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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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682ND MEETING

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

+ + + + +

OPEN SESSION

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THURSDAY

FEBRUARY 4, 2021

The Advisory Committee met via Video Teleconference, at 9:30 a.m. EST, Matthew W. Sunseri, Chairman, presiding.

COMMITTEE MEMBERS:

MATTHEW W. SUNSERI, Chairman
JOY L. REMPE, Vice Chairman
WALTER L. KIRCHNER, Member-at-large
RONALD G. BALLINGER, Member
DENNIS BLEY, Member
CHARLES H. BROWN, JR. Member
VESNA B. DIMITRIJEVIC, Member
JOSE MARCH-LEUBA, Member
DAVID A. PETTI, Member
PETER RICCARDELLA, Member

ACRS CONSULTANT:

MICHAEL CORRADINI

STEVEN SCHULTZ

DESIGNATED FEDERAL OFFICIAL:

CHRISTIANA LUI

QUYNH NGUYEN

ALSO PRESENT:

DON ALGAMA, RES

KENNETH ARMSTRONG, RES

JOE ASHCRAFT, NRR

MICHELLE BALES, RES

ANDREW BARTO, NMSS

SUSAN COOPER, RES

JAMES CORSON, RES

ERIC FOCHT, RES

RAY FURSTENAU, RES

CHARLES HECK, GE-Hitachi

DAVID HINDS, GE-Hitachi

MATT HISER, RES

COLIN JUDGE

JEFF JULIUS, Public Participant

NECDET KURUL, GE-Hitachi

LUCAS KYRIAZIDIS, RES

CHANG LI, NRR

LOUISE LUND, RES

WAYNE MARQUINO, Public Participant

WILLIAM McCAUGHEY, DOE

SCOTT MOORE, Executive Director, ACRS

SEAN PETERS, RES

DAVID RAHN, NRR

PAUL REBSTOCK, RES

JAMES SHEA, NRR

JOHN STETKAR, Public Participant

DINESH TANEJA, NRR

JOHN TOMON, RES

DANIEL WACHS, Idaho National Laboratory

GEORGE WADKINS, GE-Hitachi

KIMBERLY WEBBER, RES

FROSTIE WHITE, GE-Hitachi

JING XING, RES

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P R O C E E D I N G S

9:30 a.m.

CHAIR SUNSERI: Okay. It's 9:30. The meeting will now come order. This is the second day of the 682nd meeting of the Advisory Committee on Reactor Safeguards. I'm Matthew Sunseri, the Chair of the ACRS. I will now call the roll to verify quorum and that clear communications exist. Ron Ballinger?

MEMBER BALLINGER: Here.

CHAIR SUNSERI: Dennis Bley?

MEMBER BLEY: Here.

CHAIR SUNSERI: Charles Brown?

MEMBER BROWN: Here.

CHAIR SUNSERI: Vesna Dimitrijevic?

MEMBER DIMITRIJEVIC: Here.

CHAIR SUNSERI: Walt Kirchner?

MEMBER KIRCHNER: Here.

CHAIR SUNSERI: Jose March-Leuba?

MEMBER MARCH-LEUBA: Here.

CHAIR SUNSERI: Dave Petti?

MEMBER PETTI: Here.

CHAIR SUNSERI: Joy Rempe?

VICE CHAIR REMPE: Here.

CHAIR SUNSERI: Pete Riccardella?

MEMBER RICCARDELLA: I'm here.

CHAIR SUNSERI: And myself. I know we have quorum. The designated federal officer for this meeting is Ms. Christiana Lui. During today's meeting, the Committee will consider the following presentation oral report on IDHEAS-G: An Integrated Human Events Analysis System - General Methodology, the presentation and letter report on Advanced Reactor Computer Codes, Volumes 4 and 5, and info briefing on Post-Halden Plans.

A phone bridge line has been opened to allow members of the public to listen on presentations and Committee discussions. We have received no written comments or requests to make oral statements from members of the public regarding today's session. There will be an opportunity for public comment, and we have set aside time in the agenda for comments from members of the public listening in or members of the public attending or listening in to our meeting.

Written comments may be forwarded to Ms. Christiana Lui, the designated federal officer. A transcript of the open portion of the meeting is being kept. And it is requested that speakers identify themselves and speak with sufficient clarity and volume so that they may readily be heard. Additionally, participants should mute themselves when not speaking.

So I have a few opening remarks here. Let me get myself situated here. Okay. I'm going to turn on this camera for a few minutes. I just wanted to call attention today that Christiana Lui was a long-time member of the ACRS staff and an even longer time employee of the NRC. During her time with the ACRS, she has been involved in a number of areas, most recently supporting members with the review of PRA related activities.

When the pandemic restrictions on gathering came down, Christiana took on an additional assignment, along with a few other members of this ACRS staff, to develop the protocols and implement the technology to allow the Committee to hold its meetings virtually. This took extraordinary effort and was a resounding success.

On an individual level, Christiana has shared her knowledge and experience with me on several topics, allowing me to make better decisions and be a better member. Christiana has gotten an opportunity to further advance her career and will be taking on a position in research. So today is Christiana's last full Committee meeting as an ACRS staff member. I look forward to a future full Committee meeting where we might get to work with her in a different role.

So, Christiana, on behalf of the ACRS members thank you for your support to us and our mission. At this time, I would like to call on the members to see if anybody has any additional comments or anything they would like to say about Christiana.

MEMBER DIMITRIJEVIC: Hi. This is Vesna. Yes. I was really blessed to be welcomed by Christiana when coming to ACRS. And I don't really know what kind of member I will be, but she was an incredible support and very knowledgeable. And without her, I told her I will feel like half of the member. Christiana didn't do anything half-heartedly so whoever works with her will be blessed. And I feel blessed that I worked with her.

CHAIR SUNSERI: Thank you, Vesna. Anybody else?

MEMBER BALLINGER: Pretty short and sweet. Christiana is just flat out a nice lady.

CHAIR SUNSERI: Thank you. Others?

VICE CHAIR REMPE: Sure. This is Joy. And I also wanted to say thanks, Christiana. I've known you since you were a project manager over some research I was doing back at INL many, many years ago. But I have enjoyed my interactions with you over the years, and I was really happy when you joined us at ACRS and best of luck in your new assignment.

MEMBER BLEY: Yes. This is Dennis. I've known Chris a long time as well, even before she was busy here. And I wish her great success, and I know she'll be going back more to her roots over in research. They'll be lucky to have her. The one thing others haven't said, it's great working with Chris. But she also really makes sure we are well prepared and have thought things out thoroughly. And she's been great help all the way through. Thanks, Chris.

CHAIR SUNSERI: Thank you, Dennis. Anyone else?

MEMBER BROWN: Yes. This is Charlie. Back about a year ago was when we started struggling in this pandemic routine in our remote meetings. She recognized my limitations as the Neanderthal-troglodyte as I struggled to be able to get my computer to work. So I had several calls with her and many interactions as we started trying to get it up. And she did a marvelous job with her patience in helping me out. I much appreciated that. It's a testament to her quality. Thanks, Christiana.

CHAIR SUNSERI: She does have a lot of patience.

MEMBER BROWN: That's an understatement when it comes to me and computers.

CHAIR SUNSERI: The same applies to me, too. She's been very helpful in that regard. Anybody else?

MEMBER KIRCHNER: I would just like to add that thank you, Chris, for your thoroughness and your professionalism on many, many different matters and certainly, as Charlie said, getting us computer literate in this new world that we're working in. So thank you ever so much.

CHAIR SUNSERI: Thanks, Walt.

MEMBER MARCH-LEUBA: I also would like to say good luck in research, Christiana. We all like you and wish you great progress there.

CHAIR SUNSERI: Thank you, Jose. Anyone else?

MEMBER BROWN: I'll make one other observation. I think she's going to get bored in research. There's too much excitement over here. That's a positive comment by the way. Take care, Christiana.

CHAIR SUNSERI: Okay. Last call. Well, I think, you know, this virtual restriction, I think this is as good of a sendoff as we can give you virtually. I wish we were in person where we could really do a proper sendoff. But I think from the members' comments you heard, we really appreciate what you've done for us, and we'll miss you. So I'm going to put you on the spot and say is there anything that you would like to add before we get started with the meeting?

MS. LUI: Well, I really appreciate the feedback. And I really enjoyed with all the members and also the ACRS staff during the time I've been with ACRS. And I do want to highlight that the success is not by running the virtual. We all worked together as the team to make the transition as easy as possible, and we all play our part. Because I was the lead so I get a lot of the credit, but I really want to make sure that the whole team gets recognized for the transition because without their effort, I don't believe that this would have been as smooth as possible. So given that I have some brownie points with the members, next time when I return to make presentation in front of the ACRS, I will expect to get some passes when I get there. Hopefully, that will be the case.

CHAIR SUNSERI: Well, that's a big ask. I don't know about that one. But we'll take it under advisement.

MS. LUI: I do have one thing to add, Matt. We did receive a request to make comments from Mr. John Stetkar at the end of the IDHEAS presentation today. So we will be switching on the public bridge line to at least accommodate Mr. John Stetkar's request.

CHAIR SUNSERI: Okay. All right. Understood. That request probably came in after I put my remarks together. So thanks for the heads-up on that. Okay. Well, thank you, Chris. I do have one other announcement on the list right now. So I'm going to call on Peter Riccardella.

MEMBER RICCARDELLA: Yes, hi. On a sadder note, some of you may have heard that Keith Whitman passed away recently. Keith was a long-term NRC material guy. Perhaps you'll remember the silver hair and the big handle bar mustache. I think he retired from the NRC about 10 years ago and has been doing some consulting. But unfortunately he had a fall about four years ago and was in a nursing home and contracted COVID there. So, anyway, for those of you who knew Keith, I'm sure you'll recognize that he'll be sadly missed.

CHAIR SUNSERI: Thank you, Pete. All

right. So any members have any comments or questions about our agenda for today? We will proceed on then with the IDHEAS-G Integrated Human Events Analysis System General Methodology presentation. So, Dennis, I'll turn it over to you.

MEMBER BLEY: Thank you, Mr. Chairman. Before I turn it over to Sean Peters and Jing Xing, I'd like to make a few introductory remarks. We have a fairly long period today to let Sean and Jing go through their presentations and then a fairly thorough outline of their talk. So it's going to cover everything from the original issuance of the SRM back 15 years ago. But I had mentioned the work that led to this started even 10 years before that. So it's been a long evolution. There's been a lot of work along the way, a lot of -- some missteps and a lot of cleaning things up.

Before I give it to Sean to -- I want to apologize for something I couldn't help. But I missed the September meeting and hadn't had a chance to fully prepare for that but I wasn't able to be there. If I had, some of the comments you will hear today you probably would have heard some time back. In the last three weeks, I've had a chance to really dig into the five reports they sent us. No, actually the one before that says three reports. And I have a few comments that will come up as you go ahead, Sean.

Sean mentioned in their FLEX expert elicitation report a white paper that wasn't sent to us, but it is available publicly on expert elicitation. And I would commend that to all the members. There's a lot of good information there. At this point, I'm happy to turn this over to Sean. We look forward to your presentation.

MR. PETERS: Yes. Thank you, Dennis. This is Sean Peters, branch chief of Human Factors and Reliability Branch in the Office of Research. And I wanted to jump in also. I'd like to also thank Chris Lui for all of the work that she's done. She is one of the main drivers for the IDHEAS program back when she was my division director in the Office of Research. And she also was the one that hired me into this branch chief job and got me into the IDHEAS program. So I really appreciate that.

It will be nice to have her back because I think she had a lot of great ideas. And I think she will be able to help guide us a little bit more from the Office of Research than she was from ACRS. So I'm really happy to have Chris back. And I'd just like to also thank the members of the ACRS. I know, as Dennis said, that we've been going on for a very long time on this program and have had -- and you'll see as we go through the presentation how much progress we made.

