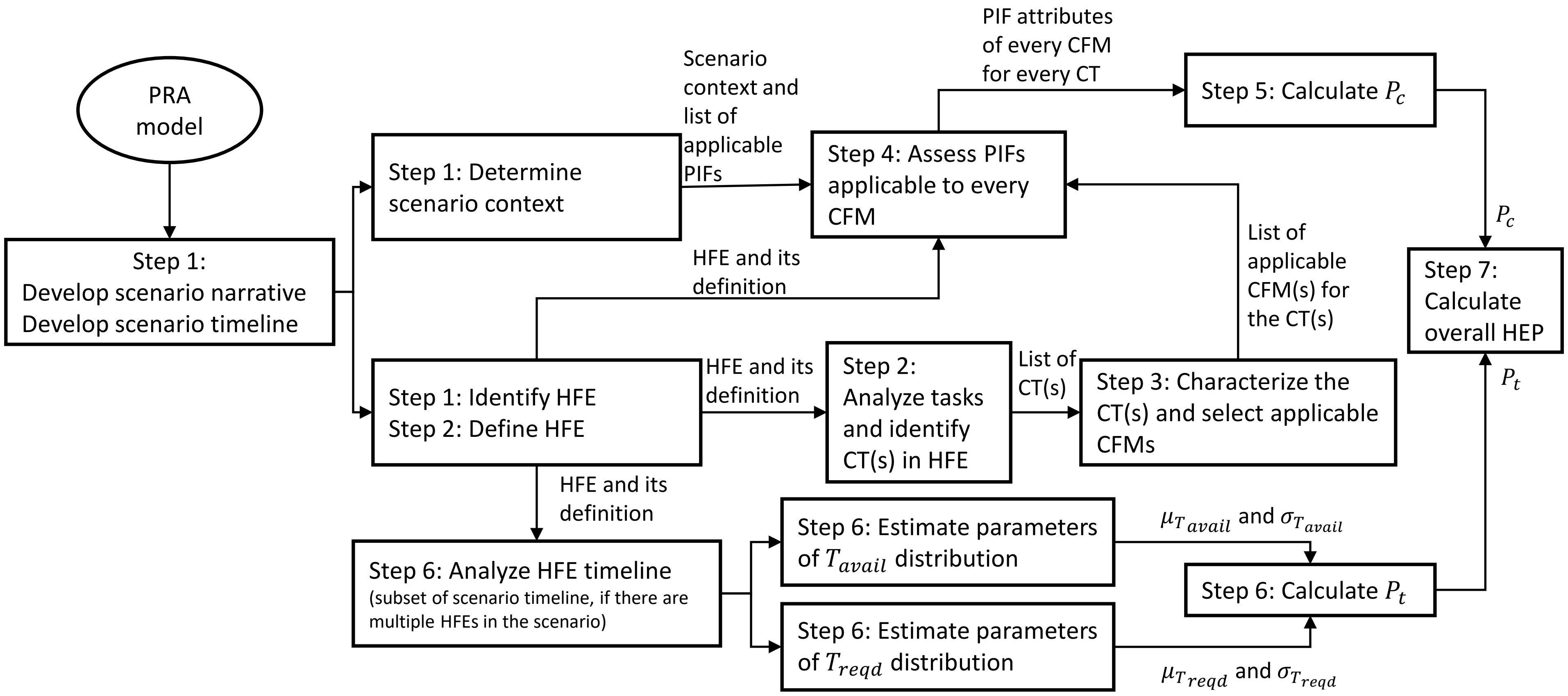
IDHEAS-ECA

- A human reliability analysis (HRA) method for event and condition assessment (ECA) in NRC’s risk-informed regulation.
  - A HRA process to
    - Identify human failure events, critical tasks, and corresponding contexts
    - Calculate human error probabilities (HEPs)
  - A software tool to implement HEP calculations and documentation
- A method aimed for all HRA applications
  - Developed based on IDHEAS-G
  - Data were documented in IDHEAS-DATA
  - Workshops conducted to evaluate the use for FLEX actions

HEP Quantification Elements

Element	Factors
Pt	Time sufficiency (Normal pace and performed as planned)
Pc	Cognitive errors in performing critical tasks
	5 Cognitive Failure Modes (CFMs): Detection, Understanding, Decisionmaking, Action Execution, and Interteam Coordination
Error Recovery	Credit the resources not available for normal team responses (e.g., extended time available)
Dependency	A task failure affects the reliability of the subsequent tasks

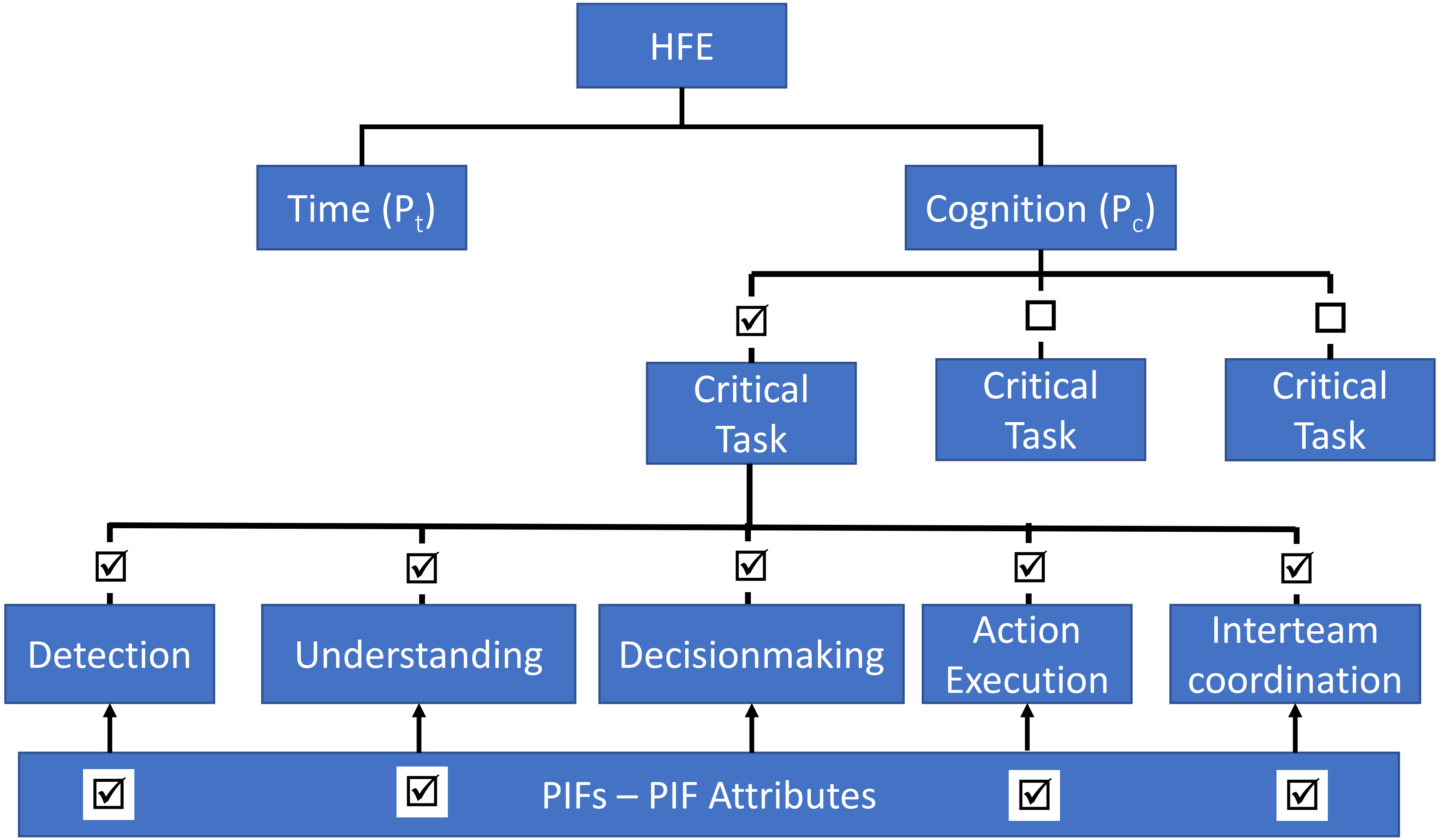
IDHEAS-ECA's HRA Process



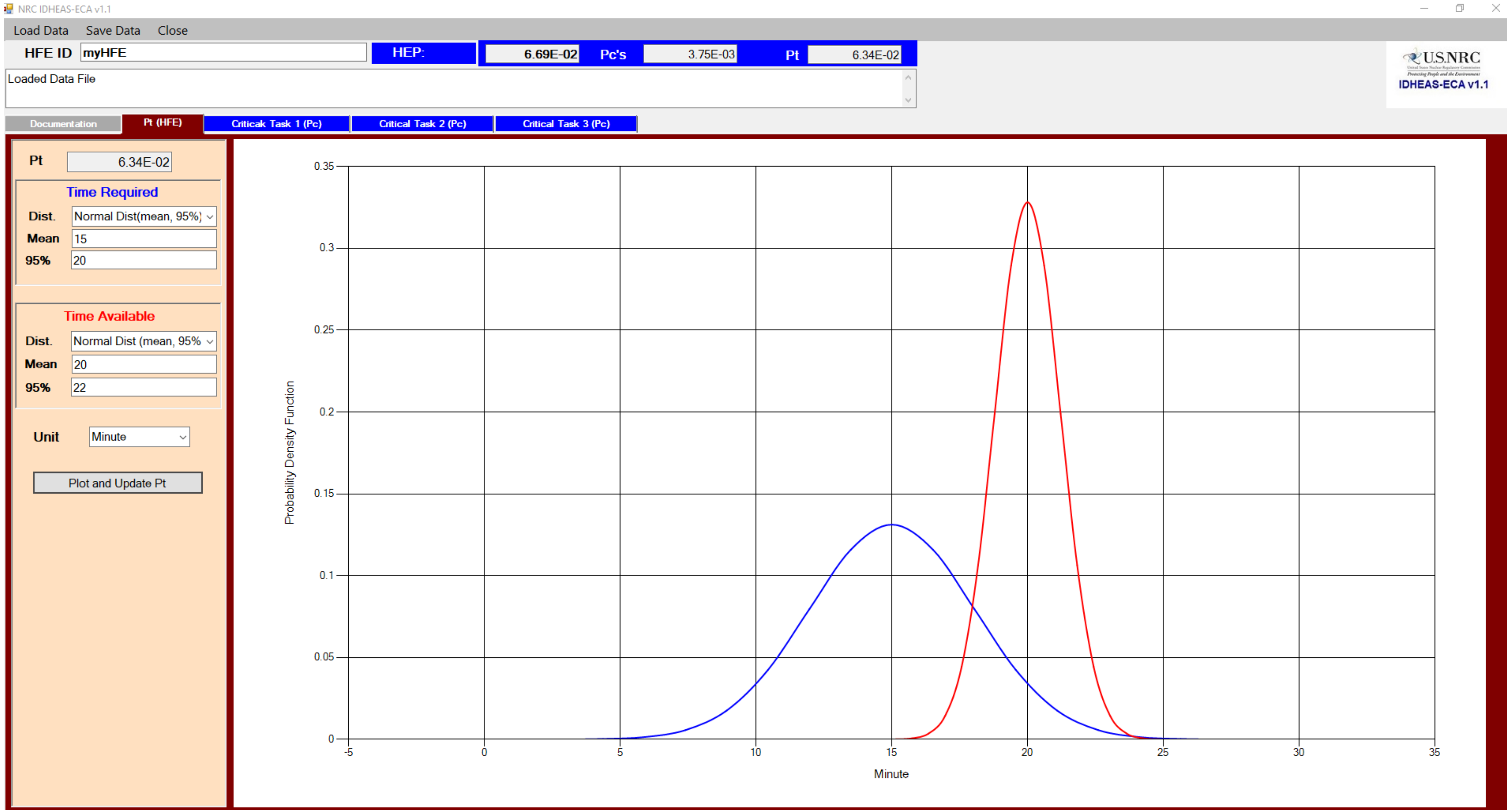
CFM = cognitive failure mode
CT = critical task
HEP = human error probability
HFE = human failure event
PIF = performance-influencing factor
PRA = probabilistic risk assessment

P_c = error probability due to CFMs
P_t = error probability due to uncertainty in T_{avail} and T_{reqd}
T_{avail} = time available
T_{reqd} = time required
$\mu_{T\,avail}$ and $\sigma_{T_{avail}}$ = mean and standard deviation of T_{avail}
$\mu_{T\,reqd}$ and $\sigma_{T_{reqd}}$ = mean and standard deviation of T_{reqd}

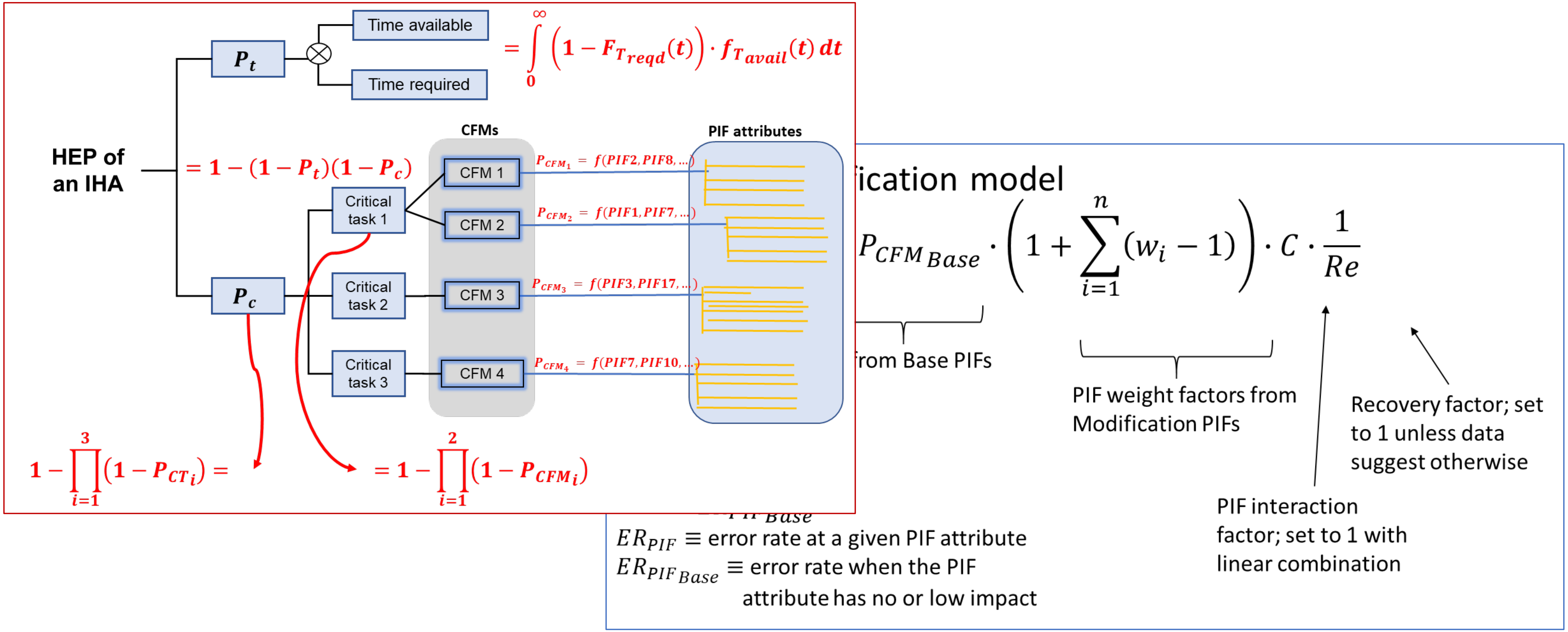
HFE's HEP Quantification Structure



Calculate Pt

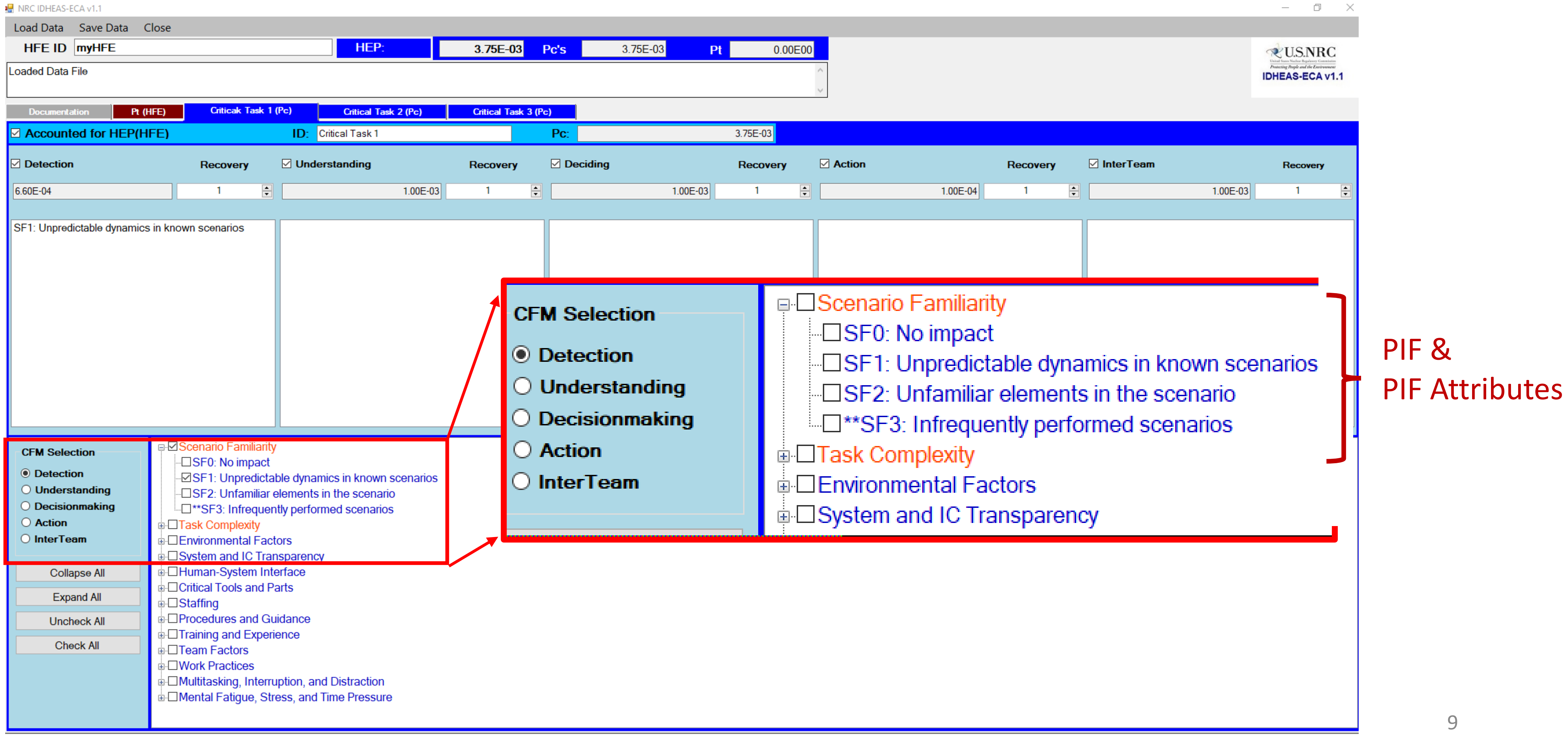


Calculate Pc



Critical Task, CFMs, PIF, and PIF Attributes

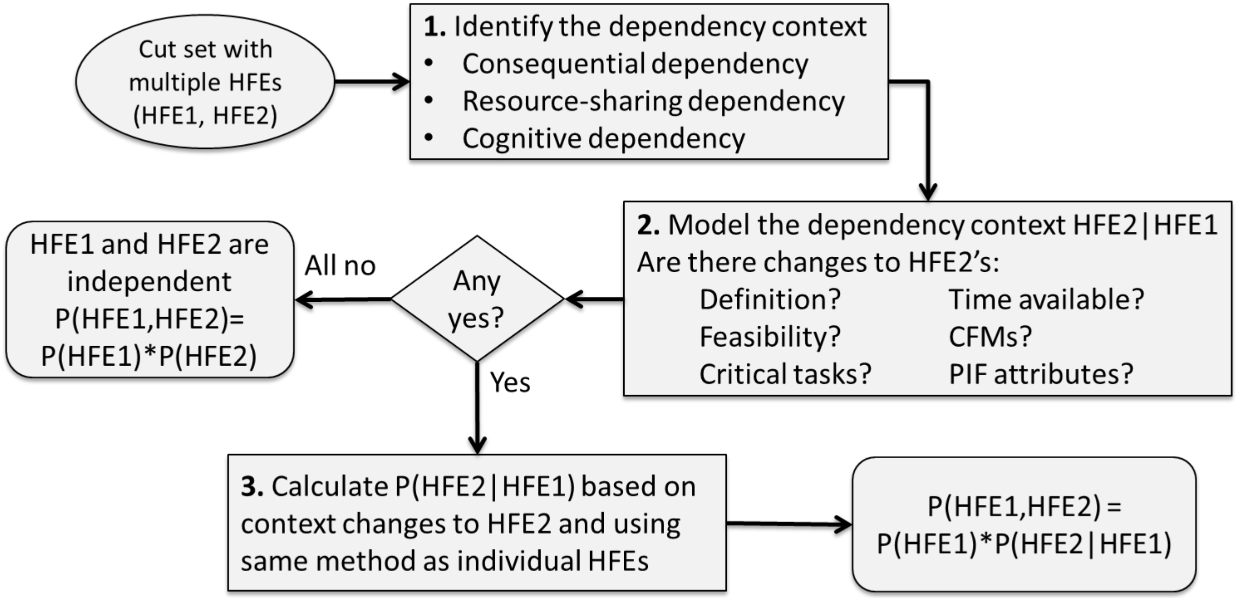
(As Implemented in IDHEAS-ECA Tool)



IDHEAS-ECA Tool Demo

Error Recovery & Dependency

- Error recovery: Only credit resources that are normally not available, e.g., extended time available, with combination of credible recovery opportunities
- Dependency: IDHEAS-G's dependency assessment process

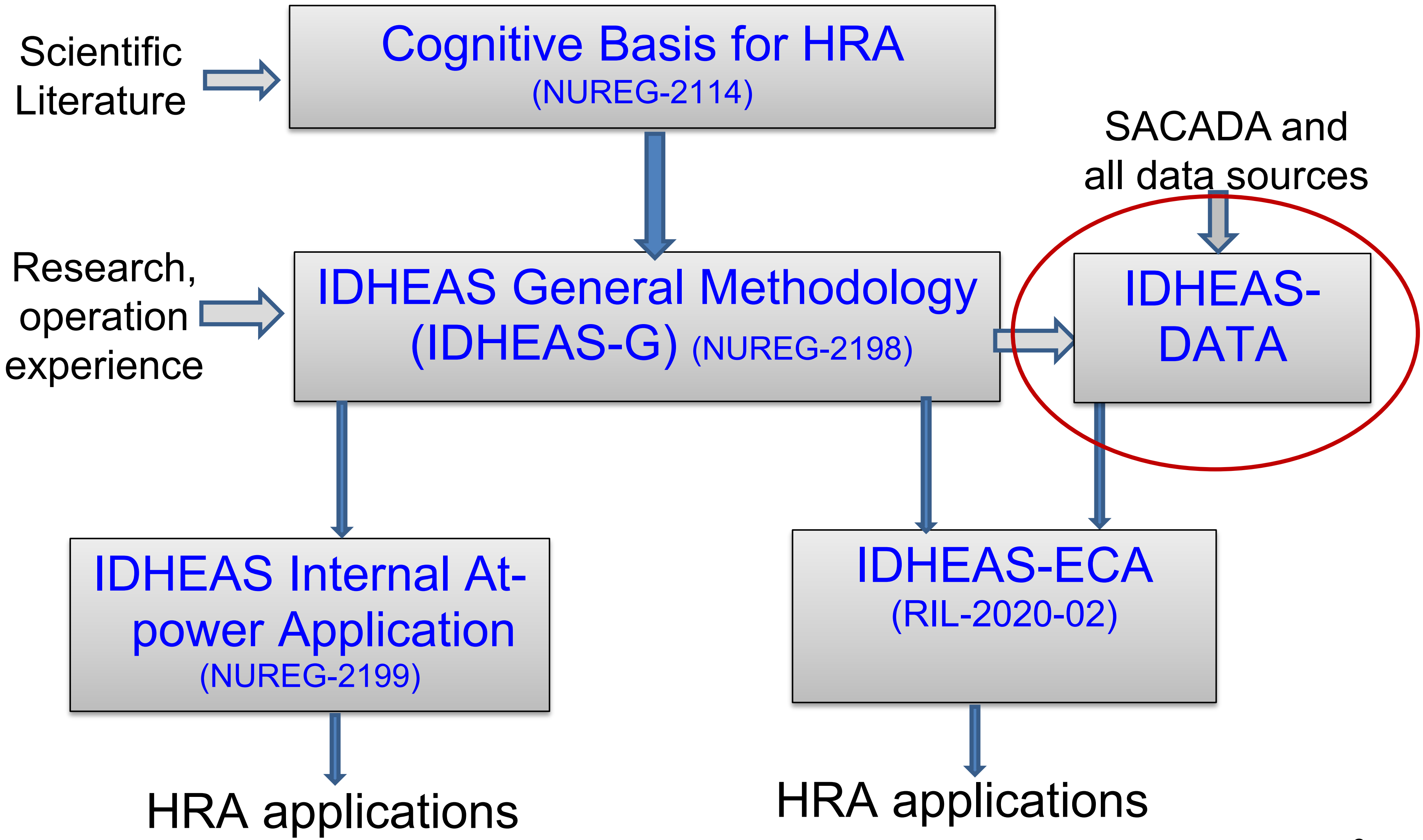


IDHEAS-DATA - Human Error Data generalized in IDHEAS-G framework

Jing Xing, Y. James Chang, Jonathan DeJesus Segarra,
U.S. Nuclear Regulatory Commission

Presented by Jing Xing to ACRS subcommittee
2020-9-23

Development of IDHEAS
- An Integrated Human Event Analysis System



Outline

I. Approach of using human error data for HRA

II. Data source evaluation

III. Data generalization (IDTABLEs)

IV. The story of PIF combination

I. Approach of using human error data for HRA

- Evaluation of human error data sources

  Human error data exist from various domains, in different formats, varying context and levels of details.

- Data generalization

  The General Methodology of Integrated Human Event Analysis System (IDHEAS-G) has an inherent structure for generalizing human error data:

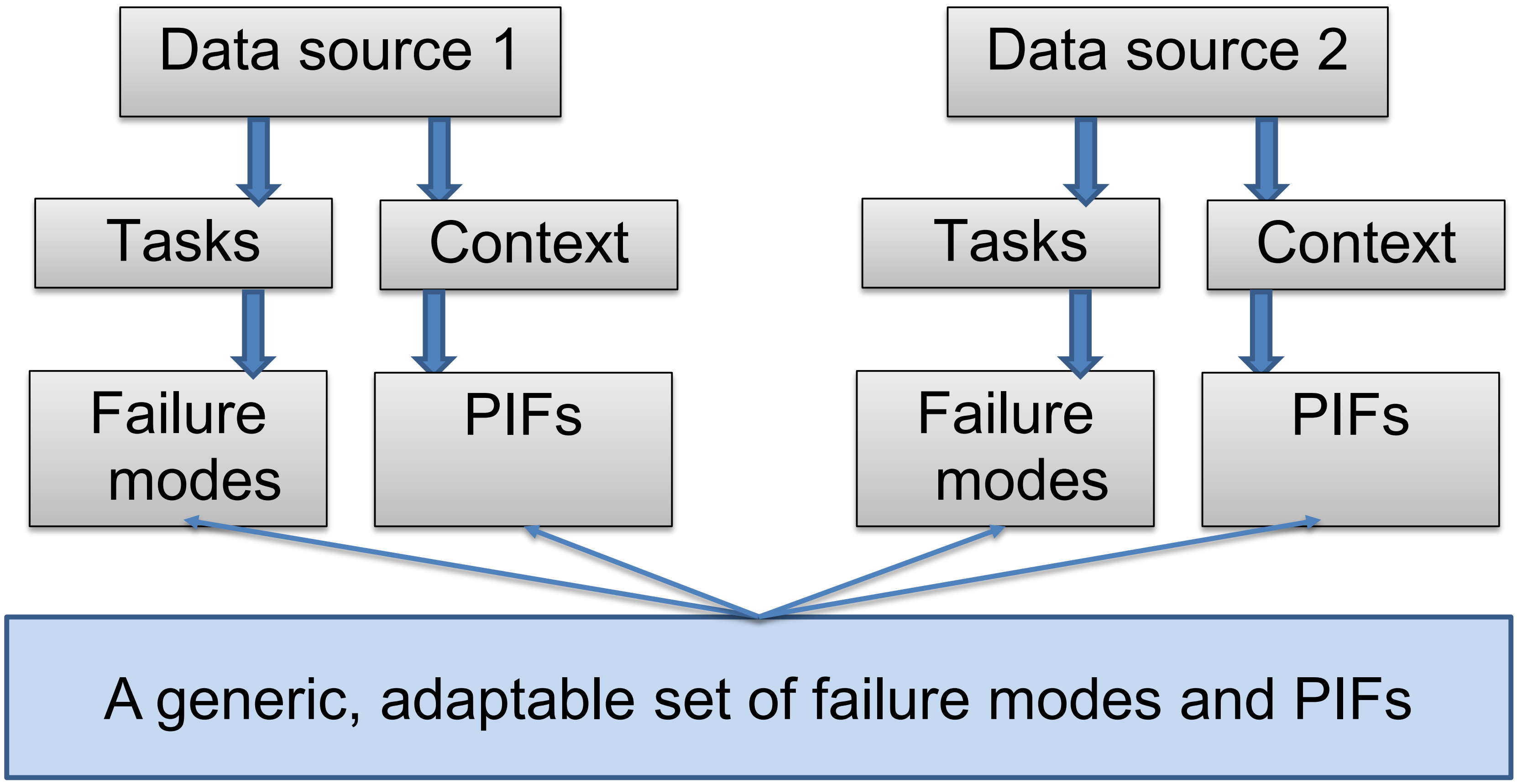
  - Five macrocognitive functions represent failure of human actions.
  - 20 PIFs represent the context that affects human performance of an action.

- Data integration for human error probability (HEP) estimation

  Generalized human error data can be integrated to inform HEP estimation for specific HRA methods and applications.