And I do want to apologize a little bit in advance because you're going to see a lot of the same presentation here from me that you saw back in the subcommittee meetings. And the main reason is because we've had some members who weren't in that subcommittee meeting who are here today. So I wanted to give them an outline of the IDHEAS program. And then after I talk a little bit about the outline of the program, Jing Xing is going to come, Dr. Jing Xing is going to come in, and present on some more of the details of each of the pieces of the program.

And then I'm going to have a really short wrap-up, kind of what we see as the future of the IDHEAS program on the back end of that. So I'm just going to go ahead and proceed to our slides. So the reason why we're here was back in 2006, Dr. George Apostolakis, as a member of the ACRS, he convinced the Commission to write a one sentence SRM on HRA.

And when I've had discussions with Dr. Apostolakis recently and kind of picked his brain about why we went down this path, and what Dr. Apostolakis was saying was that he was concerned associated with misapplication of HRA methods. That there were a ton of methods out there that were built for very specific purposes. And people started using these methods beyond that original intent. And he wasn't certain that they were built for that.

So what he wanted the staff to do and wanted the Committee to do was look at these various methods and determine which ones should be used in which circumstances or maybe develop one or propose of one that should be used for all circumstances from the NRC's perspective so the NRC should be using one or a set of methods. So that was kind of the driver for where we went down with the IDHEAS program. And I'll show you a little bit of a timeline on it. So I'm going to talk more about these little bullets here. But as Dennis was saying, we had already started several years before the SRM came out. The SRM is in red on the bottom of the screen there.

And we had evaluated methods versus the best practices. But post-SRM, we began looking at, okay, let's do an evaluation for our methods. So we developed an international human reliability analysis study. We worked and also did a U.S. empirical study. I'll talk a little bit more about that on the back end. We developed a technical basis, an HRA cognitive basis report. We also developed IDHEAS At-Power. And then IDHEAS-G, IDHEAS-ECA, we performed expert elicitations on FLEX and also did FLEX HRA using IDHEAS-ECA to calculate the HEPs.

So if you look at that, all the items in red are the products that we've developed since that SRM came out. So I just breezed by a couple slides that were associated with -- the references associated with the report. I just wanted to keep those in there for the public record. But now I'm on Slide 6. The IDHEAS development process -- you know, after the SRM was developed, we reached out with the Halden Reactor Project and the teams of international researchers. And we performed experiments on international operators at the Halden Reactor Project. And we had teams of HRA analysts come in and try to predict the performance of those operators.

And we used that as a way to compare the methods versus, you know, operational performance. And after that, we had some questions from the ACRS associated with that. And when we had presentations of the ACRS on our results and the questions, some of them came up, some of the big ones came up, is that these are like Swedish operators in a French digital simulated plant at the Halden Reactor Project. How would this actually work if we were in the United States on a more, like, knobs and dials type scenario like we have in the United States?

So we followed-up that international experiment with a U.S. experiment. We ran our U.S. operators through their own simulator. And we also saw this opportunity as a way to narrow our focus on the HRA methods that were more of interest to the NRC. And what that allowed us to do was have multiple teams use one method and then multiple teams use another method. And so what we were able to do was actually see not just method to method variability but also team to team or analyst to analyst going through those methods.

So based upon that, we found that, you know, there wasn't one method that we thought that was ideal for all situations, that they all had strengths and weaknesses. And we decided to try to take those strengths of those methods and then incorporate them into one method, so basically try to negate the weaknesses of some of the methods and try to go basically for the strengths. And so one of the things that we determined in that review was that we needed to develop a new updated cognitive basis for the methodology.

We performed a very extensive literature review and developed a scientific basis and structure for HRA. This came out as NUREG-2114. And we presented to the ACRS. And the ACRS, I believe this was about 8 or 10 years ago, that was very high accolades from the Committee members on the cognitive basis report. So we used that as our basis, and we worked with industry because our SRM indicated that we needed to work with industry to develop a methodology for the Agency to use. And so we came up with IDHEAS At-Power. And more of the main issues we tried to address in IDHEAS At-Power was this variability between analysts and between methods.

So we worked really hard on that, the IDHEAS At-Power methodology. But in the middle of the development of that method, the Fukushima event hit. And that got the focus of HRA to change at the Agency. The Agency was no longer just concerned with internal events, at-power applications. They were controlled with ex-control room, things that are out there that may have environmental effects. And a lot of other methodologies really didn't consider environmental effects because almost all of them were built for those in control room activities.

I'm going to the next slide. So we

decided we needed to take a more human centered approach. And we also needed to have a little bit of a broader concept from development that we couldn't just look at, you know, control room activities. We needed to look at things outside. And we also needed to kind of imagine what the future can be for the NRC.

We know we have spent fuel storage and transportation. We know we have long-term waste disposal. We know we have, you know, mining operations, well logging. We have medical applications. And so we developed a general framework that is human centered. So what it does is it allows us to look out at those various frameworks and select factors that would influence performance in those domains.

So IDHEAS-G, we began that development process. And this is the overall guidance document for how to build those specific methods for those domains. It gave us a framework to generalize and integrate human error data into our program. And also it's a structure that can be used not just for HRA but can also be used for analyzing human events and looking at root causes and human failures.

So it's a very general -- we have this general framework and scope that we're using to assess human reliability here and in the future. And so from that, looking at the majority of applications at the NRC, most of what we utilize is we utilize SPAR-H as a tool for significance determination process and accident analysis. And then, like, in the Office of Research, we do some development outside of that significance determination process and accident analysis framework. We do some development outside of that. But most of the brunt of the work we do is with that SPAR-H in those domains.

And so we began to develop IDHEAS-ECA to replace SPAR-H and to think of it as a way to replace SPAR-H to give it a broader breadth, to give it the ability to calculate in domains outside of the control room. So we built the IDHEAS-ECA from IDHEAS-G, and we built it to handle all NRC applications. And when I say all applications, this includes medical events. It includes spent fuel transportation. So we think we've included in IDHEAS-ECA all of the relevant influencing factors that can be used throughout domains.

As I said in the second bullet there under IDHEAS-ECA, it can be used for in and ex-control room activities and other nuclear, non-nuclear domain because it's human centered. And the nice thing about a human centered methodology is when you implement new technologies or new procedures or new control concepts that you still are looking at it as how did that affect the human? So what it does is it allows us to have a method that's not outdated when those new technologies come in. And one of the best-selling features of IDHEAS-ECA is we integrated the quantification model into our software tool. And that software tool is a very easy to use tool, and it has high accolades from our users.

So next slide. And then on the -- I think this is my last slide. But the other thing that we've done with IDHEAS is we have a data structure that ties into our existing data collection activities. So this is a strong database for the IDHEAS quantification. It's constantly evolving as we collect information through our SACADA Program. And we presented on the SACADA Program in the past to the ACRS. And we would be happy to present again in the future.

We do collect data out of our human form assessment facility that is rolling into the IDHEAS Program. And we also collect a lot of data with the Halden Reactor Project that we rolled into that. There are other sources of data and Jing will talk a little bit about that in her upcoming slides.

I'm going to double-check to make sure this is my last slide. Oh no, one more here. So just giving you a brief overview of the development of IDHEAS-G. We've had multiple ACRS subcommittee reviews of IDHEAS-G. My best guess is we're averaging about one ACRS subcommittee per year through the development process. And we've had multiple rounds of comments from ACRS subcommittee members both current and former members.

With the three formal external peer reviews, we had two extensive internal peer reviews. And we used IDHEAS-G. In the development process, we kept testing it on things like Fukushima, our U.S. benchmarking events. And we also used it to help do some fuel cycle facility analysis for user offices in NMSS. I did DCA. We used it on various FLEX scenarios in the NRC studies, which we published and you guys got to review. The industry also developed their own studies using IDHEAS-ECA. And they presented on those at the last subcommittee meeting. And they we will be presenting on them in the upcoming RIC in March.

So we should be able to see a little bit more from the industry on what they were able to do with the IDHEAS-ECA. And we got very high accolades from both industry and our internal users on those.

And we are currently using IDHEAS-ECA to analyze AST and STP events, as this is rolling in to become more of a common practice at the NRC to use the methodology.

And in April of this year, we're going to be having a public meeting to officially take in user comments on the document. We're open at all times to user comments. But at that April meeting, it will be kind of a driver for the industry and for users of the methodology to provide comments to us. And we're going to be -- and our plans are with IDHEAS-ECA right now, it is published as a rule for use. We plan to take those comments and incorporate them into a NUREG report.

And the last major product, we have a draft IDHEAS Data Report that is out there publicly available. It is currently being reviewed. So we have a contract with Pacific Northwest National Laboratories. They're doing an extensive data review looking at the structural report and how we incorporated the literature into it for accuracy purposes and for recommendations for improvements.

And we also, as we continue to collect data through our program, we plan to have regular updates of the IDHEAS Data Report. And so that is correct. That is my last slide. Are there any questions before I pass this over to Dr. Jing Xing?

MEMBER BLEY: Yes, Sean?

MR. PETERS: Yes.

MEMBER BLEY: This is Dennis. You went through a great number of peer reviews, internal and external. And I would comment that IDHEAS-G, the document on IDHEAS-G has really moved from a lot of almost scattered ideas into a very coherent presentation of some very extensive work. Are there any -- well, are you putting any published summaries of the comments you've received on all of these items, G, ECA and DATA?

MR. PETERS: That's a great question. I haven't really -- we're so much in the development process, we haven't really considered that internally. I definitely am open to that idea to publish the comments that we have gotten. Jing, do you have any thoughts on this?

MEMBER BLEY: I know you've been running like crazy. So it's harder to keep that. But --

MR. PETERS: Yes. We --

MEMBER BLEY: -- it's very useful information that's been codified in those reviews.

MR. PETERS: Yes. Jing, do you have any

thoughts on that?

DR. XING: Yes. I think that's a great suggestion. Actually, a couple weeks ago when Theresa asked for some reviewer's comment, I went through the old files. I, myself, was very much impressed again how many comments we saved and how helpful those were. So I think it will be very useful to document them. And there are too many. Like, I estimated the comments we received just on IDHEAS-G alone probably would add up to 500, 600 pages. But I think we can find a way to summarize -- I mean, actually already we have recorded summarized the comments and how we addressed them. So we just need to do some final summarizing work.

MR. PETERS: So, I guess, from Jing and myself, that sounds like a really good idea. And I think we would look into incorporating that.

MEMBER BLEY: One thing that is not clear to me. You talked about reviews on the three. You did two reports associated with FLEX. Have you had any peer review of those?

DR. XING: The FLEX Report -- one FLEX report was the FLEX expert elicitation. That's why we had the internal staff review but not external review. So FLEX evaluation was recently developed on December

27 something last year. So it hasn't been externally reviewed yet.

MEMBER BLEY: Okay. Thank you.

MR. PETERS: Yes. So, Dennis, real quick on the FLEX, we were under an Agency metric to get that out the door by December 31. It just didn't support the timelines for a peer review.

DR. XING: Yes. Just one more item. On the FLEX, the expert elicitation reporter had peer reviewed it. That's because we invited EPRI to observe the activity. I thought this should be classified as external review.

MEMBER BLEY: I agree.

MR. PETERS: Any other questions? Okay. Jing, I guess we're ready for your presentation.

DR. XING: Okay. Thanks, Sean. Thanks for the nice introduction and that really made my part easier. Okay. I'm going to share my screen. Can everyone see my screen?

MR. PETERS: We can, yes.

DR. XING: Okay. Thank you. Okay. So I'm Jing Xing working for Sean Peters in the event process of IDHEAS. So it's my pleasure on behalf of the IDHEAS team today to present IDHEAS to ACRS' full committee. So for today I will talk about the first section. First, an overview of IHDEAS program from a technical perspective and then I will introduce the three IDHEAS products, IDHEAS-G, IDHEAS-ECA and IDHEAS-DATA. After that, I will talk about the two examples of using IDHEAS, which is what we just said, the FLEX expert elicitation and the FLEX evaluation. At the end, I would like to summarize our revision to IDHEAS report up to the last ACRS subcommittee meeting.

Okay. So starting from where we were in the beginning of IDHEAS in later 2011 or beginning of 2012, so what you see on these slides are the technical areas we want to pick on. On the top three major areas, one, the scope of the HRA application. Sean Peters just talked about in 2011 after Fukushima, the Agency needed an expanded scope of HRA application. On the top right, we have seen ones that we can better and more use of the human performance data used in Chart A to enhance HRA credibility.

The middle one is the big one that we prepared in the SRM HRA data team. So at that time from what we learned in the two HRA benchmarking studies that Sean just talked, we can see in the slide what caused the variability. So I summarized that into three boxes. The first one is the uncertainty in the scenario. We don't always have perfect scenarios. It always comes with uncertainty.

And the second one is the analyst practice, even using the same method for the same scenario, analysts had a different experience, different focuses. And, of course, the big error we want to improve is the HRA method as the benchmark studies find that even there's a bigger analyst-to-analyst differences caused by the HRA methods.

So we do HRA method to benchmark the studies, identifying a number of sources for HRA variability. So the four major areas are, the first one is quality of analysis guidance. And even when you have a good qualitative analysis guidance from the method used, that would still not address the issue of how you transform the outcomes of qualitative analysis to HRA quantification. And events performance influencing factors or PIF because a big part of HRA is estimating the human error probability, HEPs. So HEPs depend on the PIFs. And we want to explain a better description of the PIFs so they can be assessed more confidently among analysts.

And the last error, probably the most important error, is the cognitive basis embedded in the HRA method because HRA wasn't just about getting the HEP number. It needs to tell how human can fail and the why they fail, how we can prevent them from making errors. So thus we need a cognitive basis to give the explanation. So both --

MEMBER BLEY: Jing?

DR. XING: So both -- yes. Question?

MEMBER BLEY: I'm going to interrupt you for a second. And I'm not sure of the best place to do this so I'm going to start here. Are you going to say more in a later slide about the uncertainties in the scenario?

DR. XING: Yes.

MEMBER BLEY: Okay. Then I'll wait on that one. On the cognitive basis, I'm going to sneak in a couple comments now because I have nowhere else to do it. I think the work you did really is excellent and makes this basis to the literature in a way that hasn't really been done. The two reports, the cognitive basis document NUREG-2114 and the IDHEAS-G itself, both delve into this. I was bothered in Chapter 2 of the IDHEAS-G report because in many places the text says the figures make various elements together. And when you look at the figures, they really don't. I'll mention a few examples.

Figure 2-3 is fine. It's identified as a causal tree. And it's kind of okay as a cartoon. It shows how one would lay out such lengths. And the cognitive basis document actually does lay out such links. One example is Figure 2-7 in that document that ties together the performance influencing factors, their mechanisms and what were called proximate causes in that report. I'm going to come back to that report.

But in your figures in Chapter 2, 2-5, 2-6, 2-8, the words say the figures show the links between cognitive activities, processors and cognitive mechanisms, and they don't show any links. They just show that they're connected. I think you ought to either change the text or change the figures to look more like what was in the cognitive basis document because they don't agree. It jumps at you once you spot it. It's easy not to see it. I didn't see it the first time through.

And then I had a -- well, let me go to the proximate causes. In IDHEAS-G, you changed the language from proximate causes to processors. But I might have missed it. I don't think you ever explained why you did that. I'm interested in why you did that. And it took me several years to get used to the first language and now there's new. And I'm not sure why you made that jump.

And the last one about Chapter 2, in a series of Sections, the first one, I think, is 2.3.1.3 on cognitive mechanisms for detection -- that's one of the macro cognitive functions -- you said you opened some bullets with some public capacity limits and that's true. But you don't show any links between those cognitive mechanisms and the elements of detection, D-l, D-2, D-3, D-4. And I'm not sure why not. It seems obvious. I tried to map them a little bit. So that one is kind of a minor one. But the other one, I think, is more important. If you can say anything about the proximate cause change of language, I would appreciate it. And I'll be quiet and listen for a while.

DR. XING: Okay. So thanks for pointing out those places. I think our team will look at the transcript of what you just said and discuss how we can change it, how we can better address that. And quickly why we changed from proximate causes to processors. Proximate causes was an earlier term when the pre-IDHEAS team tried to say what are the accompanying processes for human failures? And that's why that word was put in 2114. Later on when we moved to IDHEAS-G, we wanted to lay out more structure to accompany the model, to accompany to basic structure. And so first we look at why people fail. We look from the success phase first.

Okay. It's human need to perform detection. What are the things that they have to do in order to perform detection? And so the data is the same. If they fail, they will fail detection. So because we described the combination model from the success basis, how people do the work so, therefore, the process, even they appear at the same level as previously we called proximate causes, they are talked about the success factor. And the motivation for change was from one ACRS meeting, I think it was 2013. And there were two audiences that came to talk to me after the meeting. They really liked her. We talked about the success path first. So you need to understand how humans assess their work. They talk which is why they fail.

There was one bigger motivation we like to use the term processor instead of jump to failure, which is what a proximate cause means.

MEMBER BLEY: Thanks, Jing. I appreciate that. You know, for somebody who picks up your reports and reads them, I don't think that comes across. And it might be worth a couple words in

Chapter 2 of IDHEAS-G to clarify that. But go ahead.

DR. XING: Thank you.

MEMBER BLEY: Yes.

DR. XING: Okay. So we were in 8 or 10 years ago. Now this slide shows where we are now. So the top blue color box represents the areas that we are confident that we made an improvement in these areas. And the two areas, above that top blue color, I will talk about that later. So look what we have achieved. So in the HRA method of scope, IDHEAS in the HRA method is really for all nuclear HRA applications.

The next bullet, use of the human performance data. The human error data was basically used in IDHEAS because the method and the basic structure are based on the same cognitive basis model such that data can be generalized and used by the method. Previously, the HRA variability had issues that the data doesn't match the method so we couldn't use the data and the HRA variability. So IDHEAS improved HRA method of variability and enhanced the four areas that were identified in the HRA benchmark studies. Because it offered a systematic qualitative analysis guidance and the links between qualitative analysis outcomes to quantification of human error probabilities.

And for performance influencing factors, every performance influencing factor has a set of explicit attributes.

MEMBER BLEY: Jing, can I sneak in something here?

DR. XING: Yes.

MEMBER BLEY: I'd like to go to your bullet about data, about having it match the cognitive basis arrangement. Something came up reading the FLEX, and I think it was the expert elicitation part of FLEX. When we get into the analysis in that report, the names of the cognitive functions, not their cognitive functions; detection, understanding and so on don't get linked into this. And I'm wondering why. It makes sense on the data. It seems it would have made sense in your analysis of FLEX.

DR. XING: Are you talking to the expert elicitation or the FLEX evaluation using IDHEAS-ECA?

MEMBER BLEY: I'm pretty sure it was the expert elicitation.

DR. XING: Okay.

MEMBER BLEY: Whichever way you go, you ought to be anchoring what you're doing back to that cognitive basis in my opinion.

DR. XING: Mm-hmm. I will talk about that later. But to quickly answer your question, for expert in the FLEX expert elicitation were operational people. So we organized the data package for them in a way that was more fixed to their thinking process. We talked about it. They defined macrocognitive functions but that wasn't a major part. We asked them to do their measure. Maybe that's why you think there's a disconnection between the data and the macrocognitive function.

MEMBER BLEY: It makes sense to put things in their language. But since you've got this structure, it seems to me it would make sense to adapt their language and link it your basis, but you didn't do that. And --

DR. XING: We think --

(Simultaneous speaking.)

DR. XING: Yes. We picked the other part because one major purpose of that expert elicitation we want to have a better understanding of the PIFs, whether we can use those PIFs for FLEX and whether we can only need to subset them. So therefore, we actually itemize the data by different PIF back to the expert. And the expert found that that was very helpful. And they actually made the recommendation we should use that data from the HRA method to do the HEP estimate, stand-up behind the expert to do that.

MEMBER BLEY: Okay. Well, let me go just a little further. You're going to come to the FLEX stuff later.

DR. XING: Yes.

MEMBER BLEY: But since we've got this going right now, I want to dig a little further. Volume 1 and Volume 2 are the FLEX, the expert elicitation in the ECA, the event and condition assessment using your computer tool. You explain a little bit about why things are a little different between the two, but the reason there is Volume 1 and Volume 2 kind of implies that they all get linked together for their utility. And even if you change the language for the experts, I would think in your exposition and the expert elicitation report, adding words that would tie their language back to your structure would be very helpful in showing how the pieces all fit together. But, go ahead. Don't dwell on that now. It's a comment for your consideration.

DR. XING: Thanks. I really appreciate that comment. That was a very good comment. At the time we wrote the FLEX expert elicitation report back in 2018, we were still focused on the FLEX part because we could see this big picture. Thank you.

Okay. So we talked of a change that was made in Phase 3 error. And the model I want just to mention, the other sources, the other two sources of HRA variability. The first one, uncertainty in the scenario. The uncertainty would result in different analysis assumptions. So that kind of uncertainty, you can't do the scenario. HRA method cannot and should not eliminate the uncertainty. But what we can do is IDHEAS can provide a guidance on systematically identifying uncertainties in the scenario and the tracing for assumptions in the HRA process.

MEMBER BLEY: Can I interrupt you a second again?

DR. XING: Sure.

MEMBER BLEY: This is one that leaps at me because I've played with this one a lot. And I think the method to give more help to someone, especially if they're doing an expert elicitation, but even if they're not, if you're looking at difference in the result, we've often found when you see different, either an elicitation or people using some more prescriptive method, that when you see very broad differences in the answers and you get people to explain why they got their answers, you find that

Person A and Person B have really picked different subscenarios within the uncertainty of the definition we've given them.

And, you know, sometimes that means you might want to break one scenario into multiples to examine them but at least acknowledge where the uncertainty in the results are coming from. And then it's not so much uncertainty in performance of the method. It's variability in the thing you're analyzing, the particular scenario. And I think that's a real crucial one and one that deserves more exposition, both about expert elicitation and whatever tool you're using to quantify it.

MEMBER KIRCHNER: Dennis?

MEMBER BLEY: Yes. Go ahead.

MEMBER KIRCHNER: This is Walt. I'm sorry for interrupting. But, yes, on this one, I also am thinking at it. Now I'm an outsider. This is not my area nor is PRA, but this looks a lot like PRA. And so in this critical area of uncertainties in the scenario, would it be feasible to use the PRA of entries or, you know, that's also often done with the assistance of expert elicitation and so on, so that there's some -- I don't want to make this -- it's already fairly complex. But isn't there some way, at least for the at-power kind of scenario since some of the other, you know, going through the Level 1, 2 and 3 of the PRA for the existing fleet that you could mine that information as input into the scenarios --

MEMBER BLEY: Sure.

MEMBER KIRCHNER: -- and reduce the uncertainty? Because you would then start with what was also a -- pardon. I got a phone call. Sorry. I'll turn it off. You could use all that effort that went into the PRA to be the basis for at least starting on the scenarios.

MEMBER BLEY: Sure. And when you're saying you're not an expert, but you had some operating time and from that you can get this idea pretty well. But this method and the others all ought to be using the information in the PRA. But within a particular PRA scenario, they haven't looked at all the other things. You know, the things that get modeled there are the particular pieces of equipment that can challenge the core -- not challenge the core. But there is a whole world of other things going on and flavors within that one that can affect what the people do.