Generalizing human error data to inform HEPs

HEP = *f*(states of performance influencing factors)



Use human error data to inform HEPs

1. Evaluation - Assess data source

- Context and task
- Variables and Measurements
- Uncertainties

2. Generalization - Represent source data with the CFMs and PIFs in IDHEAS-DATA

Human tasks **->** Cognitive failure modes (CFMs)

Context **->** Performance influencing factors (PIFs)

3. Integration - Integrate the data in IDHEAS-DATA for HEP calculation

Error rates – *Base HEPs*

Change of error rates - *PIF weights (Wi)*

Others (e.g., PIF Interaction, time distribution, dependency)

II. Data sources

A. Nuclear simulator data and operational data
(e.g., SACADA, HuREX, German NPP maintenance database analysis)

B. Operation performance data from other domains
(e.g., transportation, off-shore oil, military operations, manufacture)

C. Experimental studies in the literature
(e.g., cognitive and behavior science, human factors, neuroscience)

D. Expert judgment of human reliability in the nuclear domain

E. Unspecific context
(e.g., statistical data, ranking, frequencies of errors or causal analysis)

Data source evaluation

- Participants – Normal adults, trained for the tasks, good sample size
- Measurements – Human error rate preferred, task performance measures related to human error rates
- Specificity – CFMs and PIFs identifiable
- Uncertainties – Controlled, known, or traceable
- Breath of representation – Repetitive and representative

Outline

I. Approach of using human error data for HRA

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IV. The story of PIF combination

IDHEAS-DATA Structure

- IDHEAS-DATA has 27 tables (**IDTABLEs**) documenting generalized human error data and empirical evidence
- Human error data are generalized to IDHEAS-G CFMs and PIF attributes

IDHEAS-DATA IDTABLE	
IDTABLE 1-3 Base HEPs	IDTABLE-21 Lowest HEPs of CFMs
IDTABLE-1 Scenario Familiarity IDTABLE-2 Information IDTABLE-3 Task Complexity	IDTABLE-22 PIF Interaction
	IDTABLE-23 Distribution of Task Needed
	IDTABLE-24 Modification to Time Needed
IDTABLE 4--20 PIF Weights IDTABLE 4-8 Environment PIFs	IDTABLE-25 Dependency of Human Actions
IDTABLE 9-11 System PIFs	IDTABLE-26 Recovery of Human Actions
IDTABLE 11-16 Personnel PIFs IDTABLE 17-20 Task PIFs	IDTABLE-27 Main drivers to human events

Data generalization process

Generalizing a data source is the same as performing an HRA using IDHEAS-G

- Analyze the data source to understand the context and determine the human error data for generalization
- Analyze the tasks and identify the applicable CFMs
- Map the context to relevant PIF attributes
- Identify other PIF attributes present in the study
- Analyze uncertainties
- Document the reported human error data in IDTABLE

Example 1: a datapoint for base HEP

- The NRC's SACADA database collects NPP operators' task performance data in simulator training for requalification examination. The rates of unsatisfactory performance ("UNSAT") for training objective tasks were calculated from the SACADA data available before April 2019.
- The UNSAT rates are generalized in IDTABLE-1, -2, and -3 for the three base PIFs.
- For example, SACADA characterizes Scenario Familiarity as three options: Standard, Novel, and Anomaly. The generalized datapoints are shown in the following:

PIF	CFM	Error rates	Task (and error measure)	PIF measure	Other PIFs (and Uncertainty)	REF
SF3.1	U	1.2E-1 (8/69)	NPP operators diagnose in simulator training	Anomaly scenario	(Other PIFs may exist)	[26]
SF3.1	DM	1.1E-2 (1/92)	NPP operators decisionmaking in simulator training	Anomaly scenario	(Other PIFs may exist)	[26]

Example 2: a datapoint for PIF weight

- Braunstein and White measured human errors in reading dials as the luminance on the dials was varied from 0.015 to 150 L/m^2.
- The error rate decreased with luminance. When the luminance was greater than 15 L/m^2, the error rate was low and remained the same.
- Many other studies reported similar relation between luminance and error rates.
- The following is the datapoint generalized in IDHEAS-DATA IDTABLE-5 for Visibility:

PIF	CFM	Error rates		Task (and error measure)	PIF measure	Other PIFs (and Uncertainty)	REF
VIS1	D	Luminance	Reading error	Military operators dial reading (incorrect reading)	Luminance (L/m^2)	No peer-checking, maybe HSI	VIS-9
		0.15	0.16				
		1.5	0.1				
		>15	0.08				

Overview of IDHEAS-DATA in 2020

- Data sources

  - Limited use of nuclear operation/simulation data (SACADA, HuREX, Halden studies)

  - ~300+ literature generalized; another 200+ evaluated and selected for generalization

  - 300~400 literature on task completion time to be generalized in 2021

Overview of IDHEAS-DATA in 2020

- IDTABLEs

- The data in IDTABLE-1 through -21 (base HEPs, PIF weights, and lowest HEPs) were integrated for IDHEAS-ECA.
- IDTABLE-23 and -24 (Task Completion Time) are on the way.
- IDTABLE-25 (dependency), -26 (recovery) and -27 (main drivers) are in piloting.

- Areas lacking human error data

- CFMs: Interteam Coordination
- PIFs: Work Process, Team and Organizational Factors

Outline

I. Approach of using human error data for HRA

II. Data source evaluation

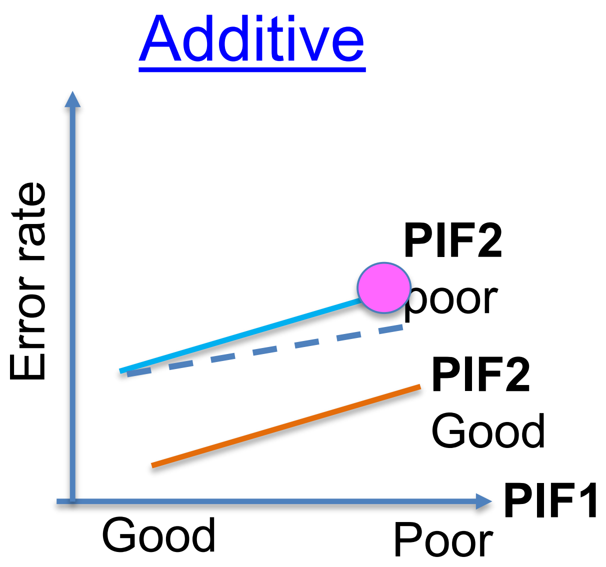
III. Human error data generalization (IDTABLEs)

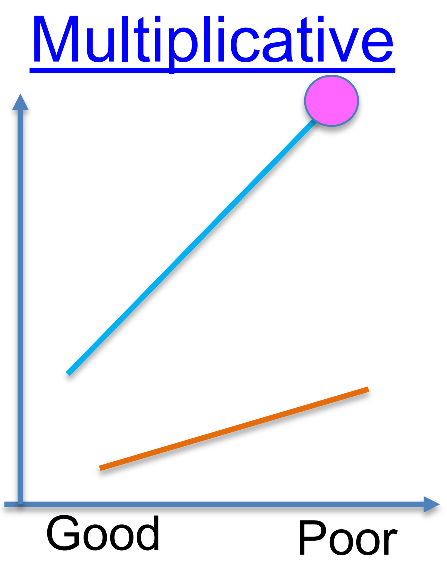
IV. The story of PIF combination

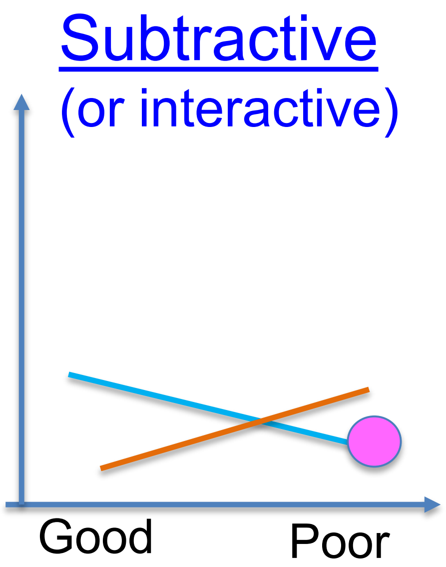
A story of PIF combination

- An operator's HEP is **0.01** in nominal conditions, **0.05** in loud burst noise environment, and **0.1** under poor visibility. What is his HEP when working under loud noise and poor visibility?
- Answer 1: <u>Additive</u> 0.05 + 0.10 = 0.15
- Answer 2: <u>Multiplicative</u> 0.01 x 5 x 10 = 0.5

What's in data

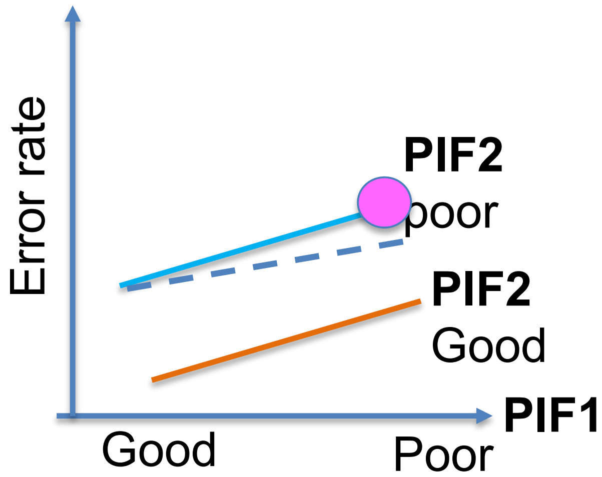






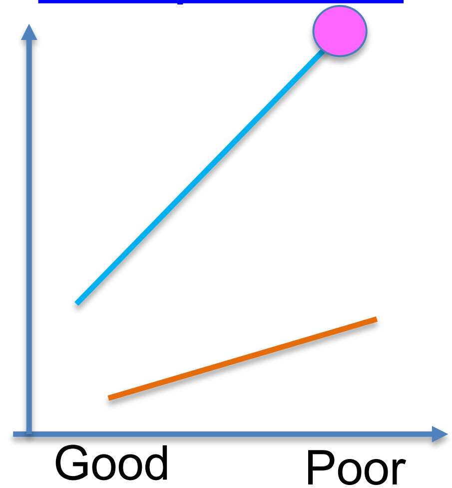
What's in data

Additive



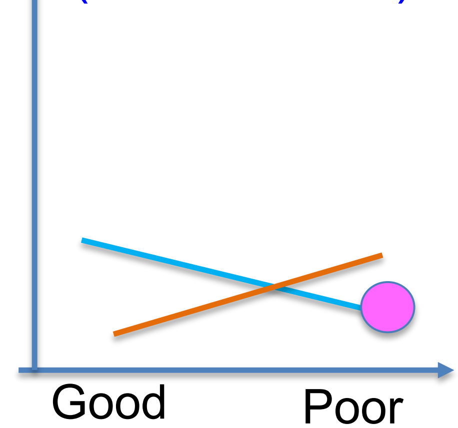
Most

Multiplicative



Some

Subtractive
(or interactive)



Rare

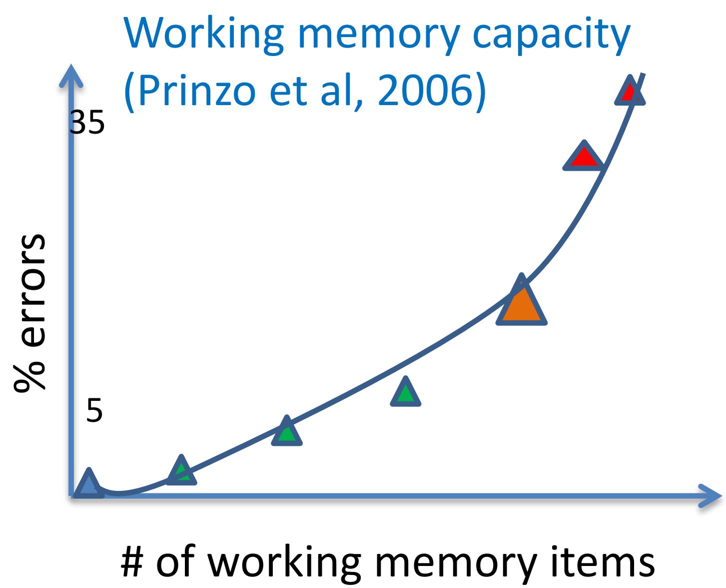
IDHEAS-DATA observation from 100+ studies evaluated with human error data under individual and PIF combination:

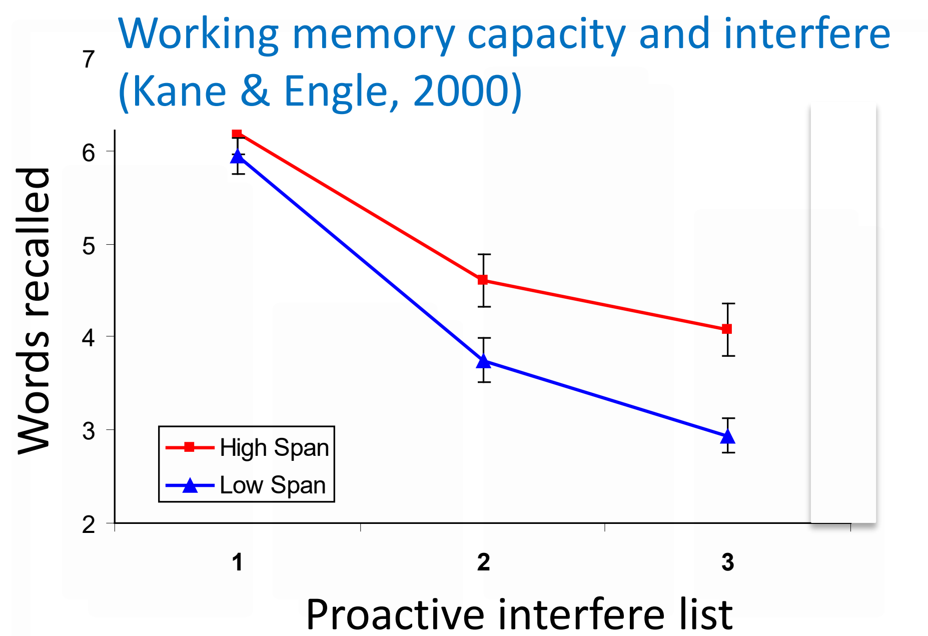
- Most datapoints are roughly additive
- Some datapoints show multiplicative

Why and when PIF combination is more than Additive?

– If both PIFs demand the same cognitive resource, and the demand of a single PIF already approaches to the capacity limit, then

- the combined effect can be more than the Additive effects;
- This reflects the catastrophic effect of exceeding the capacity limit.





Meta-analysis on PIF combination

PIFs	# of studies	Findings	Ref.
Noise, temperature, sleep loss	51 reports	Combined effect is **no more than the added** single effects and can be predicted from single effects.	Grether 1970
Noise and heat	20~30 reports	The majority of evidence indicates that noise and heat **do not interact significantly** within the ranges experienced commonly in the industrial setting.	Hancock 2010
Distraction, experience, HSI, others	23 data-points	**Additive** fits better than Multiplicative; Additive over estimates for large PIF weights	Xing 2015
Cognitive ability and motivation on performance	51 reports	**Additive** accounted for ~ 91% of job performance data; Multiplicative accounted for only about 9% of the explained variance.	Iddekinge 2017

Perspective of IDTABLE-21: PIF Interaction

- Solid evidence that most PIF combinations are additive.
- IDTABLE-21 should focus on PIF interaction:
  - Interaction between a base PIF and modification PIFs
  - More-than-additive interaction
  - “Red flag” PIF combinations

Summary of IDHEAS-DATA

- Human error data of various sources are generalized into IDHEAS-DATA with IDHEAS cognitive failure modes (CFMs) and PIF attributes

- Data generalization is generic with IDHEAS CFMs and PIF attributes; Data integration is specific to the HRA method or application that uses the data.

- Data generalization is an on-going, continuous effort; Data integration should be periodically updated.

Backup slides

Integration of human error data for IDHEAS-ECA

IDHEAS-ECA uses the HEP Quantification Model

$$P_{CFM} = \underbrace{P_{CFM_{Base}}}_{\text{HEP from Base PIFs}} \cdot \left(1 + \underbrace{\sum_{i=1}^{n}(w_i - 1)}_{\text{PIF weight factors from Modification PIFs}}\right) \cdot C \cdot \frac{1}{Re}$$

Recovery factor; set to 1 unless data suggest otherwise

PIF interaction factor; set to 1 with linear combination

IDHEAS-ECA needs:

- Lowest HEPs for the 5 CFMs
- Base HEPs of every CFM at every associated attribute of the 3 base PIFs
- PIF weights of every CFM at every associated attribute of the 17 modification PIFs

Data integration process

The process of integrating human error data is described as follows:

1) Use single-component data to make initial estimation of the base HEPs and PIF weights;
2) Use the initial estimation to **detach** multi-component data into single-component ones;
3) Integrate all the single-component and detached multi-component datapoints to estimate the range and mean of a base HEP or PIF weight;
4) Use the unspecific datapoints to calibrate the estimated HEPs and PIF weights;
5) Iterate the process 2), 3), and 4) until the obtained values represent the breath of the available data.