And, you know, one way is to identify them all in advance, which is a very big job. Another way is to do that to a reasonable amount. And one is you're quantifying when you find things that look wildly different and try to figure out why are they wildly different? Is it because just the people did it differently? Their heads weren't in the right place or the method didn't help them? Or was it because they were looking at things that were different but were within the definition of a single scenario or call it a scenario group.

And I think guidance in that area can really help and can also explain when you see a couple of orders of magnitude difference in different analyses that in many cases that's because they're looking at different detailed scenarios. Anyway, Jing, we took it away from you for a while. I'll put it back to you. But I think that's an area, for which there is plenty of experience to give better guidance. Now maybe this is done in the derivative methods or maybe it's done in some later improvements through IDHEAS-G. But go ahead.

DR. XING: Thank you. I appreciate the discussion. And the next item is related or similar to what we just said. In practice all HRA needs an analyst to interpret the information and to enter that to the HRA method. So it's largely relying on analyst interpretation. And the different analysts practices will result in different interpretation of the same scenario.

And the IDHEAS SPAR mutation, it has been also used as a structure process to make a clear documentation of each step. That provides a good possibility of transparency of analyst interpretation. We cannot eliminate the difference. They can still come up with different interpretations so we can say why they interpret it differently. So that will help us to reconcile the resulting variation. I will have an example of each of these items later on.

Okay. So we're ready to look at individual IDHEAS products. And you have seen these products in Sean's earlier slides. This one kind of recaps the process of how these products are related in such ways that go back to the combination basis for HRA. From that, we developed the IDHEAS-DATA methodology. And IDHEAS-DATA methodology is intended to developing application specific method. The first one we developed was the IDHEAS Internal At-Power Application. But I would like to say chronologically, IDHEAS Internal At-Power Application was completed before the IDHEAS-DATA methodology. We keep evolving and developing the DATA methodology.

From the general methodology used in the structured, we developed IDHEAS-DATA, use data to document various sources of human error data. And using IDHEAS-G and the data together, we developed the IDHEAS-ECA. And I should also put an arrow here so IDHEAS-ECA was also developed from IDHEAS with the input from 2018 FLEX expert elicitation. So on the bottom are a bunch of test team or pilot team applications of the products that Sean talked about earlier. For the rest of the presentation, I will give a relatively high level introduction of the three products, and I will talk about two examples of the application.

MEMBER BLEY: Jing?

DR. XING: Yes.

MEMBER BLEY: Okay. This is the last one I really want to jump on.

DR. XING: Oh, just jump on it.

MEMBER BLEY: You set me up here. The FLEX HRA expert elicitation you see as a source of data that the -- the data report and was used in the FLEX ECA. And now I want to complain about the numbers just a little bit. I don't usually like to do that. But some comments you received in public comments complained about the treatment of uncertainty. I got comments from members of the Committee before today that were very negative saying there's no real basis for how we tried to combine these distributions. For everybody else, Appendix D of the FLEX elicitation report summarizes the data from all their experts. And it gives a lower bound, an upper bound and a best estimate. I've seen some arguments back and forth.

The best estimate, at least in the report, isn't defined. Some people have said it should be the means. Some people said it has to be the median. And someone said part of the way you combined these works for me but not for median. But psychological literature, the older literature back in the 70s primarily, found that when you ask people for their best estimate, most of the time what they give you is the mode, the value that occurs the most often because that kind of gets anchored in your mind. And depending on the distribution, that might be very close to the median or maybe it's a little higher but that's a detail.

Arithmetic and geometric means on the upper, the lower and the best estimate is kind of hard to justify. Not the cognitive basis document, the report, your white paper report on the elicitation, by the way I think it's very good and Jing was one of the authors, it gives some descriptions of how you combine distributions. The one most often cited in that report as being the best way is to find a distribution that the experts agree represents the best estimate of the scientific community. And that's one I think you ought to strive for, using arithmetic or, like, additive calculations or geometric means or substitutes, and we give some basis to that.

Now the basis that talks about geometric means is really talking about an individual's high and low estimate and using the geometric means to get a mean estimate that does work in many cases quite well. By experience, I'm not sure theoretically. But whichever is right, if you go to the tables, the thing sent me to looking at the details was you make a statement that usually the geometric mean is a little bit less than the arithmetic mean for each of your combinations across the experts. And I said, I thought it would be bigger than that. And when I looked, yes, sometimes it's a lot bigger, sometimes not.

But always the geometric mean ought to be lower than the arithmetic mean. I think we've heard that one. So I don't remember the details. So I looked at the tables, and I found a number of cases where that wasn't true. The geometric mean was higher than the arithmetic mean. Those are in Tables D, delta, 5, 10, 11, 13, 16 and 21. So I took out my calculator, and I calculated the geometric means. And in all cases there was an error in the table, substantial. The geometric means are always less than the arithmetic means.

I checked a couple of arithmetic means, and most of them were right on, but a few were off, not by too much. But I don't know why they would be off at all. So you've got a bunch of errors in those tables, and you're feeding that in as data for people to use. You need to go back and fix that. That's all on that issue for me for now.

DR. XING: Okay. Thanks. I really appreciate the comment. We will come to some of that later. Before that I can quickly say something about that so backward. So for the geometric and arithmetic mean table, the errors were the -- I know where the possible errors we calculate, why analysts send their estimation later also. There are some data entry errors there. So I will definitely go back in the text and fix that.

And the tool for using the number, I am

very much with your comment on we didn't estimate before distribution. But in terms of its impact on IDHEAS-ECA, we didn't use the expert elicitation number to inform the HEP, the numbers we need to calculate HEP in IDHEAS-ECA. The reason was because expert elicitation data, because that kind of data is multi-component, the expert estimates the error to HEP of the entire action, which consists of multiple failure modes and the multiple PIF conditions.

So we couldn't disassemble that data. So we only used the expert elicitation for verification purposes, like, we got the IDHEAS-ECA, developed it. We tried out the expert elicitation and specification of the scenario. And, we say, okay, the number, you say it is not far from what a data expert got off of that expert got because different expert has different assumptions. So that's the way we -- that's what caused the numbers we used for IDHEAS-ECA.

(Simultaneous speaking.)

MEMBER BLEY: Would I be able to find that in IDHEAS-ECA? I didn't. That's why I ask.

DR. XING: Yes. It's not in the report. But I can give you my scrap of pages on -- I tried to say if IDHEAS can refute the numbers in the FLEX expert elicitation, that was a -- has two sides.

MEMBER BLEY: I think if this gives more confidence in ECA, it would be worth including.

DR. XING: Yes. And so the reason that we only had expert estimate the upfront and the low level and most like HEP, back to 2018 it was the best experienced expert did not have much experience, of survey experience, in errors of FLEX equipment. So the cognitive expert and our expert clearly indicated they didn't have sufficient analogy to come up for distribution. The best that they can do was the upfront and lower level and the most likely case.

MEMBER BLEY: Okay. I think you got to work more with it, but if your claim earlier, or Sean's claim, that IDHEAS-G is human-based and applicable across the board, you wouldn't need specific ECA experience to be able to evaluate the human -- the effects on humans of events that could occur during the FLEX operations. Are your methods general enough to cover that?

DR. XING: Yes, that's true.

MR. PETERS: But you do want to test it, though. That's a key, Dennis, yes.

(Simultaneous speaking.)

MEMBER BLEY: Did we actually test it? I don't see that we said how we tested it. I mean, I'm hearing it now, but I don't remember reading it.

MR. PETERS: Jing, would you like to answer that?

MEMBER BLEY: You don't have to do it today. That's something to think about. You know, it's almost a good story, but it ought to be written down somewhere.

DR. XING: Okay. Yes, so that was the reason we didn't do that before distribution. But the main input --

(Simultaneous speaking.)

MEMBER DIMITRIJEVIC: Sorry. I was waiting to get to the FLEX part of presentation to discuss this. But I think the one of them -- the level of discussion that you have is very good. There is the measure of elicitation in white paper, which wasn't used in the way -- the integration process as described in this paper was not used in FLEX elicitation. Developing distribution, you know, is essential for this integration process because you cannot just integrate numbers. And those were not the most likely numbers. They represented the middle. There were 50 percent that mean, like, whatever 50/50 tends to be higher or lower this number. Those are not the same as the most.

And actually we cannot even talk about 50 mode and middle without assuming distribution and how integration of the basic FLEX was assuming to talk to the symmetrical distribution where the 50 percent and mean are the same. But the difference between 1 and 99 percent, well, anyway, not to put the contents in technicality, I think that proper integration of the data presented in FLEX external elicitation was not done, and it should be done. And in that case, maybe this integration fact would be omitted from the report without discussing distribution. It doesn't make any sense to do integration.

(Simultaneous speaking.)

MEMBER DIMITRIJEVIC: -- the interval in distribution but that should be also part of preparation. And I think that this data has a value even if it wasn't integrated because obviously you were not using integrated results in the Volume 2. So maybe this moment, this integrated result should not be presented.

MEMBER BLEY: Well, Vesna and the Committee and Jing, the real reports, regulatory information letters on this, have been published. Where I'm leaning is to say if or before you ever publish a NUREG based on this, this should be revisited. Anyway, back to Jing.

MR. PETERS: Yes, and, Dennis, I'd like to just weigh in just a little bit. The original intent of the FLEX HRA expert elicitation, we did this in 2018. This was prior to the development of IDHEAS-ECA and prior to its publication. So the original intent of that work was to give our reviewers over in NRR a concept for the feasibility and capabilities of FLEX because they're trying to encounter this in a day-to-day, like, license amendment or, you know, no ed type situation where they wanted to get some type of credit for this work.

So what we saw in this was an opportunity to get some data from it. But it's original intent was not to develop data for IDHEAS-ECA, but it was to help the users in NRR. And so from that, obviously, direct, as Jing indicated, direct one to one data capture is not kind of the way we would normally do it in an IDHEAS-ECA program because, you know, IDHEAS-ECA is built from the micro level. And this is kind of macro data that comes in. So I just wanted to give a little more context behind it.

MEMBER BLEY: Yes, thanks, and, you know, the horse is out of the barn sort of thing. That makes sense. A few words in the introduction to put that in context might have helped, but it makes it up.

DR. XING: Thanks for this discussion. I really appreciate it. Okay. So let's move forward. So we will move to the next section, the individual products, beginning with IDHEAS-G. So just quickly what is IDHEAS-G? First, it's an methodology for developing applications specification to HRA method, and it's also a platform for generalizing and integrating human error to support HEP estimation.

And finally by itself it is the general -- it can be used as the general HRA method for human event analysis and human error root causal analysis if you don't want to have to get an HEP number and are only interested in what are the causes and how to prevent the causes. So I didn't see -- it is consists of with the three parts. It's consists of a combination model as the framework for HRA. And it's the implementation in the HRA process that makes it an HRA method and the detail, the guidance for HRA application. So we had all those appendix into a bunch of them for having the guidance for different elements in IDHEAS-G.

So the combination model has two parts, a combination basic structure, which is discussed in Chapter 2 that Dr. Bley mentioned earlier and a PIF structure. We implemented the combination model in both stages of the HRA process. Stage 1 is the scenario analysis. Stage 2 goes into the detailed modeling of important human interactions in the scenario. Stage 3 is for HEP quantification. Stage 4 is integrative analysis, which includes uncertainty identification documentation and dependency analysis.

So I will talk about each of these elements at a very high level, but feel free to interrupt me. Okay. So the combination basic structure, the human task that is represented takes place inside a micro combination function. We take the information and in expanding the situation, make divisions of plans and executing the plans of the position and the inter-team coordination in the bigger complex working environment.

So failure of each of business microcompany function can lead to the failure of the human task. And each macrocompany function is achieved through a processor, which each processor is a key element to how you achieve the function. For example to achieve with the texture. It's not just that you take a quick look at that and stop. It starts with the basic you know what you're going to look at so you have a mental model for what you're going to look at.