Approaches used in integration process

The confidentiality in integrating a set of data to generate a single representative value or probabilistic distribution depends on the sample size and quality of the data set.

The following approaches were used in the integration for IDHEAS-ECA:
(See notes)

1) Aggregation of multiple datapoints for a base HEP or PIF weight
2) No single-component data exclusive for a base HEP or PIF weight, but there were multi-component datapoints on the combined effects of several CFMs and/or PIF attributes
3) No datapoint for a PIF weight
4) Consistency checking and adjustment with benchmark values

Example - IDHEAS-DATA IDTABLE-21 Lowest HEPs for Failure of Detection

	Error rate	Task	Criteria for lowest HEPs: TA - Time adequacy SelfV - Self verification TeamV – Team verification Rec - Recovery O - other factors (Y-Yes, N – No, M-Mixed Un-Unknown)	Uncertainty	REF
1	2.1E-3 (4/1872)	NPP operators alarm detection in simulator training. Alarms are self-revealing	TA-Yes, SelfV-Y, TeamV-Y, R-Unknown O – Y (unspecified)	(Other PIFs may exist)	[26]
2	3.4E-3 (3/870)	NPP operators check indicators in simulator training, procedure directed checking.	TA-Yes, SelfV-Yes, TeamV-yes, Rec – Unknown O - Y (unspecified)	(Other PIFs may exist)	[26]
3	5E-4	Military operators read meters, Alphanumeric reading, Detection straight-forward	TA-Y, SelfV-Y, TeamV-No, Rec-No	(Maybe time constraint, 10K+ source data trials)	[109]
4	E-4	Estimated lowest probity of human failure events	TA-Yes, SelfV-Yes, TeamV-yes, Rec - Unknown	(Engineering judgment)	[110]
5	E-4	Simplest possible tasks	TA-Yes, SelfV-Yes, TeamV-Unknown, Rec - Unknown	(Engineering judgment)	[111]
6	E-3	Routine simple tasks	TA-Yes, SelfV-Yes, TeamV-Unknown, Rec – Unknown O – Maybe weak complexity	(Engineering judgment)	[111]
7	5E-3	Line-oriented text editor. Error rate per word	TA-Yes, SelfV-Yes, TeamV-No, Rec - No	No apparent uncertainty	[112]
8	5E-3	Reading a gauge incorrectly. Per read	TA-Yes, SelfV-Yes, TeamV-No, Rec – Unknown O – HSI	No apparent uncertainty	[113]
9	E-3	Interpreting indicator on an indicator lamp. Per interpretation	TA-Yes, SelfV-Yes, TeamV-Unknown, Rec – Unknown O- complexity in interpreting indicator	(Engineering judgment)	[109]
10	9E-4	NPP operator simulator runs	TA – Y, Selv-V – Y TeamV – Y, R – Unknown O – Mixed complexity	No apparent uncertainty	[114, 115]
11	5.3E-4	Gather information and evaluate parameters	TA – Y, Selv-V – Y TeamV – Y, R – Yes	No apparent uncertainty	[116]
12	9E-3	Collision avoidance and target monitoring in	TA – Y, Selv-V – Yes	Dual task	[27]

Detaching multi-component human error data

The critical step in the process is detaching multi-component datapoints. The following rules are derived from initial estimates of base HEPs of task complexity and PIF attribute weights. They are used for detaching:

1) If SelfV=NO or TeamV=NO, the detached error rate is the original error rate divided by a factor of 5; If both are NO, the detached error rate is the original error rate divided by a factor of 10.
2) If Recovery = YES, the detached error rate is the original error rate multiplied by a factor range of 2 to 10.
3) If there are other PIFs, the detached error rate is the original error rate divided by multiplication of a factor range of (5 to 10 for complexity) and the sum of the weights of other PIF attributes. The weights of the PIF attributes are from the initiation estimation of the single-component data in IDHEAS-DATA.

Table 3-8: Detached human error rates for the lowest HEP of Failure of Detection

CFM	Error rate	Criteria for lowest HEPs	Detached error rate	Notes
1	2.1E-3 (4/1872)	TA-Yes, SelfV-Y, TeamV-Y, R-Unknown O – Y (unspecified)	2.1E-3 / (5 to 10) = 2.1E-4 to 4E-4	A factor of 5 to 10 represents the combined effect of possible other PIFs
2	3.4E-3 (3/870)	TA-Yes, SelfV-Yes, TeamV-yes, Rec – Unknown O - Y (unspecified)	3.4E-3 / (5 to 10) = 3.4E-4 to 7E-4	A factor of 5 to 10 represents the combined effect of possible other PIFs
3	5E-4	TA-Y, SelfV-Y, TeamV-No, Rec-No	5E-4 / 5 = 1E-4	Divided by 5 for no team verification
4	E-4	TA-Yes, SelfV-Yes, TeamV-yes, Rec - Unknown	E-4	No change
5	E-4	TA-Yes, SelfV-Yes, TeamV-Unknown, Rec - Unknown	E-4	No change
6	E-3	TA-Yes, SelfV-Yes, TeamV-Unknown, Rec – Unknown O – Maybe weak complexity	E-3 / 5 = 2E-4	Divided by 5 for weak complexity
7	5E-3	TA-Yes, SelfV-Yes, TeamV-No, Rec - No	5E-3 / 10 = 2E-4	Divided by (5+5) for lack of self and team verification
8	5E-3	TA-Yes, SelfV-Yes, TeamV-No, Rec – Unknown O – Maybe HSI	5E-3 / (5+2) = 7E-4	Divided by (5+2) for lack of self verification and possible HSI attributes
9	E-3	TA-Yes, SelfV-Yes, TeamV-Unknown, Rec – Unknown	E-3 / 5 = 2E-4	Divided by 5 for no team verification.
10	9E-4	TA – Y, Selv-V – Y TeamV – Y, R – Unknown O – Mixed complexity	9E-4 / (5 t o10) = 9E-5 to 4.8E-4	Divided by (5 to 10) for mixed complexity
11	5.3E-4	TA – Y, Selv-V – Y TeamV – Y, R – Yes O – Mixed complexity	5.3E-4 x 2 / (5-10) = 1.06E-4 to 2.12E-4	Multiplied by 2 for existence of recovery
12	9E-3	TA – Y, Selv-V – Yes TeamV – No, R – Yes O – Dual task, and maybe mixed complexity	9E-3 / (5 to 10) x (5-10) = 9E-5 to 3.6E-4	Divided by (5 to 10) for mixed complexity and divided by (5 to 10) for dual task.

Table 3-9. Single-component and detached multi-component human error rates for the lowest HEP of Failure of Detection

	Single-component	Multi- component detachable	Bounding
A - Nuclear operation		2.1E-4 to 4E-4, 3.4E-4 to 7E-4, 9E-5 to 4.8E-4	
B - Other operation	1.06E-4 to 2.12E-4	1E-4, 2E-4 7E-4	
C – Controlled experiment		E-4, 2E-4 9E-5 to 3.6E-4	
D – Expert judgment	E-4	2E-4	
E - Unspecific			

Table 3-9. Single-component and detached multi-component human error rates for the lowest HEP of Failure of Detection

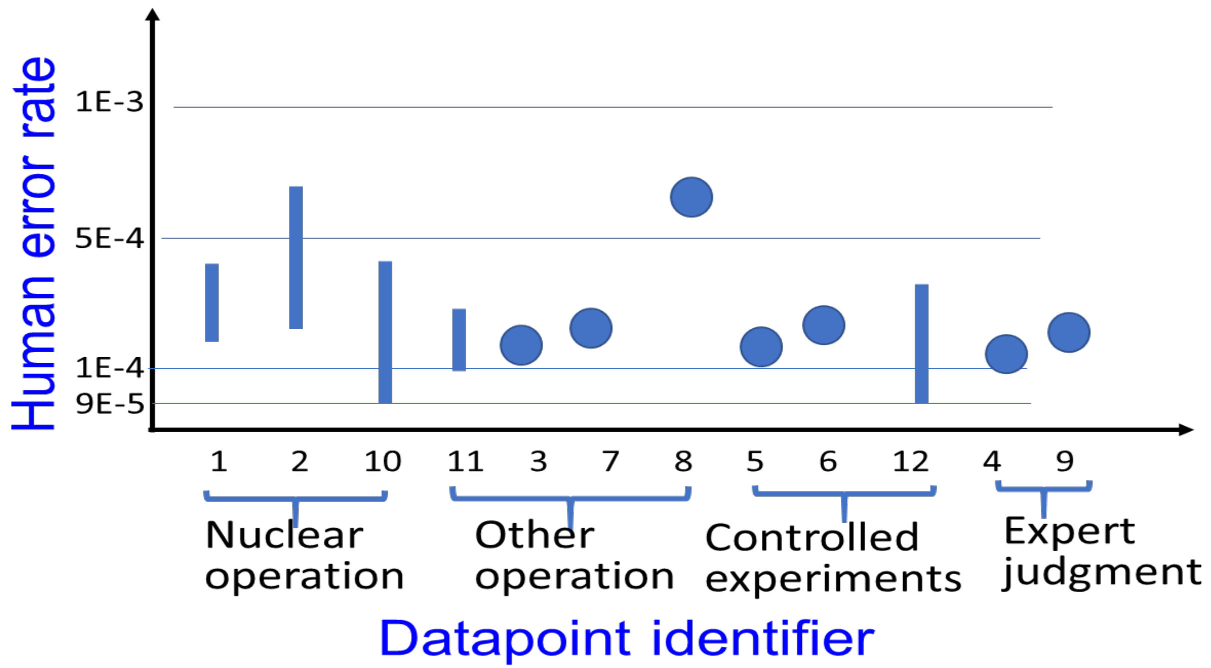


Figure 3-1. The human error rates for the lowest HEP of Failure of Detection

Category A datapoints: [1.8, 3.6, 5.3]E-4 for lower bound, mean, and upper bound;

Category B datapoints: [1.06, 2.8, 2.1]E-4

Category C datapoints: [0.9, 1.7, 3.6]E-4

Category A, B, C datapoints: [1.4, 1.8, 4.4]E-4

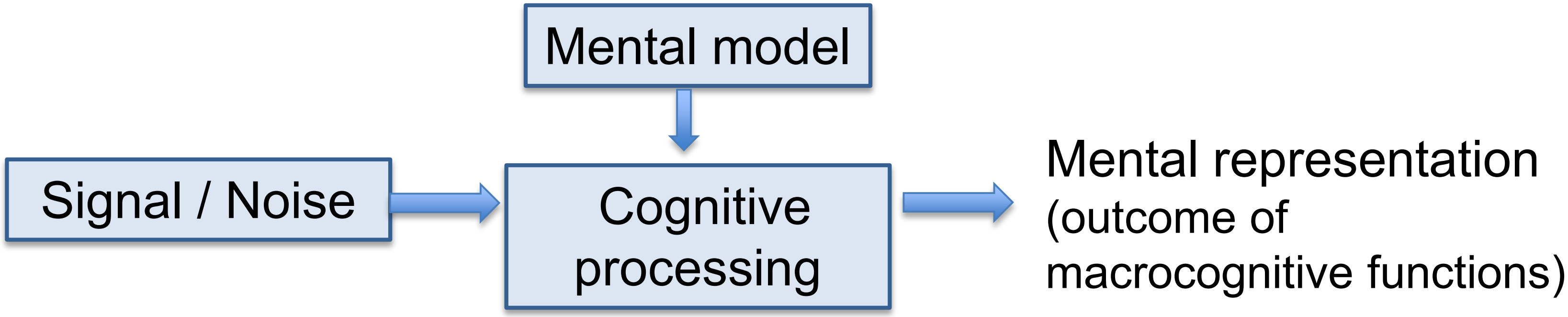
Based on the data, the value **1E-4** is taken as the lowest HEP for Failure of Detection.

A story of two type of PIFs

(Backup slides)

A story of two type of PIFs

1. What ‘s in the cognitive basis

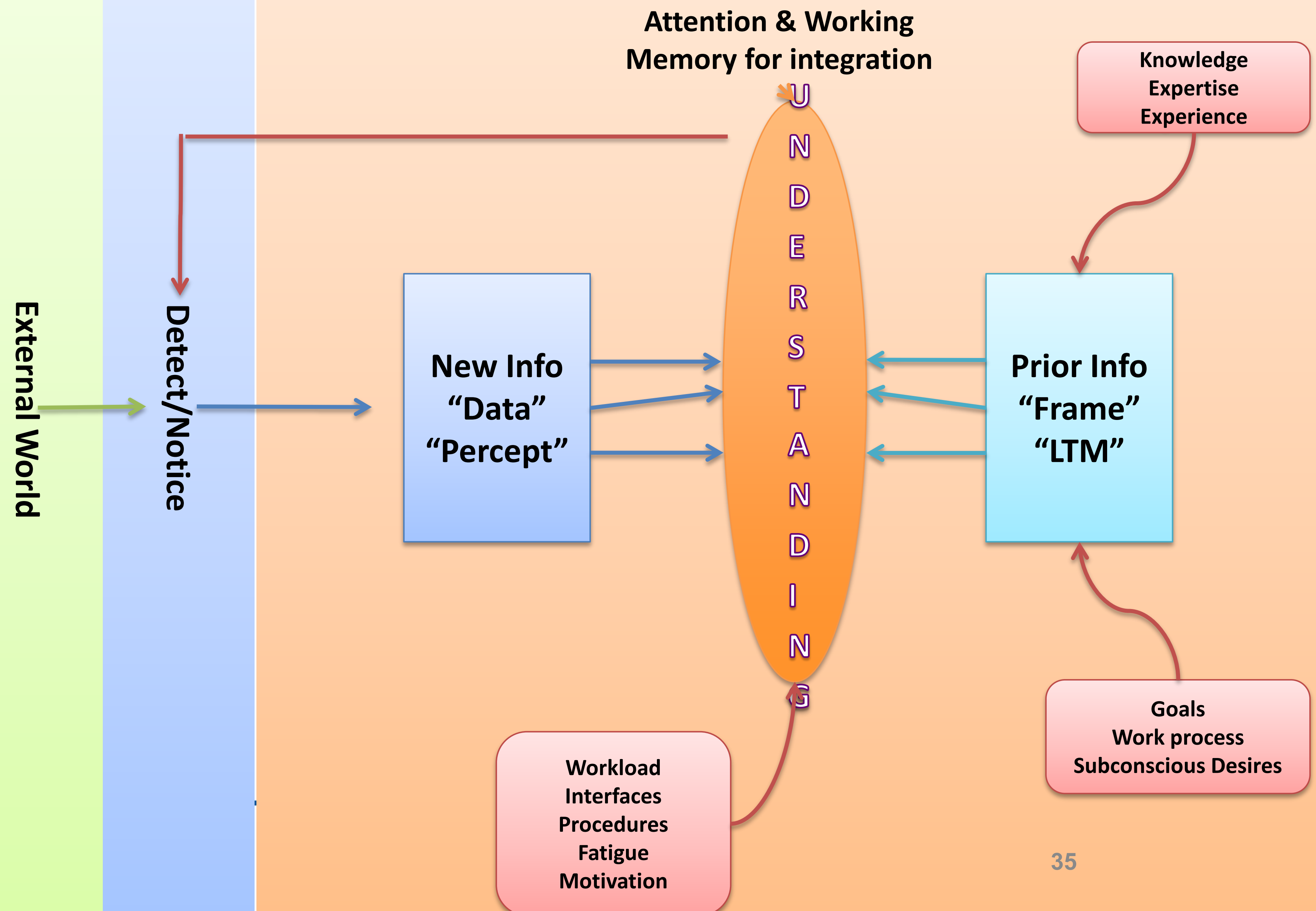


Base PIFs

- Signal-noise ratio - Information Availability and Reliability
- Mental model – Scenario Familiarity
- Demands for cognitive processing – Task Complexity

Modification PIFs – modify the base PIFs

How human achieves Understanding (NUREG-2114)

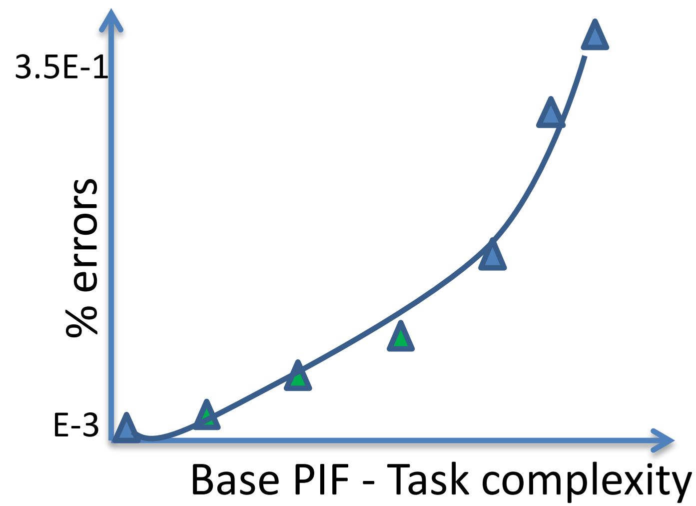


A story of two type of PIFs

2. What's in data about PIF effects on HEPs

Base PIFs

Information Availability and Reliability can vary HEP from nearly 0 to 1;
Scenario Familiarity can vary HEP from nearly 0 to 1;
Task Complexity can vary HEP from nearly 0 to 1;



Modification PIFs –
A single modification PIF attribute typically varies HEP in the range of 1.1 to 10 times, with a few exception high up to 30 times for feasible tasks.

2. What's in data about base PIF effects on HEPs
– example data from German NPP maintenance performance database

Memorized task step not remembered in carrying outa sequence of tasks

Relevant PSFs	m_i/n_i	q_{50}, $[q_5, q_{95}]$
Highly trained, no error promoting factors	1/15,200	$7.78 \cdot 10^{-5}$, $[1.1, 26] \cdot 10^{-5}$
Frequently performed, no error promoting factors	3/3067	$1.03 \cdot 10^{-3}$, $[0.3, 2.3] \cdot 10^{-3}$
Rarely performed, no error promoting factors	1/48	$2.45 \cdot 10^{-2}$, $[0.3, 7.9] \cdot 10^{-2}$
Rarely performed, moderately high level of stress	3/185	$1.71 \cdot 10^{-2}$, $[0.5, 3.8] \cdot 10^{-2}$
Rarely performed, moderately high level of stress, ergonomically deficient work environment	2/41	$5.62 \cdot 10^{-2}$, $[1.4, 13] \cdot 10^{-2}$
Rarely performed, moderately high level of stress, error prone PSFs and dynamic work environment	1/7	$1.61 \cdot 10^{-1}$, $[0.2, 4.4] \cdot 10^{-1}$
Extremely rarely performed, no error promoting factors	1/3	$3.52 \cdot 10^{-1}$, $[0.6, 7.7] \cdot 10^{-1}$

Scenario Familiarity (frequently to extreme rarely performed tasks) varied the error rate from 7.78E-5 to 3.52E-1

FLEX HRA
Expert Elicitation

Michelle Kichline
Senior Reliability and Risk Analyst
Office of Nuclear Reactor Regulation

Purpose

- The purpose of the expert elicitation was to use expert judgment to support the development of an HRA tool that can be used to quantify the human error probabilities (HEPs) associated with the use of FLEX equipment.
- The objectives of the expert elicitation were to:
  1. Quantify the HEPs associated with a few typical strategies for using FLEX equipment during both FLEX and non-FLEX accident scenarios.
  2. Develop a unique set of factors associated with FLEX strategies that influence performance.
  3. Quantify the contribution of those performance influencing factors (PIFs) on the HEPs.

Process

- Expert judgment was obtained following the guidance in the NRC's "White Paper: Practical Insights and Lessons Learned on Implementing Expert Elicitation," (ADAMS Accession No. ML16287A734).
- The expert elicitation was performed in Spring 2018 with an expert panel of three NRC staff members and three industry experts knowledgeable in PRA, HRA, and the implementation of FLEX strategies.
- The expert elicitation is documented in DRAFT Research Information Letter, Volume 1, "Utilization of Expert Judgement to Support Human Reliability Analysis of Flexible Coping Strategies (FLEX)," (ADAMS Accession No. ML20245E458).

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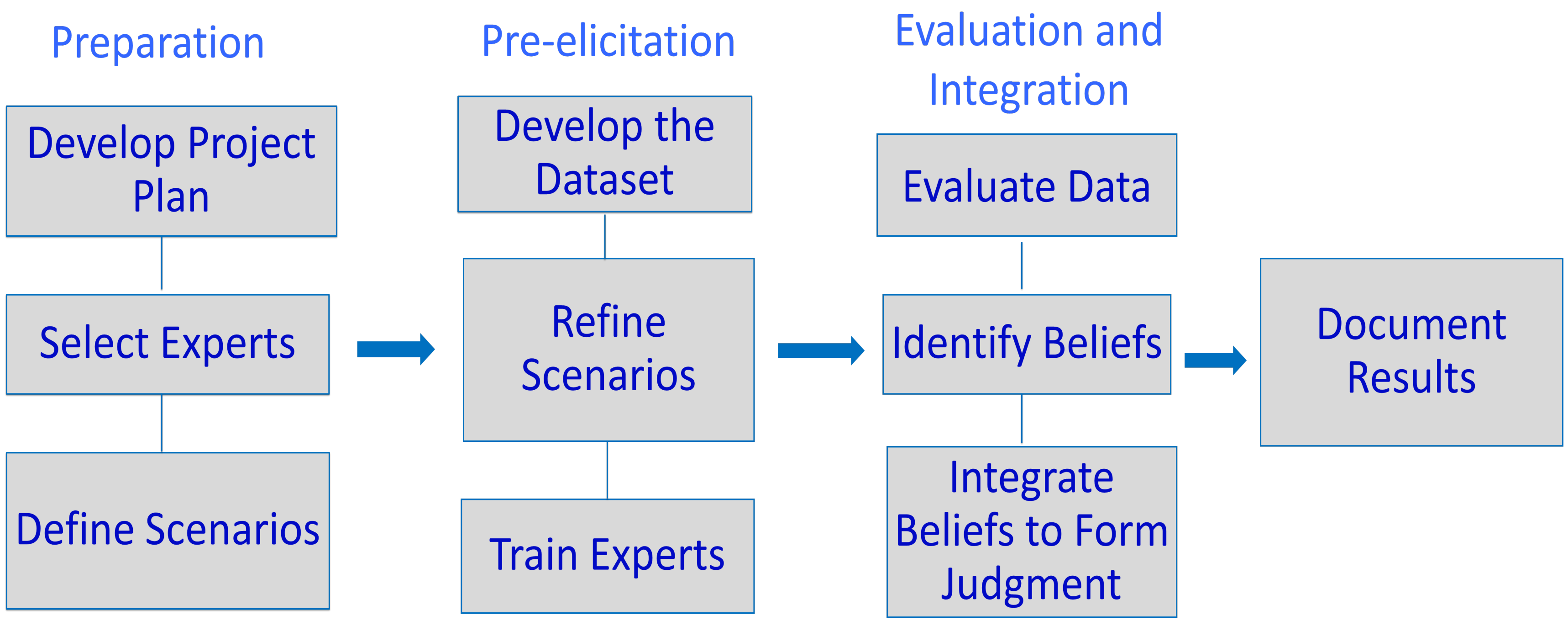
Process



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Basis for Expert Elicitation

The NRC project team compiled an information package for the experts to review, evaluate, and use as the basis of their judgment. The package had four parts:

1. Examples of human errors in actions performed external to the main control room at nuclear power plants.
2. HEPs or human error rates for human actions similar to portable equipment actions from other fields (off-shore oil drills, space-shuttle operation, railroad operation, etc).
3. PIFs that have been demonstrated as important to human actions similar to portable equipment actions.
4. Quantification of how individual PIFs change human error rates from literature.

HFEs Evaluated

HFE 1: Transportation, connection, and local control of portable generators

HFE 2: Transportation, connection, and local control of portable pumps

HFE 3: Refilling water storage tanks using alternate water sources

HFE 4: Extended loss of AC power (ELAP) declaration

HFE 5: Deep DC load shed

Scenarios Evaluated

- Scenario 1 (Non-FLEX-designed scenario) – Scenario 1 evolves in two parts. In the first part (Scenario 1.1), one diesel generator (DG) is out of service, a loss of offsite power (LOOP) occurs, and there is a good chance that the second DG may fail. The plant chooses to use (stage) the FLEX portable equipment without declaring an ELAP. In the second part (Scenario 1.2), the scenario progresses to the point that the plant loses the second DG and decides to declare an ELAP.
- Scenario 2 (FLEX-designed scenario) - An external hazard causes a LOOP, loss of both DGs, and, therefore, leads to a station blackout (SBO).

Expert Elicitation Results

NRC HFE	NRC Sub-Task	Scenario 1 (Non-FLEX) HEPs (1st, 50th, and 99th)			Scenario 2 (FLEX-designed) HEP (1st, 50th, and 99th)		
HFE 1: Use of Portable Generator	Decide	0.016	**0.052**	0.101			
	Transport	0.023	**0.057**	0.27	0.038	**0.14**	0.52
	Connect and Start	0.027	**0.088**	0.31	0.043	**0.16**	0.41
	Operate	0.024	**0.052**	0.22	0.036	**0.12**	0.44
HFE 2: Use of Portable Pump	Decide	0.034	**0.055**	0.1			
	Transport	0.016	**0.058**	0.23	0.023	**0.12**	0.47
	Connect and Start	0.019	**0.078**	0.27	0.036	**0.13**	0.45
	Operate	0.017	**0.05**	0.21	0.043	**0.14**	0.44
HFE 3: Refill CST	Decide	0.034	**0.057**	0.11			
	Refilling	0.01	**0.046**	0.28	0.072	**0.14**	0.36
HFE 4: ELAP Declaration	Decide	0.046	**0.31**	0.66	0.089	**0.19**	0.35
HFE 5: Load Shed	Open 18 breakers	0.011	**0.057**	0.22	0.025	**0.08**	0.31

HFE Comparison - Operators Fail to Declare ELAP 2018 Expert Elicitation

- 2 Scenarios – non-FLEX (1) and FLEX (2)
- For both scenarios, information about when AC power will be restored is uncertain.
- Procedural Direction: If AC power is not restored to the emergency 4kV busses within 60 min and is not expected back within 4 hours, then declare an ELAP within 60 min.
  - Similar to less definitive wording used for Cases 2 and 3 in 2019.

HFE Comparison - Operators Fail to Declare ELAP 2019 IDHEAS-ECA Workshop

- Scenario – BDB seismic event occurs at a BWR while at 100% power. One EDG is out of service for maintenance, the other EDG fails to start due to damage from the seismic event, resulting in an SBO. Similar to 2018 FLEX scenario.
- Procedural Direction –
  - Case 1 – ELAP is clearly defined. Procedure states that an ELAP exists when it is expected that <u>no</u> 4 kV bus will be re-powered within one hour. Diagnosis is obvious.
  - Case 2 – ELAP is less clearly defined. The procedure states that an ELAP must be declared within 1 hour if AC power cannot be restored within 4 hours. Diagnosis is obvious.
  - Case 3 – Wording from Case 2, but it is <u>not</u> obvious whether power can be restored within 4 hrs.

HFE Comparison - Operators Fail to Declare ELAP 2018 vs 2019

2018 Expert Elicitation

Scenario 1 (Non-FLEX) HEPs (1st, 50th, and 99th)			Scenario 2 (FLEX-designed) HEP (1st, 50th, and 99th)		
0.046	**0.31**	0.66	0.089	**0.19**	0.35

2019 IDHEAS-ECA Workshop

Variation	HEP Estimates
Case 1 – Definitive wording, obvious diagnosis	Low E-3
Case 2 – Less definitive wording, obvious diagnosis	Low E-3 to Low E-2
Case 3 – Less definitive wording, diagnosis is not obvious	Low E-2 to Low E-1

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Expert Elicitation Insights

- The implementation of FLEX strategies can fail because of the failure of any one of the key actions, including declaration of ELAP, deep load shedding, use of the portable generator, or use of the portable pump.
- Expert judgment estimated failure probabilities in the range of 30–60% when the key actions are combined.
- The decision to declare ELAP drives the HEP results in both scenarios.

Additional Insights

- Training, scenario familiarity, and procedures were the most significant PIFs affecting the failure probability estimates.
- Experts expect these factors to improve with standardized training and hands-on experience.
- Procedure improvements could improve use of FLEX strategies for defense-in-depth.
- Procedure improvements could reduce the reluctance associated with the decision to declare an ELAP.

Expert Elicitation Limitations

- The HEP estimates from the expert elicitation are only valid for the specific context under which they were evaluated.
- Both the FLEX and non-FLEX scenarios evaluated by the expert panel were intended to be challenging.
- The actions evaluated were based on the minimum required set of FLEX procedures, as written to implement the orders.
- The expert panel did not consider the impact of time or include recovery in the HEP estimates.

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Summary Remarks

- The NRC considers plant-specific FLEX information and data as needed to support the agency's regulatory response.
- Enhancements in HRA for FLEX, equipment performance data, and operating experience will better inform FLEX PRA results.
- Enhanced use and staging of FLEX equipment for defense-in-depth will increase familiarity with FLEX, which can result in improved FLEX HEPs.

Back-up Slides

Part I: Errors in actions performed external to the control room

We reviewed 300+ LERs involving personnel errors in external actions. Examples include:

- Inoperable Diesel Generator due to overcurrent logic wiring error
- Loss of Emergency Bus 23-1 due to a shorted cable while performing wiring verification
- Unplanned Diesel Generator ESF actuation when a potential transformer sensing circuit shorted due to personnel error
- Primary Containment System Isolation Valve unable to close fully on automatic signal due to wiring discrepancy
- RHR Reservoir inoperable due to blocked divisional cross-connect line results in condition prohibited by Technical Specifications
- Auxiliary Feedwater Pumps inoperable due to inadvertent blockage of a ventilation flow path assumed to be open in an accident analysis
- Failure to perform Valve Testing Leads To Unit Operation In A Condition Prohibited by Technical Specifications
- Inadvertent Group IV & V isolation when replacing PCIS coils

Part I: Errors in actions performed external to the control room

Examples:

"...(1) the upstream trip isolation valves would require the operator to stand on a piece of angle iron (because the area was too cramped to use a ladder) and (2) the isolation valves for the steam to the turbine driven auxiliary feedwater pump require climbing over hot steam piping. These valves could be operated, but that the hazardous conditions might cause the AO to become incapacitated."

"During containment spray system testing, operators closed a valve in the wrong train rendering both trains inoperable. Access is poor since both heat exchanger valves are operated with reach rods and only magic marker labels with no train identification were present."