And you will attached it to the top of the queue, and you perceive the information but you also need to recognize and classify that information and the unique verifiers of that information. But you process the information you need to verify and properly need to correct it. Then at the end, the last of the process, you need to export what you perceive. You either use it for your own use in your decision-making or you gave that to your teammates or whatever. So those are some processors for obtaining the detection.

MEMBER BLEY: Hey, Jing.

DR. XING: Yes?

MEMBER BLEY: Yes. This is Figure 2-3 out of your report, which I said was a good cartoon. And it does show that a single PIF can affect more than one cognitive mechanism and likewise cognitive mechanisms can affect more than one processor. And that's what disappears in the figures as it continues through the chapters. I just wanted to make that clear to you.

DR. XING: Okay. Thank you. Now I see what you mean. Okay. Probably we want -- maybe because we wanted to make the figure look less messy.

MEMBER BLEY: It is much less messy, but the words don't match it any longer.

DR. XING: Thank you. I'm pleased you said that. Yes. Yes. As you said, the messy part is because they're multiple things not the one to one thing, I think, like the combination mechanism for attention not the company's mechanism for detection is attention. But it also affects other processes, other functions. And with that, so the last part of this slide is most common are the PIFs. So basically if you look from left to right, a PIF can effect a combination, mixed mechanism not exact thing. Then the mechanism leads to increased chance of error in one or more processes and an error in the process would be a failure of the detection.

MEMBER BLEY: Jing, you explained why you changed the language to processors. But is that common language in the psychological literature?

DR. XING: No. Well, I took it upon myself from my years working on companies on combination with your side. There wasn't a single term to describe all those things.

MEMBER BLEY: Okay, That's what I thought.

DR. XING: Yes. I tried many, many versions, I tried to come up with a word that makes sense. Okay. PIF structure. So IDHEAS uses the PIFs to model contacts. Contacts are the combinations that challenge of a facility of human performance in this scenario.

So IDHEAS collected by contacts in four categories, in environmental institutions and systems, personnel and organization and tests. For each category there are several PIFs associated. Some parts look at the first category, environmental elicitation. The PIFs are acceptability to the workplace and include the entire path. And the workplace visibility, noise, cold and heat, humidity and the resistance to physical movement.

So based on the PIF that's at a high level. And as we said, to give a more explicit description of the PIFs, in others you can assess them more consistently, but each PIF will develop a set of PIF attributes. Every attribute represents one way that the PIF can challenge a combination method and therefore increase the likelihood of failure or human error. So we can look at example of the attributes. So one cause of PIF, human system interface, the detonation into HSI, human system interface, refers to indications such as takes place in indicator amounts and the controls. So the indication is for the technical information controls up for team actions of systems.

Some attributes, this is not a full list. Some attributes, like first off was the indication, it's similar to other processes nearby, are the indications that have no work, or come to the control. The labels on the controls do not agree with what you have documented. And in a worst case, controls are not reliable if the person is not aware of the controls are not reliable so based on the more explicit description of what a PIF is.

So looking at IDHEAS-G, how IDHEAS-G model human failure event that comes to other HRA process. So Stage 1, scenario analysis, and Stage 2, modeling human action. So starting with the human failure event and we have guidance to identify the human actions and context in the event and the event contexts but that's the scenario for this part.

Also scientists will model the task this with a five micro combination function or the more detailed lever, you can model the failure of the task, basically, the failure of those processors, which now we can say the failure of a processor is what we call the proximate cause in 2114 or you can model the failure of a task in very detailed and elaborate using application specific failure mode developed for the processes. IDHEAS-G provides a set of examples for the detailed failure mode.

For modeling the context that we have plenty PIFs and their attributes. And we also have model templates. So after that model, now we come to Stage 3, quantification. For quantification, the HEP of the human study event consists of two parts. PTs attributing to 10 available and 10 requirements. So when you have less time, when you have time available on what you require it to do to complete a task, the failure have a chance of error. So PT is the probability that less time.

And the PC is the error probability attributing to the combination failure mode. So you look at the complicated human error event, and we had multiple critical tasks. Each critical task may have one or more failure modes if you look at all the failure modes. That's the probability appropriated back to the total HEP. And IDHEAS-G, this slide shows the three ways to estimate HEP off of the PC part. Ideally, you can do the calculation from the number of errors, you may divide it by the number of occurrences you perform test --

MEMBER BLEY: Jing?

DR. XING: Yes.

MEMBER BLEY: Just so we don't confuse each other and ourselves, on your last slide, when you talk about critical failure modes, if we go back to what was Figure 2-2 in the IDHEAS-G report, human action and the number of tasks and under that the macrocognitive functions, the critical failure modes correspond to a particular task, right?

DR. XING: Yes, the failure mode corresponds to --

MEMBER BLEY: A task somebody has to carry out, and they fail it. Yes. Just so they have a relate back to the IDHEAS-G book.

DR. XING: Mm-hmm. Yes.

(Simultaneous speaking.)

DR. XING: Thank you. After this, I would like to mention that I think that very useful in IDHEAS-G. The HRA community has been -- how we break down our human event to the task, where is the level to stop? IDHEAS-G has a guidance on what it means by critical test and how to break -- where you should start breakdown time. And so far the feedback we got that was a very useful thing. The main concept is you break down into critical tests only when you have to, which means a the PIF can't in the HEP so you cannot apply. Then you have to break them down.

Okay. So back to the calculation. Yes. If you perform this -- you have the data that you performed identical tests and the identical context for 10,000 times. And you can certainly get the error probability from that data. But unfortunately the data is really eventful. So we still need enough time to rely on expert judgment. That's another way to estimate HEP. And IDHEAS-G also comes with HEP quantification model that you can use that model to calculate HEP.

MEMBER BLEY: We're getting --

DR. XING: Yes?

MEMBER BLEY: You just brought up the language I wanted to get up eventually. Some of the comments you repeat, some others talked about this. You just presented us, we can use expert judgment or we can have data. The FLEX expert judgment report does the same thing. And as some of your commenters pointed out, it's not either or on this. In fact, rarely is your data so perfectly applicable that you don't need to bring your judgment to the process.

And often a good place to start is an elicitation to get what invasion analysis you'd call prior probability distribution, which is a good place to start. And as you get more data, you update that. I would say the one caveat there is when you generate such distributions, you need to ensure they have at least some tail because anywhere the prior is identically zero, no data was ever affected. So you have to be careful about that, and there's a number of ways to deal as you update things using Bayes' theorem, ways to double-check and make sure you haven't started to acquire what's causing a problem.

But you don't talk about that anyway. You kind of make it -- you either use expert judgment or you use data. And I don't find that a reasonable approach. I think you use a combination to the extent it makes sense. And when there's more data to accumulate, you use the data long with what you have previously. And I don't know anywhere you talk about that either in IDHEAS-G or in the FLEX expert elicitation report. And I'm not sure if you talk about it in the white paper. It would make sense if it were in the white paper. It probably is, but I don't remember for sure.

DR. XING: Okay. Thanks for the questions. The quick answer is that's the reason we got so far with data in the report by saying you can use one based approach or a combination of this.

However, it was our intention, we purposely failed to mention the prior approach you just talked. The reason was we saw from the studies actually in the IDHEAS scope and used that approach. The result shows that the less you set the prior because we don't have a huge, huge amount of data, the final result is putting innovation out of the final outcome is pretty much from the advised prior. I think, as you said, it had to be cautioned with the prior. So --

MEMBER BLEY: Yes, but if you don't have much data that's probably better than using data that might be peculiar.

DR. XING: Yes. So at this point we don't have good confidence, which use data that might mislead you or not use it. You don't know where to start. So we would rather wait, like, in the future if we are more mature in that area, with more studies and then we introduce that into future versions of the report.

MEMBER BLEY: Well, I reiterate, it's not an either or proposition. And the example you cited is just the example I would cite to the other argument. If your data is so sparse that they don't mean anything, you're probably better using the best judgment you can bring together on an issue. We can talk about this more later. It's not in any of the reports except maybe the white paper. And it ought to be somewhere. So be thinking about it.

DR. XING: Okay. Yes, the white paper. I wrote that, like, five years ago. I will read it. But I definitely agree that we should discuss it in the white paper. Okay. So the last stage, integrating analysis, I would like to mention based on ACRS subcommittee's recommendation from the previous meeting, the previous, previous meeting, 2019 meeting, the staff developed IDHEAS dependency model, which this model is different from what has been traditionally used to start model.

I wanted to go through the details on this slide how the model works. Basically, it's based on the IDHEAS combination structure. So you identify dependency context and the model dependency context, the IDHEAS failure modes and the PIF then calculate the HEP for that context. That was basic the concept. And that now we have a workgroup going through the analyses for guidance for how to use this dependency model. So when we get that guidance advanced, we will update IDHEAS-ECA and put the guidance in the IDHEAS-ECA report and software.

So a summary of IDHEAS-G, just as we said earlier, I think we said, we already talked about the first of three bullets. I just want to emphasize that because it's human centered, the last bullet is applicable to all nuclear applications. So if no more questions on IDHEAS-G, I will move to IDHEAS-ECA.

MEMBER BLEY: Let's not move. Let's say we're an hour and a half in, and it's time for break. I don't know how many slides you have, Jing. Is this more than halfway through or about halfway?

DR. XING: I think it's one-third.

MEMBER BLEY: Only one-third?

DR. XING: Yes. IDHEAS-ECA and IDHEAS-DATA, because we already had most of discussion upfront.

MEMBER BLEY: Okay. So maybe you can skip some of that. Okay. Well, let's take a break. And we have to finish it, I think, 11 o'clock my time and 1 o'clock in Washington. Let's take a 20 minute break, about a 20 minute break. Let's come back at 25 after 11 Eastern Time, and we'll take this up again. And when we get to places we've already discussed, feel free to go quickly or even skip some slides.

DR. XING: Okay.

CHAIR SUNSERI: Hey, Dennis. Hey, Dennis. This is Matt. Let's just round it off to 11:30.

MEMBER BLEY: Okay. Good idea. Be back at 11:30.

CHAIR SUNSERI: Thank you.

MEMBER BLEY: We are -- I almost used the wrong word. We are in recess.

CHAIR SUNSERI: Thank you.

(Whereupon, the above-entitled matter went off the record at 11:07 a.m. and resumed at 11:30 a.m.)

CHAIR SUNSERI: Okay, members. It's 11:30. We will reconvene the ACRS session here. I'll start with the roll call to confirm that we have the quorum returned. Ron Ballinger?

MEMBER BALLINGER: Here.

CHAIR SUNSERI: Dennis Bley?

MEMBER BLEY: Here.

CHAIR SUNSERI: Charles Brown?

MEMBER BROWN: Here.

CHAIR SUNSERI: Vesna Dimitrijevic?

(No response.)

CHAIR SUNSERI: Walt Kirchner?

MEMBER KIRCHNER: Here.

CHAIR SUNSERI: Jose March-Leuba?

MEMBER MARCH-LEUBA: Here.

CHAIR SUNSERI: Dave Petti?

MEMBER PETTI: Here.

CHAIR SUNSERI: Joy Rempe?

VICE CHAIR REMPE: Here.

CHAIR SUNSERI: Pete Riccardella?

(No response.)

CHAIR SUNSERI: And Vesna Dimitrijevic?

MEMBER DIMITRIJEVIC: I'm here. Sorry.

(Simultaneous speaking.)

CHAIR SUNSERI: And Pete Riccardella?

(No response.)

CHAIR SUNSERI: Okay. Dennis, we have a quorum. Pete, I'm sure, will join us as soon as he gets back. So I'll turn it over to you for continuation.

MEMBER BLEY: Thank you very much, Mr. Chairman. I mentioned to the committee that we've had so many discussions with the staff before this meeting. And our main purpose here is to look very closely at IDHEAS-G and decide what is the primary intent of the SRM.

We are also looking at the other reports and we'll address their stage. But the main focus is IDHEAS-G. At this point, I'll turn it back over to Jing and we'll continue with the presentation. And just a reminder, Jing, we do end at 1:00 o'clock your time. And so jump through the things that we've already discussed. Go ahead.

MS. XING: Yes, thanks. So I think I'll go quick, IDHEAS-ECA and IDHEAS-DATA, to leave us time to look at the two examples and talk about the revision. So some IDHEAS lead to IDHEAS-ECA. Basically, we're talking of developing application specific method.

So this is an approach we develop specific methods. Of course we have guidance in IDHEAS-ECA, IDHEAS-G. But to make it short, you just try to make your best tradeoff between going through very detailed analysis and meet users' needs.

So essentially, every IDHEAS is a specific method. It's a subset of IDHEAS-G, one way or the other. So for IDHEAS-ECA, it was measured from our users in NRR.

The scope of the method was to be able to perform event and condition assessment for all NRC risk informed application. Specifically, the method should be applicable for plant HRA. The requirement is easy to use, not overburden HRA analysts.

And the resource we had, we had human error data. We had -- we already performed the FLEX expert annotation, of course, IDHEAS-G. I just want mention, look at the data between IDHEAS-G and IDHEAS-ECA.

It's important to realize the qualitative analysis guidance for application specific method stay the same as in IDHEAS-G. And for failure mode, we use IDHEAS-ECA, use the high level setting mode. And we talked to experts in --

(Simultaneous speaking.)

MEMBER BLEY: Jing?

MS. XING: One per person was to select a subset of PRA that was specific for FLEX. Then it turned out all the 20 PIFs are important. So IDHEAS-ECA preserved all the 20 PIFs.

Total, the PRA have a compressed set of PRA attribute, means we combine the sub-attribute. And then the special feature of IDHEAS-ECA is it use the HEP quantification model. The numbers of the prong to in the model came from IDHEAS-DATA.

We're not going to talk this. This is a quantification model. We're not going to talk this again. But mainly, I would like to --

(Simultaneous speaking.)

MR. PETERS: Hey, Jing.

MS. XING: Yeah?

MR. PETERS: Dennis is trying to break in.

MEMBER BLEY: Thanks. Can you go back one slide?

MS. XING: Okay.

MEMBER BLEY: You started up at the qualitative analysis guidance being the same as IDHEAS-G and that really deserves some emphasis. The empirical studies that Sean discussed really flag that as a key area where a lot of HRA analysis has gone bad in the past and that people didn't really thoroughly look at defining what they were analyzing and what was important. And that's the real reason why you're requiring that qualitative analysis to be thorough in every application. Go ahead.

MS. XING: Okay. So mainly I want to say too, in order to use the quantification model, we need to get all the numbers, the failure HEPs for every failure mode and every PRA attribute. So properly, I never calculate it. But probably we need around somewhere from three to five hundred numbers. All those numbers came from IDHEAS-DATA.

And I just would like to emphasis. So here is the IDHEAS-ECA process of diagram. So that diagram we had in our report.

What you want to look at this line, the three colored boxes are the ones in our software that's for calculation for calculating HEP. And all the rest are qualitative analysis. And also at the end is certainty documentation is not in the software yet.

So we're really emphasizing you need to go through this whole qualitative analysis before you use the software to calculate HEP. That's what we emphasize, but no guarantee analyst will do that. So we have the ECA report and --

MEMBER KIRCHNER: Jing?

MS. XING: Yeah?

MEMBER KIRCHNER: This is Walt Kirchner. Can you go back one slide?

MS. XING: Yeah.

MEMBER KIRCHNER: Your slide makes the point that I had asked earlier. It shows the PRA as kind of the input for the scenario narrative development. How close coupled are those? Do you take the event trees to develop your scenario narratives and timelines? Or what's the relationship there in a typical application of the PRA model as input to the IDHEAS-ECA process?

MS. XING: Okay. We just in our dependency workgroup so far five -- so far four people presented how they take from PRA model go to the scenario narrative. And when they only have a PRA model, they do the event tree. They take the event tree and go to the developer's scenario narrative.

Then in that process, you have to make many assumptions. And there's other examples we had in dependency workshop were from HEP. There you have more detailed information. Pretty much, you already have a scenario there. You just need to organize the information to IDHEAS qualitative analysis for guidance format.

MEMBER KIRCHNER: Since the PRA often involves expert elicitation or PERTs and so on, does that then replace the need for that expert elicitation to develop these scenario narratives and timelines? Or is that -- see where I'm going with that? Is that a redundant thing, or does the PRA suffice to kind of give you a consistent framework to develop the narrative and timelines?

MEMBER BLEY: Jing, can I help on that because I know --

MS. XING: Yeah.

MEMBER BLEY: -- you don't do PRA. Walt, if you don't mind, I'll --

(Simultaneous speaking.)

MEMBER BLEY: -- because in a well done

PRA that's integrated with this HRA. You might do all of that together, or you would at least do a lot of it, as you suggest. And then when you refine the HRA, you might and do additional investigation. But -- and you start with the PRA, but that's why -- and I don't remember if IDHEAS-S really recommends this, but it ought to. The team doing the HRA ought to include the people who are really knowledgeable about the PRA and the engineering of the plant.

MEMBER KIRCHNER: Yeah, that's where I was going with that, Dennis. Thank you.

MS. XING: Thank you, Dennis. Okay. So we talk in the process to enforce the course guidance. We have a set work center making the analyst do step by step, follow that process. And we also develop preliminary training materials. I think that's an area we really need improvement to develop better training materials.

And the good news is we have IDHEAS-ECA software. So for everyone, it's a computer interface and placement in the ECA for HEP calculation. We start out to recommend you need to first analyze the event documents that result in the work space, then enter that information in calculating HEP.

However, because the software is so

lovely, we couldn't prevent people from jumping to play with the software. That's something we need to think about in the future. This is the PDF snapshots of what the software look like. So any question on IDHEAS-ECA?

(No response.)

MS. XING: Okay. So I will move to IDHEAS-DATA. We always say HEP is a function of PIFs. It's easy to say that, but not so easy to solving that function with a lot of data.

The good news, we know that lots human error data exist from various domains. And the bad news is it varies in format, basically the content, the number of details. We talk about that has been a hurdle of using data.

So the IDHEAS approach is simple. The way of performing IDHEAS HRA for every data source, you take the data source thinking about this analogy to the PRA event. And then you identify the task in the data source, the context. Then model the task with IDHEAS combination failure mode and model the context with PRA. Therefore, at the end, we will get not human error probability, most likely a human error rate of a failure mode for the human PIF.

MEMBER BLEY: Jing?

MS. XING: Yeah?

MEMBER BLEY: Sorry. I keep interrupting and telling you to go faster. We are awaiting your peer review work that's been done on the data report. But I will make one comment for me. I've read it and I have a lot of trouble understanding what I find in the appendices.

And I don't know if you're still working on that or not or if you think that's all complete. But it's not transparent to me yet. I'll keep working on it. Go ahead.

MS. XING: Yes, actually, I fully understand when you say is not transparency to see how we come from the data sources. We bound them to a 30-page report to one line in the appendix table. So yeah, I agree that documentation part, we intend to publish that documentation.

MEMBER BLEY: Good.

MS. XING: Okay. Any question?

(No response.)

MS. XING: Okay. So I will keep going. So we do the same to another data source. So it put the entire data application, but it will still end up, it will end with the error rate of some failure mode and some other PIFs. So that's what we call it data generalization, generalize them into the same format.

So the process with the first evaluation is assess the data source, locate the context, the variable measurement to use the uncertainty in the data source and user generalization by representing them with the CFM and PIF, and finally, integrated the analyzed data for our purpose. And I would like to talk about the data sources. I would say over the last decade since the beginning we collecting human error data, we probably would do several thousands of research papers that had numbers on human error rate of related measures.

So we have collect them and based them in five categories. The first category are nuclear simulated data and operation data such as the NRC's SACADA database collecting operator simulator performance. And the HuREX is a similar database that carry the current nuclear power plant operators and the German's nuclear power plant maintenance database. So those are the sources for this category.

And the second category is operation performance data from other domains that are delegated to some action in nuclear power plants such as transportation, offshore oil, manufacturing. And a lot of the data come from experiment studies in the literature when the combinated (phonetic) behavior sites the human factors in the neuroscience literature. That we have thousands and thousands of the literature.

And we also collect data from expert judgment. Also we don't use them to calculate HEP. We use them for verification.

MEMBER BLEY: Jing?

MS. XING: Yeah?

MEMBER BLEY: I'm going to go back to C. Oh, first, we urged you to do this a long time. It's a massive job and that you've taken it on is really wonderful. Experimental studies in the literature, many of them I've read are kind of graduate school projects that people are doing. And so for those kind of studies, have you found ways to adapt what you see there to somehow account for the fact of the relevance of expertise to the tasks they're doing in some way that relate to what people would do in nuclear power plants or in other professional fields?

MS. XING: Well, it's a talking detail. I can talk about that all the way to five o'clock today.

MEMBER BLEY: Is there anywhere you've documented that? I don't know that I saw it in the data report, but maybe you have documented that in there.

MS. XING: It's not documented, but that's a very good point. So we should document it.

MEMBER BLEY: It's really key for some of this, at least for some readers who say, I don't think that's relevant at all. And if you can explain the relevance, and you can't write books on each of these. I know that. But somehow clearing up the relevance to the particular element of human performance that you're addressing, I think it would add a lot of confidence to users of the data and ECA, of course.

MS. XING: Okay. I think I was at least probably add appendix just on the selection of data sources. And to make --

MEMBER BLEY: I know this keeps ballooning. But it's --

MS. XING: Yeah.

MEMBER BLEY: -- so much work already that to not make it clearer would be a disservice.

MS. XING: Yeah. So maybe the next slide can sort of answer your question, not specific on this category. So this slide is about data source evaluation. And especially for those experiment literature. We look at the participants, like they are last -- at the last meeting, some are asking why we use the normal thought --

There's a typical word used in experiment literature means -- for example, one study can study the people with a color vision deficiency. So that's not -- we're not going to use that data. And for the participants and there are plentiful from the past, and there's a good sample size in the study.

And we look at the measurements used. Of course, human error is preferred. Sometimes the test of performing measures relating to human error rate, we also take that. And the specificity, if the experiment of the original data source give a clear description of the task and the context, therefore we can say what are the CFMs, what are the PIFs. You can identify those.

And that's what I say. I can talk about, find out how to evaluate it. It varies, uncertainties, in the data source. And we look at uncertainty in the data source.

Ideally, uncertainties are controlled. They made a specific control on the uncertainty. And basically they talk about what are the uncertainties, how they would affect the results. That's what we need this for.

And also the breadth of representation, that's related to Dr. Bley's question. I can give a rough estimation. We probably select less than one percent of the experiment literature we reviewed for our -- codified for our data sources. So in regard to them not codified because of more reasons than this five elements.

MEMBER BLEY: So that's really interesting. And I think having that appendix you talked about would really enhance this report.

MS. XING: Okay, thanks. And we generalize basically for each piece of data source we selected. We likely performed that and applied IDHEAS-G and then take the generalized data, document it in IDHEAS-DATA structure.

I guess they had 27 tables, one table for each performance influencing factors. That's Table 1 to 20. And we have seven other additional tables to capture other information we need in HRA. Like, where was the HEP of failure mode which means though apparent PIF, there still can be some hidden of uncertainty there. You're still getting a low HEP rate.

And how the PIF interaction document in the data on the effect of more than one PIF come to play, how they get combined. The attribution of time needed to complete a task and largely how the various factors modify the time needed. There's the data that you perform this task in daytime or in the dark, for example.

And we also collect -- I wouldn't say those -- probably we shouldn't call that data. But we call that empirical evidence on dependency, on recovery of human action, and the main drivers to human events. The last three tables are still preliminary. We just started.