Part II: Human error rates for similar actions in other fields

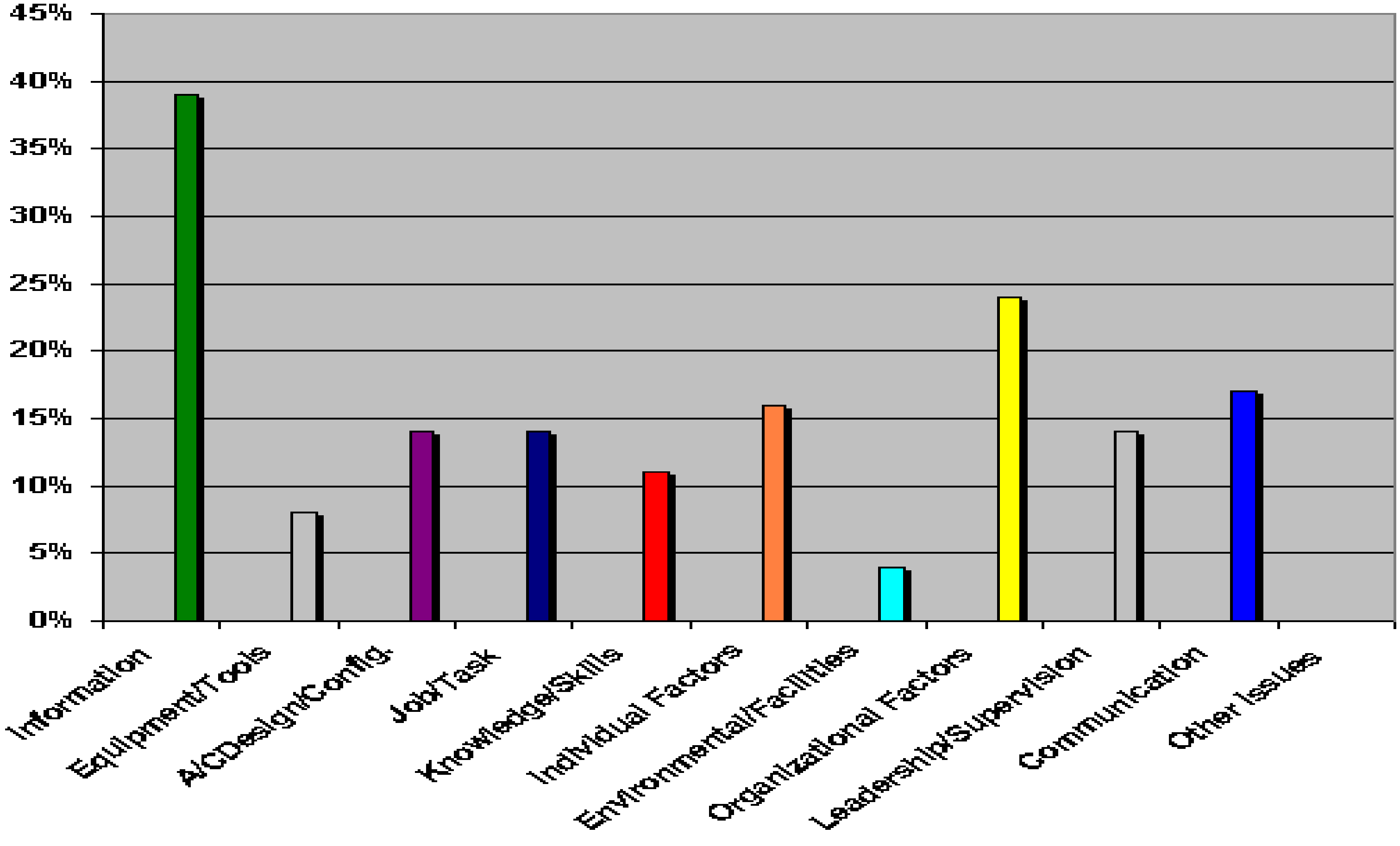
- NUREG/CR-5572 “An Evaluation of the Effects of Local Control Station Design Configurations on Human Performance and Nuclear Power Plant Risk”
  - HEP = 2E-2 for ideal conditions and
  - HEP = 0.57 for challenging conditions

- German maintenance operation database error rates:
  - 1/490 for operating a circuit breaker in a switchgear cabinet under normal conditions;
  - 1/33 for connecting a cable between an external test facility and a control cabinet;
  - 1/36 for reassembly of component elements;
  - 1/7 for transporting fuel assemblies

- HEP for maintenance for process plants:
  - Milling = 5E-1
  - Electric installation = E-1
  - Panel Wiring = 2E-3

Part III: Performance shaping factors important to human actions

Airplane maintenance error contributing factors:

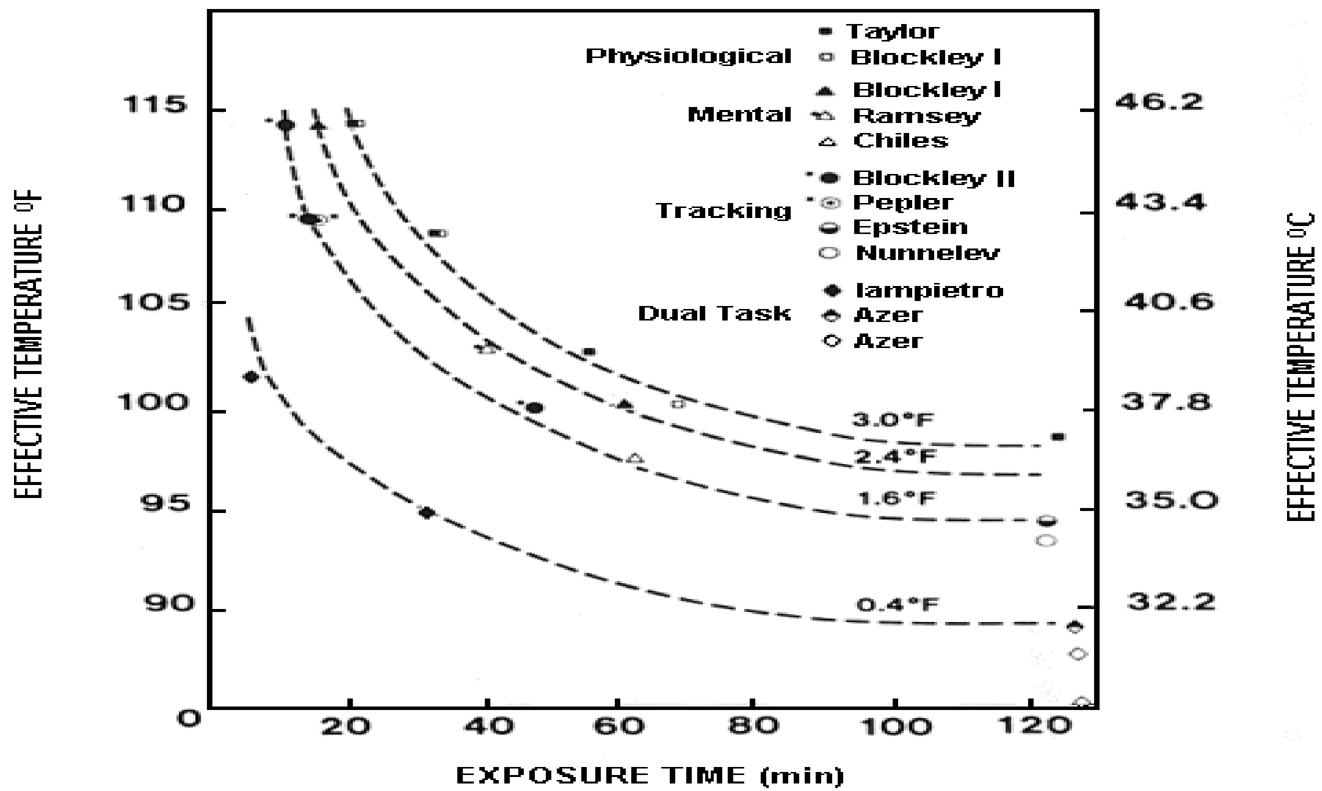


Part IV: How performance shaping factors change human error rates

- Error rates for NPP maintenance tasks:
  - **1/888** for frequently performed tasks
  - **4/173** for rarely performed tasks in normal conditions
  - **3/22** for rarely performed tasks with additional performance shaping factors

- Airplane pilot deicing decision-making errors:
  - **8%** with accurate and adequate information
  - **21%** with accurate but inadequate information
  - **73%** with misleading information

Effect of Temperature on Human Performance



- Hot temperatures of 90 degrees F or above resulted in a **14.88%** decrement in human performance.
- Cold temperatures of 50 degrees F or less resulted in a **13.91%** decrement in human performance.

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FLEX HRA USING IDHEAS-ECA

Dr. Susan E. Cooper and Carmen Franklin, NRC/RES

ACRS PRA Subcommittee Meeting
September 23, 2020

Today's Agenda

- Objectives of FLEX HRA effort
- Summary of Technical Approach
- Key Resources
- Key scope and limitations
- Scenario Development
- Scenarios and Quantification Results
- Insights and Lessons Learned
- Next steps?

Project Objectives

1. Perform an HRA/PRA for FLEX and Non-FLEX scenarios using FLEX strategies and/or equipment
2. Use IDHEAS-ECA
   – To assess the HFEs in FLEX and non-FLEX scenarios
   – Evaluate the ECA software tool

Underlying Objectives

- Develop a set of credible HRA/PRA scenarios involving the use of FLEX equipment
- Develop sufficiently detailed qualitative HRA analysis inputs
- Facilitate a face-to-face workshop
- Obtain feedback from both NRC and industry HRA analysts

Technical Approach

- Identify and collect information on FLEX strategies, equipment and associated operator actions
- Identify HRA analysts to represent both NRC and industry to participate in this project
- Identify FLEX and operational experts to assist in the development and assessment of FLEX scenarios and associated operator actions
- Develop credible HRA/PRA scenarios involving the use of FLEX equipment

Technical Approach (continued)

- Identify and define human failure events (HFEs) associated with using FLEX equipment in each scenario
- Develop qualitative HRA analysis inputs for each HFE that is sufficiently detailed to support HRA quantification
- Train HRA analysts on IDHEAS-ECA prior to the workshop
- Conduct face-to-face workshop with HRA panelists to use IDHEAS-ECA to perform HRA

Key Resources

- Prior studies, e.g.,
  - NRCs Expert Elicitation project and report
  - EPRI’s FLEX “Human Reliability Analysis (HRA) for Diverse and Flexible Strategies (FLEX) and Use of Portable Equipment” (EPRI 3002013018)
- EPRI’s facilitation of industry involvement via Memorandum of Understanding (MOU) with NRC/RES
- FLEX Overview meeting
- Industry reports related to FLEX implementation and training
- Plant site visits
- FLEX and operational experts

Key Resources (continued)

Technical Support Staff
Susan Cooper – NRC
Michelle Kichline – NRC
Matt Humberstone- NRC
Mary Presley – EPRI

Owners Group Support
Greg Krueger – BWR (NEI)
Roy Linthicum – PWR (Exelon)

FLEX & Operations Experts
Phil Amway – Exelon
Randy Bunt – Southern Company
Frank Gaber – Palo Verde
Josh Miller – NRC
Sue Sallade - Exelon
William Webster, Dominion
BWR & PWR site staff
Jim Lynde - Exelon

HRA Analysts
Frank Arner - RI
Mark Averett, Florida Power & Light
John Bretti - Entergy
Scott Freeman - RII
Kaydee Gunter – Jensen Hughes
Chris Hunter – NRC/RES

Key Scope and Limitations

Three factors influenced the scope and limitations of this research effort:

1. Technical requirements for developing credible HRA/PRA scenarios,
2. Available resources (e.g., calendar time, personnel, existing technical inputs), and
3. Project schedule

Some key limitations for this project include:

- There were no existing PRAs that were directly relevant to the scenarios
- There were no existing technical calculations to support realistic definitions of some HRA/PRA success criteria.
- A PRA was not developed to support this effort.
- Existing HRA-relevant information for FLEX strategies (e.g., FLEX validation times) was not developed to support PRAs. As a result, some of this information may be conservative for HRA/PRA purposes.
- HRA analysts participating in this effort had limited time outside the FLEX HRA Workshop to perform HRA quantification with IDHEAS-ECA.

Scenario Development

- Principal objective and predominant effort was to develop scenarios that:
  - Were sufficiently detailed to support HRA quantification
  - Mostly representative of a specific NPP
  - Reflected the understanding of FLEX strategies and equipment gained from plant site visits and FLEX and operations experts
  - Were accepted and understood by all participating HRA analysts
- FLEX and operational experts provided inputs throughout project (e.g., before, during, and after plant site visits)
- HRA analysts participated in development by:
  - Attending plant site visits (most attended at least 1 NPP visit)
  - Reviewing plant site visit notes
  - Reviewing and discussing which scenarios and associated HFEs to develop
  - Reviewing and discussing scenario descriptions
  - Using scenario descriptions to develop human error probabilities (HEPs) with IDHEAS-ECA in face-to-face workshop at NRC (December 2019)

Scenario Development (continued)

- Three scenarios and associated human failure events (HFEs) developed:
  - FLEX scenario for a BWR
  - Non-FLEX scenario for PWR: Loss of all feedwater
  - Non-FLEX scenario for PWR: SBO with pre-staged FLEX Plus diesel generators
- Because scenario-specific PRAs were not available, “PRA work” also was necessary (e.g., definition of HRA/PRA success criteria)
- Bulk of scenario description was developed and provided to HRA analyst prior to face-to-face workshop
  - Some additional details were discussed and identified during the workshop (with assistance of attending FLEX and operations experts)

Scenario Development (continued)

- Scenario descriptions consisted of:
  - Assumptions (general and scenario-specific)
  - High-level description
  - Event tree(s) and fault tree (s) (if available/applicable)
  - Scenario “script,” timeline, and/or procedure path
  - Relevant procedures (e.g., EOPs, FLEX Support Guidelines (FSGs))
  - Timing information (e.g., times developed for FLEX validations)
  - Key operator actions and associated HFEs
  - Description of HFEs
  - Variations on scenario/HFEs (if applicable)
  - Relevant HRA-insights (from plant site visit notes or FLEX/ops expert inputs)
- Assumptions/information were especially important
- Focused on FLEX-related actions only

Scenarios and Quantification Results

- Plant site visits
- Summary scenario descriptions
- Human failure events (HFEs)
- Key assumptions and information
- Quantification Results

FLEX Scenario for a BWR

- Beyond-design basis external event (BDBEE) – seismic event (i.e., no debris removal required)
- Key information/assumptions:
  - 1 (of 2) emergency diesel generator (EDG) is out-of-service for maintenance
  - Plant-specific procedural guidance in EOP for the loss of offsite power
  - EOPs - flowchart format with different “sheets” for different numbers of EDGs running
  - Simulator training provided; Systematic Approach to Training (SAT) used to develop content and frequency (consistent with other EOP-driven operator actions)
  - Consensus on details (e.g., how many times will they try to start failed EDG?)
  - Implemented standardized FLEX connections and simple-to-use FLEX equipment, systematic approach to training (SAT) for FLEX actions, etc.
- HFEs:
  - Operators fail to declare extended loss of AC power (ELAP)
  - Operators fail to perform FLEX DC load shed
  - Operators fail to deploy FLEX diesel generator (DG)
  - Operators fail to perform containment venting

FLEX Scenario for a BWR (continued)

Operators fail to declare ELAP

- Base case (Case #1):
  - Short battery life
  - Prominent "Note" defines "ELAP:" "Extended loss of AC power exists when it is expected that no 4 kV bus will be re-powered within one hour" – considered "explicit guidance"
  - Severe BDBEE with severe and wide-spread damage
    - Other power options clearly unavailable
- Variations:
  - Case #2: Severe BDBEE; longer battery life => "IF AC power cannot be restored within 4 hours, declare ELAP within 1 hour of losing all AC power" – considered ambiguous
  - Case #3: Same as Case #2, but less severe event, less obvious when power can be restored
- HEP results:
  - Base case (explicit guidance): 1.1E-3 to 2.7E-3*
  - Variation #1 (judgment required): 1.1E-3 to 3E-2
  - Variation #2 (judgment and less severe event): 1.6E-3 to 1E-1

* One analyst explicitly made certain choices for this HFE **only** and case to illustrate a point about difficulty in making choices within the method; range of results for this analyst was 1.4E-1 to 1.5E-1

FLEX Scenario for a BWR (continued)