So a quick summary where we are in IDHEAS-DATA. By 2020, we documented and generalized the data in the nuclear operation simulator data in SACADA, HuREX, and some human studies, not all. So far, we generalized somewhere between three to four hundred paper literatures of data sources.

Another 200-plus were selected for generalization. We hadn't got time to do it. And the generalized data were independently verified and revealed by PNNL. So it would be a NUREG report on their evaluation which will fill in the data in IDHEAS-DATA how you going down from 100 pages to two lines.

So in the future, we do need human error data for teamwork and organization factors. They're not related to these errors, but they don't talk about the human errors. The performance used cannot somehow relate to human error.

Overall, data generalization is an ongoing continuous effort. And the data integration should be periodically updated. That's the -- I think Sean will talk about that at the end. Okay. Any questions on IDHEAS-DATA?

(No response.)

MS. XING: Okay. So I will move to the two examples of using IDHEAS, the 2018 FLEX expert annotation and the 2019 FLEX evaluation. So the objective for 2018 FLEX expert annotation, as Sean talked earlier, one, because NRR at that time had the (audio interference) reviewed the PRA applications related to crediting FLEX equipment. And we -- sorry, yeah. And I did at that time did not directly generate HEP numbers.

So we intend to develop an application-specific method from IDHEAS-G for that purpose. So we go back to the message we want to first, a better sense to quantify some HEPs of representative FLEX action to give us some benchmark where the HEPs are likely to be. And we do that for using FLEX equipment to do the FLEX design scenario and for added defense-in-depth during the non-FLEX design application. That's what our NRR users need.

And another important purpose is to evaluate the performance shaping facts -- performance enhancing factors in IDHEAS-G. And with the information we hope that maybe we can select a subset of PIFs that are unique for use of FLEX equipment. And also, we --

(Simultaneous speaking.)

MEMBER BLEY: Well, are you going to say more about that?

MS. XING: Yes, for short, we can say we select the object. We were not able to select the subset. That's why IDHEAS-ECA had all 20. So yeah --

MEMBER BLEY: Okay. That doesn't surprise me. In your report on Item 1 here, you point out that you kind of try to generalize these to be appropriate at most places but not all. And then in the ECA report, they were very specific to plan. So the details of plan specifics and scenario specifics I assume is what makes number 2 not quite work the way you had hoped.

MS. XING: Yeah, like, especially when you come to the FLEX design scenarios, everything can happen. All those PIFs can play a role. And the first objective as we also said, the intention was to have the experts to quantify the contribution of the PIFs, the HEP.

And that's when we ask them to think about the macrocognitive functions, how this PIF would change the error rate, the probability of failure detection and failure decision making. And again, I would say we didn't achieve the objective. But we got a very useful message from our expert panel.

The experts were given the human error data of (inaudible) by different PIF. And they said, you already have this data. You should use this data to develop a method, not from our judgment. So that was a good message we got.

So the expert elicitation process, it was sponsored by the NRC. And we use the white paper guidance in place that, yes, we already talked. And the author of the white paper guidance, we didn't quite follow the process in term of coming -- have an expert come up with a probability distribution.

So what we did, we had an extensive data set on HEP, gave those to the expert. And we had five meetings and one face-to-face workshop. The expert panel consists of three NRC staff and three industry experts who are knowledgeable in PRA, HRA, and implementation of office of FLEX strategies and the maintenance practices at a nuclear power plant.

So we had a former shift supervisor operator, and we have an expert from PWR Owners Group. And we also have an NRC expert approve text (audio interference). And the expert presented two scenarios and a FLEX design scenario and which means in the scenario, basically IDHEAS-G is followed by an SBO.

So when IDHEAS-G is done, you will prepare to think about use the FLEX equipment as a backup. And the FLEX design scenario and which is the SBO caused by a super severe -- by a severe external event with super strong winds and flooding. And we evaluate five FLEX actions of practice use of proper generator, proper pumps within a water storage tank, ELAP restoration and disabled shed.

And one thing we did use, this is an answer to Dr. Bley's earlier question. One thing we did offer the expert to come up with a scenarios. We characterize them with IDHEAS-G performance utilizing factors.

And so this was an iteration process. Expert will come up with the performance shaping factor. We were able to ask more detailed information to experts. So experts will fill in more official information.

And for example, this is the environment context for the non-FLEX design scenario. It was a design that the environment has no impact. It had no weather. But it was a normal day. And there may be some water in the plant due to lots of ups and downs. They bring down some debris which can cause difficulty to transport FLEX equipment.

It was -- we purposely said it was cold. But the experts, it's cold, but not to the extent making error or unable to work. So in the FLEX design scenario, so we have this data change. You've got poor lighting for some parts of the work. Darkness, fog, smoke, and dust, all this could happen.

And there are some places the water's accumulated so the cold can have difficulty to the travel path. And the physical resistance faces a lapse in environmental PIF. So you got strong winds that would focus the debris to intake structure. Therefore, you have difficulty. Experts have difficulty access the covered path, and it's very cold.

So I -- well, already we talked probably it doesn't make sense to average -- do an arithmetic average of expert's judgment. But I will just show the -- illustrate some insight we learned from expert elicitation. So this would result from declare ELAP.

The action is declare ELAP by 60 minutes if power is not back within four hours. So you need this judgment there. And so expert actually come up for high, high, high and stays here on the average. Pretty much, every expert gave a higher HEP for the non-FLEX scenario compared to the FLEX design scenario.

So we got a pages and pages of experts' insight. What are the challenges to perform this action? What are the ways to facilitate this action? And what are the uncertainties we don't know?

That's those insights to our project team are more valuable than the HEP number. For some example insight, we had expert talk. The information was incomplete with uncertainty. I don't have any information yet right this minute because the diagnosis of the work done, these are generated, takes longer than one hour. So I need more information to make a decision.

And more importantly, why they got a high HEP for this because at that time the -- let's see -- FLEX support guidance, FSG, were not integrated with the OPs. In the non-FLEX scenario, the expert consider the OPs is there, if they're not. And the OP direct them, restoring the power. Then first the supply team restoring the power instead of going to ELAP, and that was a good lesson learned.

So compared to the non-FLEX scenario, the FLEX design scenario has zero uncertainties. So even you don't know when that these are generator, if I open a door, you see the way it is outside. You know you should be declaring most likely. You should declare ELAP.

So both are considered real valuable insight we gain from this expert. So this is the example I promised earlier. It talk about the HRA morbidity due to uncertainties in the scenario.

Let's take a look at the example, the action, DC load shed. We specified it's open 18 breakers in two locations. We didn't specify in the first place the expert come to the questions when going through the PIFs and what is specified.

During the uncertainty, some uncertainties in the scenario, that is the lay ups and the labels of the breakers. Some plants have FLEX specific labels that are shiny so you can see it. Some plants don't. And who does the work? And the travel path to the breakers, do you need an elevator to exit the room? Will the elevator work when you have these single strategies and the like affect the stresses?

So these factors can change from plant to plant. Even the same plant can change from scenario to scenario. Those are the uncertainties. I mean, we, of course, in the expert presentation, we can make assumption of this. But we appropriately left that open to the expert.

So let the expert use their guess of their assumption of this uncertainty. But we ask them to document what their assumptions are. So let's look at the two expert.

Expert A got a very relatively high HEP, 0.2, as he consider this. I mean, no matter even if it's in a non-FLEX scenario, whatever get you into using FLEX equipment, it got to be something terribly wrong. So operators would be in high stress. And there's variations in the economic interface. And they are entering with the breakers that they need to open for FLEX -- using for FLEX.

On the other hand, if we look at Expert C got a much lower HEP. The justification was these are the similar actions to what operators' performances made on a routine basis, just to open and close the breaker. And schedules should have no impact. So this, we can say how the uncertainties in the scenario carried us into the ASME HEP. So any question, comment on this example?

MEMBER KIRCHNER: Jing Xing?

MS. XING: Yeah?

MEMBER KIRCHNER: This is Walt Kirchner. I think someone else has their mic on. Let me step back. Let me try again. What does the 1 percent, 99 percentile mean?

MS. LUI: Jing, you need to unmute your mic.

(Pause.)

MS. LUI: Jing, your mic is muted.

MEMBER BLEY: And whoever has a phone number ending in 03 is not muted.

MEMBER KIRCHNER: Yeah, there's a guest on the line that's causing feedback.

MS. XING: That was an automation. I didn't unmute it.

MS. LUI: So the 03 number is the public bridge line.

MEMBER KIRCHNER: Someone on the public bridge line has their mic open then.

MS. XING: Oh, can you hear me now?

MR. PETERS: Yes, we can hear you, Jing.

MEMBER KIRCHNER: Yes.

MS. XING: Okay. Thank you. Yes, the question was, what happen at 1 percentile and 99 percentile? And the other expert made a long list of their justification and the potential uncertainty that they see. The 1 percentile represent for the uncertainties in their consideration, everything is ideal.

Like in baseline, I may not -- like I said, may not match what's in the report of what baseline you would consider. Okay? It's the experience the operators did the work and that there's no problem on the travel path. You have a clear label on the breakers that go to the 1 percentile. So several experts actually said if the breakers that had specific FLEX label, that would make an order of magnitude difference in the HEP.

MEMBER KIRCHNER: I should've been more explicit, Jing. What is the basis? Is this the numbers that are using the IDHEAS GE software? These are the numbers that are generated?

MS. XING: No, these are the numbers the expert estimated.

MEMBER KIRCHNER: Wow. That's a precision that I find, well, questionable. Let me say it like that. Not to judge the experts. These kind of numbers with these significant decimal points is what you get when you run critical heat flux experimental tests. And you run several hundred data or more data points to get that kind of precision. So just given that we're dealing with humans, I just question the -- certainly down at the 1 percentile.

MR. PETERS: We're looking at it -- if we think about it from the reliability perspective, when you look at a 0.2, it's not really a very precise number. What we're talking about is 2 out of 10 people fail. If you look at the 0.01, 1 out of 100.

So it's really a rough estimate that we put down into a really refined decimal. Now if we had, like, 123 out of 1,000, okay, well, that's very precise, right? But 1 out of a 1,000 is not -- it's just a rough guess from the experts.

MEMBER KIRCHNER: But Sean, then -- and Jing, how do you actually use those numbers? I mean, I know you're trying to deal with uncertainty. But I just -- I'm scratching my head figuratively here thinking that kind of precision is what you see from experimental data with many, many tests. I get the 50th percentile, but just I'm questioning the tales, I guess, with such precise numbers.

MS. XING: Yes, our expert also had mention it in the training for coming up the probability. And they also expressed basically coming up to the 1 percentile and the 99 percentile. So the training we gave them for calibration, just think in the worst case everything -- for the all uncertainties you have in your mind, everything goes bad. And how many of your crew would fail this action out of 100 times that they try this?

MEMBER BLEY: So if I could help a little. Walt, I think your envisioning a precision that's not intended. On that first slide for Expert A, a 0.5 would mean it's a toss of a coin. It could go either way. And they're saying, well, it's not quite that bad but it's almost that bad. And then you expect the D, the difference between the 50th and the 1st percentile is saying about 1 in 10 which is a really high failure rate. You don't see that in most things people do in the plant.

MEMBER KIRCHNER: Yeah.

MEMBER BLEY: And this is going to be a lot higher than we usually see in the plant. It might be a factor of 10 less than that. It might be a factor of 3 higher. But you can't get much higher than a 0.3 or a 0.5, even if everything is going against you, it's hard to get to a guaranteed failure unless it's an --

MEMBER KIRCHNER: Yeah.

MEMBER BLEY: -- impossible situation. There isn't -- I don't think there's the precision you're seeing in what the estimates mean.

MEMBER KIRCHNER: Yeah, yeah. Thanks, Dennis. Yeah, that's what I was thinking too. The first one, for example, in my simple-minded approach to it is to say, well, there's 0.2, 1 out 5 chance that it's not going to work. And then yeah, probably things are really compounded. It's twice as bad. So you come up with 0.4.