<u>Operators fail to perform FLEX DC load shed</u>

- Key information:
  - EOP “sheet” for ELAP clearly identified FLEX load shed as a priority
  - FSG provides procedural guidance for this action
  - Relatively few breaker manipulations are required
  - Blue “FLEX tag” identifies breakers that require manipulation
  - Procedure checkoff mimics panel layout
  - 10-20 critical manipulations
  - Overall, action is similar to SBO load shed (except fewer manipulations & better human factors) – could be supported better than SBO load shed(!)
  - Important note: “Success criteria” for this operator actions is unclear (e.g., “failure” would not occur if 1-2 loads are missed)
- HEP range: 2E-3 to 6E-3

FLEX Scenario for a BWR (continued)

Operators fail to deploy FLEX DG

- Two critical tasks: 1) fail to transport and 2) fail to connect and start
- Key information:
  - Transport vehicles are staged for departure, have "hard cards" for operation, and require only "journeyman" level of experience to operate
  - Standardized and color-coded connections; push button operation for FLEX DG
  - Field operator training content and frequency developed per SAT
- HEP range:
  - Fail to transport: 1E-3 to 3E-3
  - Fail to connect and load: 1E-3 to 1.2E-2

Non-FLEX Scenario for PWR: Loss of All Feedwater

Initiating event followed by loss of feedwater after 1 hour

- Key information/assumptions:
  - NPP has only 2 motor-driven auxiliary feedwater pumps (AFW);
    - 1 AFW pump is unavailable due to maintenance
    - All 4 condensate pumps fail
  - FLEX pump deployment takes 1 hour (i.e., FLEX validation time is realistic)
  - If 1 AFW pump runs for 1 hour before failure, there is >1 hour until feed-and-bleed criteria are reached (i.e., action is feasible)
  - Loss of heat sink procedure (FR-H.1) is modified to include use of FLEX pump
    - Integrated into simulator training
  - Procedure guidance is salient and unambiguous (e.g., no instructions in NOTES or CAUTIONS; any instructions in a CAUTION do not have operators skipping procedure steps)
- One HFE: Operators fail to initiate use of FLEX pump
  - Cognitive portion only: Operators fail recognize need for FLEX pump

Non-FLEX Scenario for PWR: Loss of All Feedwater (continued)

- HEP results: 1.7E-3 to 1.6E-2
- <u>Actual instruction</u> in modified FR-H.1 was placed in CAUTION prior to step
  - If at any time it has been determined that restoration of feed flow to any SG is untimely or may be ineffective in heat sink restoration, then the AF crosstie should be implemented per Step 5 (Page 8).
  - Other cues available, but unclear based on available information if sufficient time was available to get to those steps
- HRA analysts preferred to evaluate case using assumption rather than actual instruction:
  - More plant-specific information would have been required to address "actual" situation
  - Likely, the actual situation would have resulted in higher HEPs (because of ambiguity in cues, judgment required, instructions in a CAUTION)

* Time reliability results were not captured, but Time Available was assumed for this scenario in absence of scenario and plant-specific thermal-hydraulic calculations.

FLEX Scenarios: Insights and Lessons Learned

- In most cases, FLEX validations and integrated timelines are sufficient to demonstrate HRA feasibility
  - Some difficulty with FLEX actions that are taken on side-wide basis, but are modeled by HRA/PRA for a single unit
- At present, debris removal is outside preview of HRA
- Important to understand and represent P-S implementation of FLEX <u>because FLEX actions can be different than what is typically modeled in HRA/PRA</u>, e.g.,
  - How is decision to "declare ELAP" supported (especially compared to other decisions made within EOPs)?
  - How is FLEX DC load shed supported (especially as compared to SBO DC load shed)?
  - Have industry-wide recommendations for FLEX implementation been followed (e.g., was systematic approach to training used for FLEX actions)?
  - What actions need only a "journeyman" skill set (and associated training)?
  - Does recent operating experience support assumptions that FLEX equipment is easy to operate?

FLEX Scenarios: Insights and Lessons Learned (continued)

- Because most HRA methods are designed to represent in-control room, licensed operator actions taken using EOPs, HRA analysts must appropriately “interpret” their understanding of FLEX when using most HRA quantification tools, e.g.,
  - How “cut-and-dried” has the decision to “declare ELAP” been made in procedures and training? (Or, are operators given flexibility, introducing some ambiguity or competing goals?)
  - Has “SAT” been used to develop training? Does the simplicity of the action compensate for less training than traditionally acceptable for HRA/PRA? Can operator interviews, walkdowns, etc. verify?
  - How to assess actions that require only a “journeyman’s” skillset (and may not be performed by an operator, e.g., FLEX equipment transport)?
- What do reviewers need as “justification” for HRA modeling and quantification choices?
- In this effort, IDHEAS-ECA provided reasonable results

Non-FLEX Scenarios: Insights and Lessons Learned

- Non-FLEX scenarios are likely to very plant-specific, starting with what initiating event and plant function or system are important, e.g.,
  - An NPP with “extra” FLEX diesel generator capability might focus on station blackout scenarios
  - “Lessons learned” may not be sufficient to address future non-FLEX scenario needs
- Important for HRA, PRA, and FLEX experts to work together determine new event tree branches, end states, and associated timing, e.g.,
  - What is “success”? Does it align with existing HRA/PRA definitions?
  - Under what conditions could “success” be claimed for deploying a FLEX pump in a feed-and-bleed scenario?
- New thermal-hydraulic analyses may be needed to support new event tree branches or end states when crediting FLEX equipment
  - Assumptions were used in place of plant-specific T-H calculation for NRC’s FLEX HRA effort

Non-FLEX Scenarios: Insights and Lessons Learned (continued)

- FLEX timing information is NOT likely to be sufficient to demonstrate feasibility
  - Timing for most traditional PRA scenarios (e.g., time to core damage, time to feed-and-bleed criteria) is shorter than for most FLEX scenarios
- Important to understand plant-specific approach to incorporating FLEX equipment into EOPs, e.g.,
  - Are the cues for using FLEX equipment unique?
    - Or, are they the same as others already addressed in EOPs?
    - Are cues supposed to result in BOTH normal control room response AND implementation of FLEX?
      - If so, what compensatory measures are used to BOTH assure normal MCR operator response AND response to use FLEX equipment?

Non-FLEX Scenarios: Insights and Lessons Learned (continued)

- Important to understand plant-specific approach… (continued):
  - How does decision to use FLEX equipment compare to other decisions in EOPs?
    - IF xxx, THEN yyy?
    - Or, more operator flexibility (and ambiguity)?
  - How is decision to use FLEX equipment supported, e.g.,
    - Are formal procedures used (with associated formatting and syntax)?
    - Are instructions are in main body procedure (rather than "NOTES")?
- NRC's HRA for non-FLEX used scenarios modified from original P-S design
  - HRA analysts were more comfortable with modified scenarios because HFE characteristics were more like with typical HFEs and increased likelihood for operator success
  - Could original scenarios been assessed?
  - How would they be assessed with HRA?
  - Are two non-FLEX scenarios sufficient to identify HRA modeling needs?
- What do reviewers need as "justification" for HRA modeling and quantification choices?

Next steps?

- FLEX understood better from HRA/PRA perspective
  - Would be good to capture this understanding
  - There are context-specific factors that need to be addressed differently than for traditional HRA/PRA
    - More guidance could be helpful (generally for HRA and specific to IDHEAS-ECA)
  - More example scenarios with different plant details?
- Review and assess feedback from:
  - Effort to apply IDHEAS-ECA to FLEX
  - NEI FLEX Summit
  - ACRS PRA Sub-Committee meeting

BACKUP SLIDES

Plant Site Visits

- Two plant site visits:
  - BWR: September 17-19, 2019
  - PWR: October 2-3, 2019
- Instrumental to understanding FLEX strategies and equipment:
  - an opportunity to review site-specific FLEX procedures and walkdowns of FLEX strategies, equipment, staging locations, and operator actions
  - a basis for comparison to operator actions modeled in internal event Level 1 HRA (i.e., traditional HRA) and post-core damage response using Severe Accident Management Guidelines (SAMGs) and Extensive Damage Mitigation Guidelines (EDMGs)
  - confirmation of the importance how FLEX strategies have been implemented (e.g., industry-wide standardization of fittings, color-coding of electrical cables, simple-to-use design of FLEX equipment)
  - a vehicle for HRA analysts (both NRC and industry) to form a common understanding of FLEX strategies, equipment, and associated operator actions
  - an opportunity for HRA analysts to communicate face-to-face with FLEX experts who have a broader knowledge of FLEX strategies
  - a transparent means of collecting and interpreting HRA-relevant information, regardless of HRA quantification method, on FLEX strategies, associated equipment and operator actions

Plant Site Visits (continued)

- Information gathered:
  - Plant-specific notes and combined notes
  - HRA/PRA insights
- Basis for FLEX and non-FLEX scenarios:
  - Direct inputs for FLEX scenario development and HRA quantification
  - Understanding of FLEX strategies, equipment, and FSGs and how they might be integrated into EOPs

Non-FLEX Scenario for PWR: Station Blackout with pre-staged FLEX diesel generators

Initiating event response to non-FLEX SBO with 1 EDG out-of-service for maintenance: Use Pre-Staged FLEX Plus DGs instead of declaring ELAP

- Key information/assumptions:
  - 1 EDG out-of-service for long-term maintenance; 2nd EDG fails to start
  - Long battery life
  - 3 FLEX Plus DGs pre-staged to “replace” EDG
  - Contingency plan formalizes guidance on putting FLEX Plus DGs into service
    - Written with formatting and logic similar to EOPs (e.g., IF… THEN…)
    - Clear cues for implementation
    - Contingency plan briefed every shift
    - Field operator designated to perform necessary actions; available 24/7
    - Sufficient time for actions (without needing formal “ELAP” declaration)
    - Extra, reactor operator (RO) is designated to implement
- HFE: Operators fails to connect and operate 3 FLEX Plus DGs*

* HRA analysts identified “loading FLEX Plus DGs” as another part of larger HFE but decided not to address due to lack of plant-specific information or applicable general information.

Non-FLEX Scenario for PWR: Station Blackout with pre-staged FLEX diesel generators (continued)

- HEP results: 1.1E-3 to 2.5E-2
- Actual situation did not include an extra RO in MCR designated to implement contingency plan
- HRA analysts preferred to evaluate case using assumption rather than actual situation:
  - More plant-specific information would have been required to address "actual" situation, e.g.,
    - simulator observations of how contingency plan is implemented in parallel with normal initiating event response
    - Operator interviews on response to cue that prompts entry to both SBO procedure and contingency plan
  - Likely, the actual situation would have resulted in higher HEPs

User Feedback on IDHEAS-ECA

Michelle Kichline
Senior Reliability and Risk Analyst
Office of Nuclear Reactor Regulation

United States Nuclear Regulatory Commission
Protecting People and the Environment

IDHEAS-ECA Rollout

- Informal training given at last 2 Senior Reactor Analyst (SRA) Counterpart meetings.
- IDHEAS-ECA is being piloted for use for quantifying human error probabilities (HEPs) for detailed risk evaluations (DREs) conducted as part of the Significance Determination Process (SDP).
- IDHEAS-ECA is also being piloted for use in Accident Sequence Precursor (ASP) program risk evaluations.

User Feedback

- Training attendees commented:
  - User interface was easy to understand
  - Appreciated that human failure events (HFEs) could be evaluated at the same level as in SPAR-H
  - Dependency and recovery models are needed
- Users commented:
  - User interface was easy to use
  - Results were reasonable
  - Choices were more detailed than SPAR-H - expect the result is more accurate
  - Timing module was confusing

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Workshop Attendee Feedback

- User interface was easy to use and provided reasonable results
- Ability to document results in the tool was useful but should be expanded to make it easier to use
- Calculating the impact of time on HEP was confusing
- Pop-ups providing information about PIFs were useful and should be expanded to provide more information
- Requested more information on how to break down an HFE into its critical tasks, especially since it may be different than other methods

Summary

- All users found the user interface easy to use and understand.
- Both industry and NRC users found that the method/tool provides reasonable results.
- IDHEAS-ECA has more detailed PIF options than SPAR-H, especially for actions outside the control room, and is expected to provide more accurate HEPs than SPAR-H.

PWROG
PWR Owners Group

Global Expertise • One Voice

Benchmark of IDHEAS versus HRA Calculator

Roy Linthicum – RMC Chairman/Exelon

Agenda

- Insights from Supporting IDHEAS-ECA Development
- Scope of Benchmarking
- Results
- Conclusions

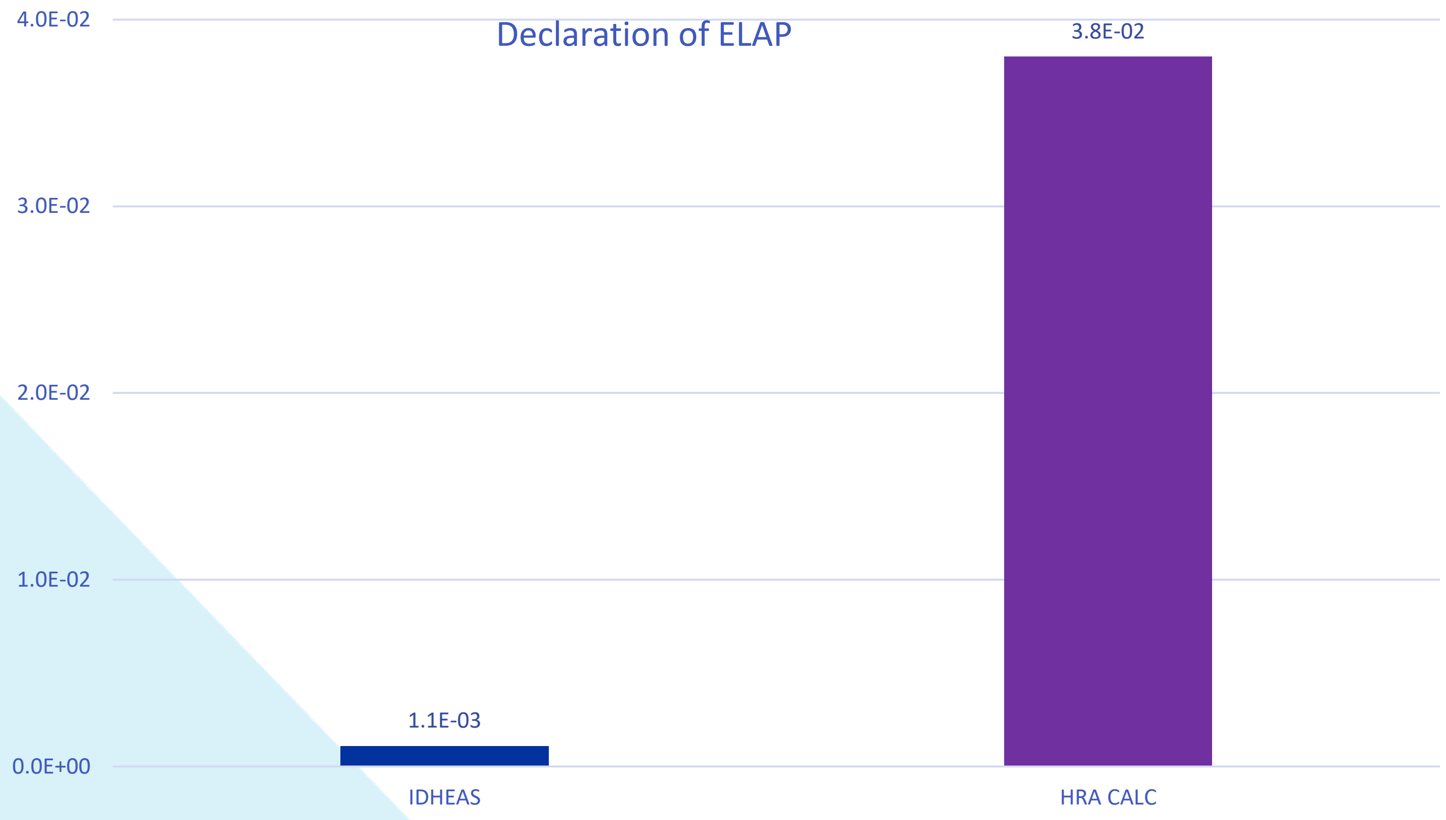
Insights from Supporting IDHEAS-ECA Development

- Realistic Modeling of HRA requires:
  - Walkdowns/Observations
  - Knowledge of EOP use/Conduct of Operations
  - Well defined scenarios are needed for risk significant actions

Scope of Benchmarking

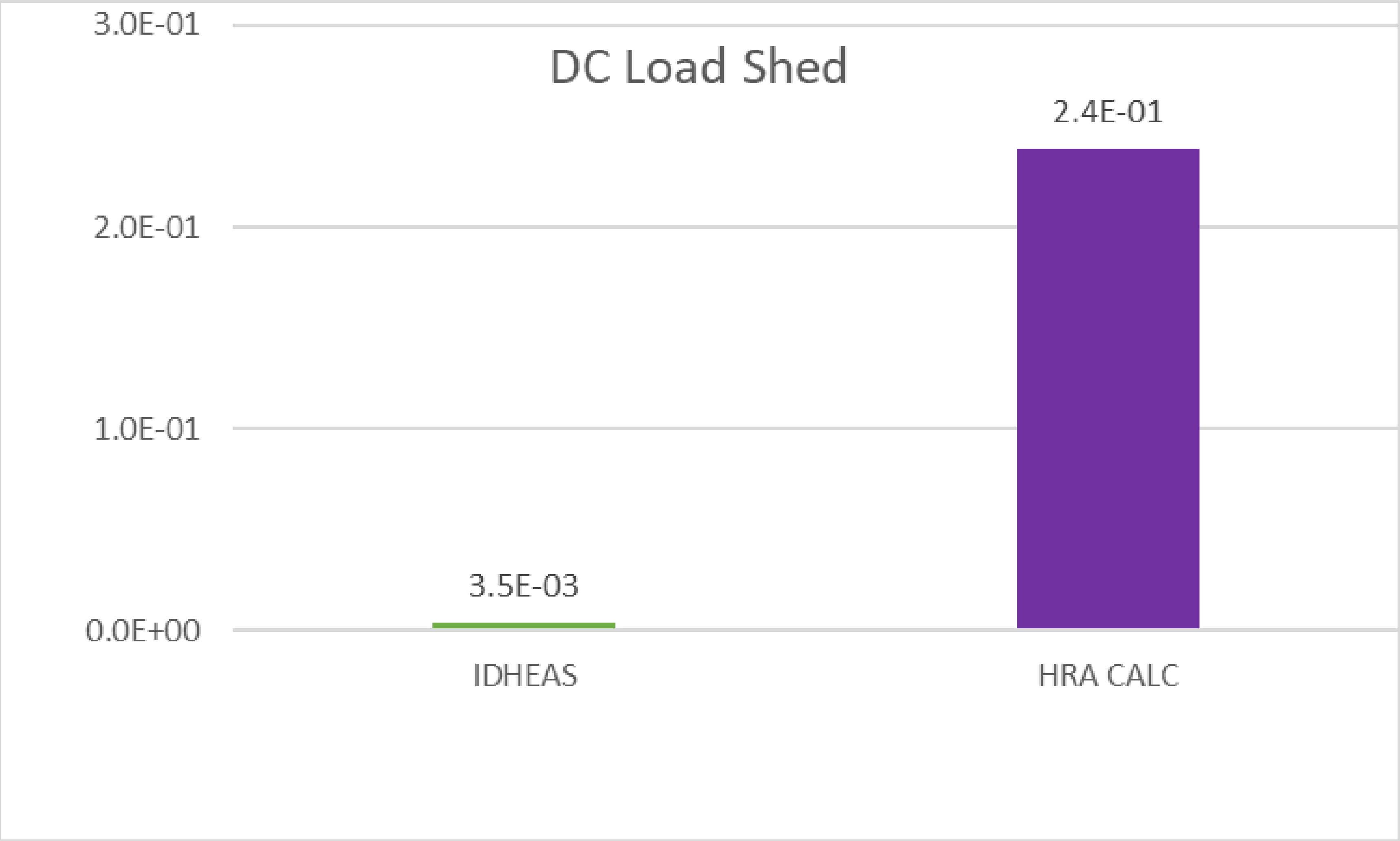
- 5 Flex Actions Modeled
  - Declaration of ELAP
  - DC Load Shed
  - Flex Deployment
  - Initiate Low Pressure Injection
  - Refuel Flex DG
- Same scenario, assumptions and boundary conditions applied to IDHEAS-ECA and HRA Calculator

Declaration of ELAP



- Plant procedures have a time requirement for declaration
- IDHEAS-ECA cognitive model provides better reflection of operator training

DC Load Shed

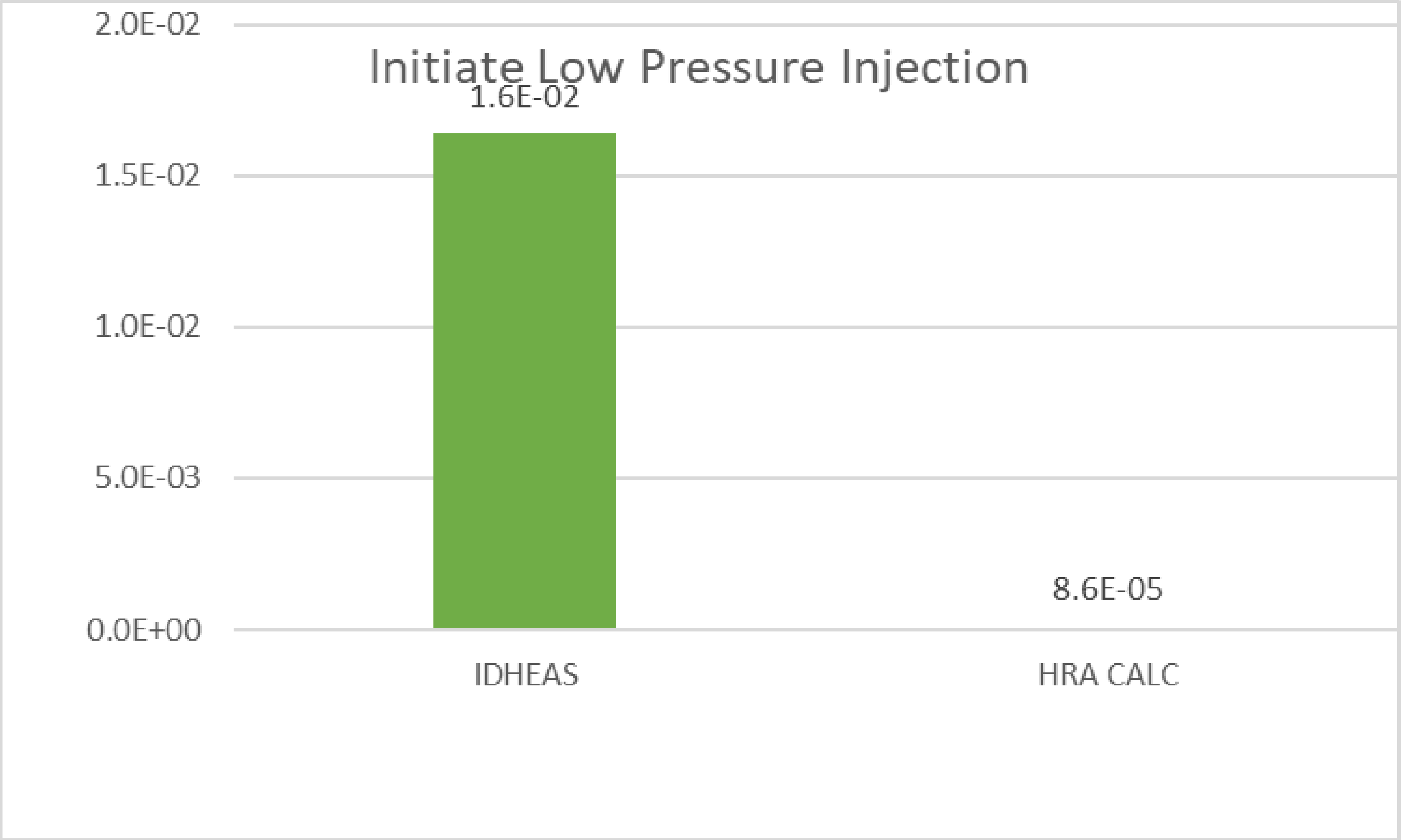


- Unrealistic High Values from HRA calculator driven by aggregation of individual circuit failure manipulations
- IDHEAS-ECA use of critical task with cognitive failure modes provides more realistic values when number of tasks is high

Flex Deployment

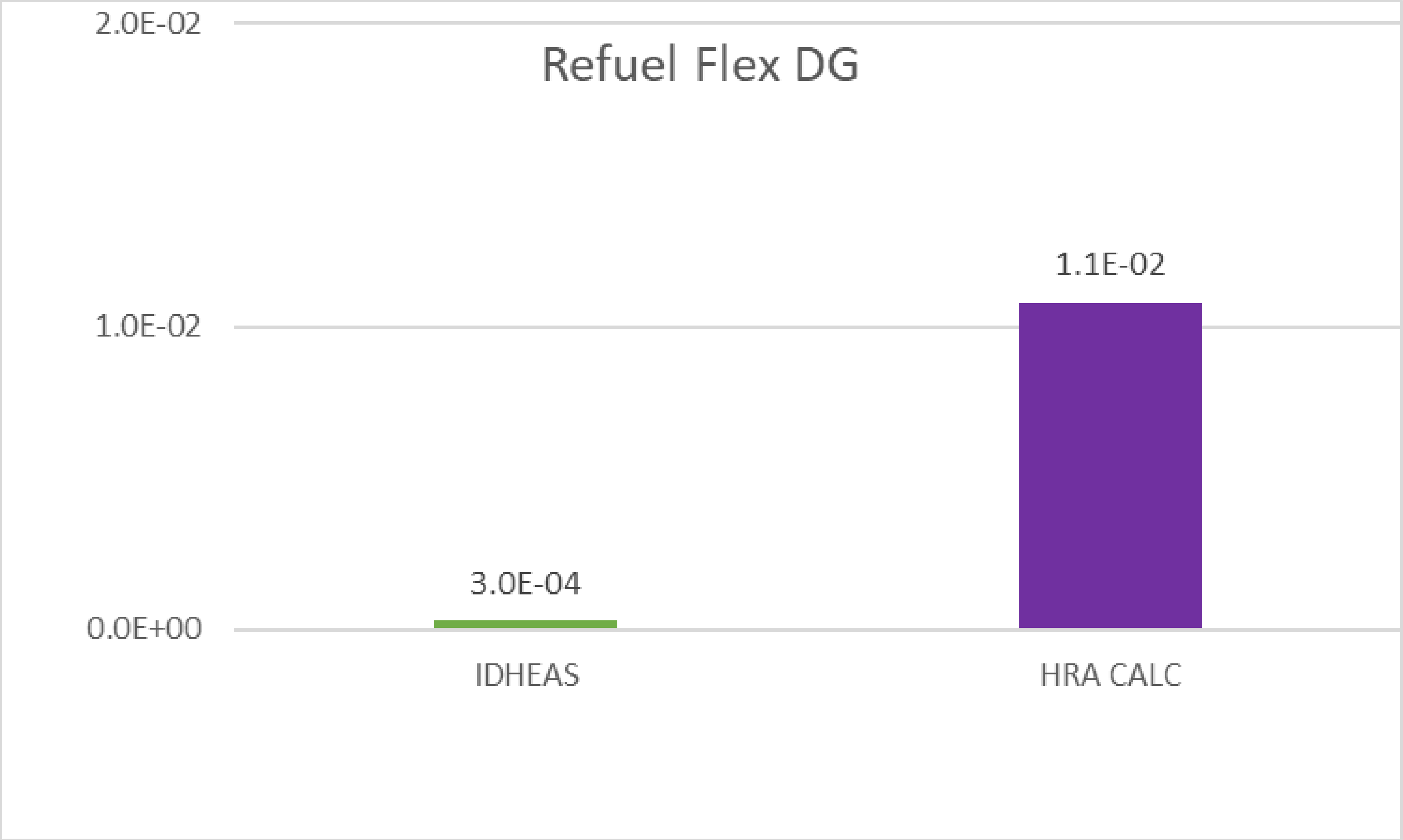
- Scenario represents hoses, valves only – pump is permanently installed

Low Pressure Injection



- Neither method appears to be realistic

Refuel Flex DG



- IDHEAS-ECA may be optimistic

Additional Insights

- Development of IDHEAS-ECA used significant input from Operations personnel reflecting current operational practices and training
  - Improved understanding of EOP use/interpretation
  - Simultaneous procedure use
- Current version does not include treatment of dependencies
- Additional guidance on treatment of recovery would be beneficial

Conclusions

- IDHEAS-ECA is a significant step forward in obtaining realistic Human Error Probabilities
- Current tools incorporate decades old methods and Data
    - IDHEAS-ECA has been updated with more recent data
    - Better guidance on use of tools can provide more realistic values
    - Should reduce disagreement in regulatory applications
- Current version does not include treatment of dependencies
    - Expected in future update
- Significant differences are still being investigated
    - Strive for realistic HEPs

?

The Integrated Human Event Analysis System (IDHEAS) Program Path Forward

Sean E. Peters

Advisory Committee on Reactor Safeguards
Reliability and PRA Subcommittee Meeting
September 23, 2020

IDHEAS Future Work

- IDHEAS-G - Publication
- IDHEAS-ECA – Refinement/Rollout
  - Dependency
  - Recovery
  - Timing
  - Integrate with SAPHIRE/SPAR Models
  - Publication of revision
- IDHEAS-DATA
  - Completion
  - Peer review
  - Publication
  - Revision

Other HRA Work

- Minimum joint human error probabilities
- **Data!**
- Wish List
  - Errors of commission
  - Org Factors
  - Security (Physical and Cyber)

Path Forward for the ACRS

- Complete/Practical HRA Method
- Improvement to the current state of practice at the NRC
- Human-centered, scientific and data-based
- Program for continuous updates based on user feedback and data
- Can be applied to all NRC applications

- Closure of SRM-M061020?

QUESTIONS/DISCUSSION

Meeting Participants

Vesna Dimitrijevic	ACRS Member (Meeting Chair)
Ron Ballinger	ACRS Member
Charles Brown	ACRS Member
Walt Kirchner	ACRS Member
Jose March-Leuba	ACRS Member
David Petti	ACRS Member
Joy Rempe	ACRS Member
Matt Sunseri	ACRS Member
Stephen Schultz	ACRS Consultant
Charles Morrison	Court Reporter
Christiana Lui	ACRS Staff (Designated Federal Official)
Scott Moore	ACRS Executive Director
Christopher Brown	ACRS Staff
Larry Burkhart	ACRS Staff
Makeeka Compton	ACRS Staff
Thomas Dashiell	ACRS Staff
Shandeth Montgomery	ACRS Staff
Hossein Nourbakhsh	ACRS Staff
Sandra Walker	ACRS Staff
Weidong Wang	ACRS Staff
Derek Widmayer	ACRS Staff
Frank Arner	NRC Staff
James Chang	NRC Staff
Mike Cheok	NRC Staff
Stephanie Coffin	NRC Staff
Susan Cooper	NRC Staff
Jonathan DeJesus	NRC Staff
Carmen Franklin	NRC Staff
Michelle Kichline	NRC Staff
Sean Peters	NRC Staff
Mark Thaggard	NRC Staff
Jing Xing	NRC Staff
Roy Lithicum	Exelon (PWROG)