If I -- thank you. If I look at it in that sense, fine. But it's just the visuals for me just kind of misled how much precision really is --

MEMBER BLEY: I feel what you're saying.

MEMBER KIRCHNER: -- achievable.

MEMBER BLEY: But you got to get used to these a little. A 0.5 is about as bad as it gets, the toss of a coin kind of thing where it goes. Unless it's just locked in, there's nothing you can do. Then there isn't much question about human performance. You just can't do it.

MEMBER KIRCHNER: Yeah, you just can't do it if it's very cold and everything freezes. You're just -- that particular function impacted by that environmental factor, yeah, the chance of it going, it's just not going to work.

MEMBER BLEY: Yeah, the 0.5 is probably getting close to what you're talking about, and that's probably somebody who didn't want to say 1 in 100 and wanted to say maybe it's not quite that bad.

MEMBER KIRCHNER: Yeah, okay.

MS. XING: I didn't mention the definition for failure in this action. It's very restricted. It's failure of any of the 18 breakers is considered a failed action. That's another factor contributing to consider.

MEMBER KIRCHNER: Okay. I read this differently. I thought there were 18 breakers and two locations to deal with so that you -- to be successful, you had to open all of them. Okay. Thank you.

MEMBER DIMITRIJEVIC: That was one of my questions for you, Jing. The definition of the -- there is no clear definition of the failure here. Is it to open all breakers and in what time frame? So I mean, it's not really -- I mean, but I have -- when I read your -- the report, it seems like you provided the same qualitative information to all the experts. So they have the same understanding of the scenario, right?

MS. XING: On a large scale, yes. But on the microscale, people may still have some, what Dr. Bley said, are the sub-scenarios. Like, some people would think, oh, I will always access there. Well, I have to go through elevator. Elevator was down, no other ways. The staircase was blocked. So there are always sub-scenarios that they don't -- even if we ask them to document everything, all their assumptions, there could be assumptions they just took it for granted.

MEMBER DIMITRIJEVIC: Just to give to Walt some additional information. Those scenarios were not supported by PRA because PRA was not developed for the FLEX scenarios in this time. So the success criteria and timing and everything is based on the different FLEX procedures.

MEMBER KIRCHNER: Right. Thank you, Vesna.

CHAIR SUNSERI: Hey, this is Matt. I have a question, just a time check. It's 20 after the hour. We're scheduled to go to 1:00. We know we have some stakeholder input that we're going to receive at the -- public stakeholder input at the end of the meeting. So I just want to be mindful of the schedule.

MS. XING: Okay. Thanks. Appreciate that.

MEMBER BLEY: Yeah, Jing. I think you can put a little light on details in the examples. We have all the reports if we want to delve into them in more detail.

MS. XING: Okay. Thanks. So mainly the insight we got from 2018 expert elicitation. So we kept this particular technical community's knowledge about the uncertainties, challenges, and opportunities in FLEX in this FLEX action. And when estimate HEP are valid only for the very specific assumptions and specifications we made for the scenarios and the action in the study so that do not recommend people use this HEP for their PRA application.

And yeah, this is what we said earlier. We find we have -- we need to use all of the PIF for in FLEX. And the expert recommend we should use human error data to inform the HRA being measured. That's what we did in ECA.

Okay. So I'll quickly go on the 2019 FLEX

HRA evaluation. So this was received by NRC and EPRI. So the main purpose was to evaluate several represented FLEX action and using IDHEAS-ECA and also provide feedback for improve IDHEAS-ECA. And in this study, teams of FLEX and the HRA experts modeled several FLEX action.

Both teams had two plant data to better understand FLEX strategies associated with equipment to operate the action. And the FLEX expert create a set of realistic scenarios and the HFEs for using FLEX equipment. Then the HRA experts start to modify the scenarios and quantify the HEPs using IDHEAS-ECA software.

The expert had a three-day workshop to finalize their -- to discuss their analysis and finalize their quantification. The three scenarios were -- one was beyond the design basis seismic event. It's a PWR that result in SBO and the loss of the water. So you need to deploy the FLEX pump. And the SBO is pre-stage FLEX diesel generator.

Okay. So I'll probably spend some time to say another source of HRA variability which is analyst practice as an example. So this scenario is beyond the design basis, a seismic event. So it's obvious that power cannot be restored quickly.

So for that, we had three cases. The base case is easy. By 60 minutes power not back, you're going to declare ELAP. By the second case, Case 2 is like what we had in 2018 expert elicitation. If AC power cannot be restored within four hours, you need to declare ELAP within one hour of no AC power.

Case 3 is pretty much the same. You have same instruction as Case 2, but the situation is less obvious that the power cannot be restored. So there's big uncertainties there.

So we look at -- let's take a look at Case 2. In this instance, here are the five analysts' estimation. Look at A and B. They both chose the same failure mode decision making. And they both chose the same PIFs. Information is unreliable or uncertain. That PIF has a human error entered in. They both chose the number 2.

And some justification prevails and actually they think will be very dependent on the details of what the procedure guidance would say. And the level ranges from 3 to 5 given some examples presented to the team. So that's the uncertainty in that event.

But now if we look at the other three experts, they select the same failure mode. But they ultimately know the PIF has no impact. So why is the information uncertainty has no impact?

Their justification was uncertainty to the plant. But the operators, they talked and told them. So by our time frame, it's set in stone. A decision have to be made. Therefore, even the information is uncertain, they would declare ELAP.

So this is the analyst's interpretation or belief. So in this situation, we wouldn't -- these two group of expert gave no other -- HEP had one order of magnitude difference because of that information, uncertain information, uncertainties. We wouldn't say which one is right and which one is wrong. I think both group capture something important about declaring ELAP. The potential pitfall in the first group and the way that you can mitigate that pitfall by improving the procedure of the instruction.

MEMBER BLEY: Jing, a quick question.

MS. XING: Yes?

MEMBER BLEY: Were they given a chance to talk to each other and understand why they decided differently on this? It could be they come from different plants and they actually work differently. Or it could be they don't have as much experience and they think people will do what they're told without ever being confused. There's a lot of reasons that could be driving it.

MS. XING: Yeah, all of the experts visited both plants. So in the, you probably saw the information, it should be equal. However, and I think Susan Cooper got the lead of this project. She also told me that every operator they talked to told them they would declare ELAP. And that's where I think they got the information that they got delayed that one hour frame is set in stone. But in --

MR. PETERS: Jing, Susan wanted to jump in with an answer real quick to Dennis' --

MS. XING: Okay.

MR. PETERS: -- question.

MS. XING: Susan, go ahead.

MS. COOPER: Thank you. Susan Cooper, Office of Research. Just a couple clarifications. Not all of the HRA analysts went on all of the plant trips. But all of them had participated in discussions to get agreement and a common understanding of the scenarios, the associated HFEs in context, and plant site visit notes.

I'm not remembering the specifics of who is who here. But I think Jing is correct that even though every -- all of the analysts had access to the same information and one of my objections was to make sure they had the same understanding as best I could. There still are indications in the results that individual analysts may interpret or that understanding in a different way. Or there may be other information, again, based on their experience.

All of the analysts -- I mean, Jing did mention. So we had three analysts from industry, all of whom were quite experienced. And then we had one analyst, an analyst of the Office of Research, and then we had one inspector, and SRA.

So most -- all these people were very experienced and had some operations background. But they obviously had different background. And some had more experience with FLEX and multiple plant sites than others.

MEMBER KIRCHNER: I would just make a quick observation. This is Walt Kirchner. What you're seeing there in those highlighted justifications is culture. I'll let you think about that.

MS. COOPER: You could be right.

MR. PETERS: And you're right that with people's backgrounds, they filter differently. Absolutely.

MEMBER KIRCHNER: Yeah, organizational background is reflected there.

MS. XING: Yes, and also it was quite interesting. This was very different from what we heard in 2018 expert elicitation. Back then, the expert has more -- they had information that people are more hesitant in using declare ELAP. So maybe that plant make them improve the guidance or instructions on how to use the FLEX equipment. That could reflect that change.

MEMBER BLEY: Yeah, that was the period of time we were getting briefs from the industry on this. And the approaches were changing pretty rapidly over that time. So it's a good point, Jing. But you got to hustle along. There's a lot to cover.

MS. XING: Yeah. Okay. So anymore questions?

(No response.)

MS. XING: I'll move on. So some insights we learned from 2019 FLEX evaluation, we see the analyst variability generally is between an order of magnitude for most human action. But this still remained a concern.

Even you use IDHEAS-ECA, but we saw in the PRA there's still uncertainties in the scenario variation in HR analysts' practice. We think we found the measured probability and support a better understanding where the variability comes from. Therefore, make it easy to recall finding the variability.

MR. PETERS: Hi, Jing. This is Sean. I'd like to make one real quick interruption. What we've found with this one order of magnitude is in the U.S. and the international empirical studies, we tended to average around the order of three orders of magnitude variability back then. So I don't know if this means we can prove variability. But it's definitely (audio interference) --

MS. XING: Sean, you're breaking up.

MR. PETERS: -- we were seeing in those other reports. Sorry. I'm done. I was just saying that our variability was lower than what we saw in those other reports.

MS. XING: Thank you, Sean. And important insight we learned from this exercise was, as Dr. Bley mentioned earlier, the procedures for using FLEX equipment in our FLEX scenarios are important for predicting FLEX in PRA. And that plan has been made lots of improvement on that since FLEX was initially invented. Okay. Anymore questions on this part?

MEMBER DIMITRIJEVIC: I have a question, a general question in this quantification -- because this was from quantification, right? Even if it's not obvious, it looks like, you know, it's from this station because you know, there's two PFIs.

How did time component contribute? Was the time component evaluated? Because your probability of HEP has two components, right? One is time related that we get from those time distributions, another one which is the PFI related. So was the time component part of this quantification?

MS. XING: I think the answer is -- Dr. Cooper can correct me when I supply this. I think in the study to make it easier, the assumption is throughout the human action, they have adequate time to perform the action. That was actually a requirement in FLEX audit. Susan, do you have anything?

MEMBER DIMITRIJEVIC: So you just assume that they have the time required, the time available where that was not contributing? Is that what you're saying?

MS. COOPER: No.

MEMBER DIMITRIJEVIC: Okay.

MS. COOPER: So I think specifically for

declaring ELAP, I think that was the HFE. We did look at a timing contribution. There is a feature in IDHEAS-ECA that allows you to do that. No one had completed that -- tried that before the workshop. We walked through it ourselves, identified some difficulties, made a calculation, and it was negligible.

The timing -- it could've been that declared ELAP or it could've been FLEX DC motion. I can't remember which. But it was one of those in the FLEX scenario.

So -- and then the other ones had more time available. So mostly due to lack of time, we didn't pursue that. And then to the non-FLEX scenarios, because we didn't have any timing calculations or estimates that were based on engineering, we made assumptions. We didn't evaluate it at all for the non-FLEX scenarios.

MEMBER DIMITRIJEVIC: Thanks. And my other question was you never really -- what I noticed within one or two there is some connection discussed in the text. The expert elicitation was used for benchmarking. But actually, you never really connected those two volumes in any way, right?

There is not any -- you did not really --

for the base HEPs, you didn't look in that presentation. And there is a big difference also in the HEP values because Volume 1 and Volume 2. And I notice some limited discussion-wise that one was done in 1980 and one was done in 1990. So obviously, it seems like you learn much more about FLEX scenarios between the one we have. But basically, those two volumes don't talk with each other.

MS. COOPER: If you don't mind, Jing, this is Susan, I'll answer real quickly. So the FLEX expert elicitation effort was used as a lessons learned for approaching the using IDHEAS-ECA FLEX HRA effort. There was some overlap of personnel, especially among industry members, those that helped us develop scenarios and so forth.

But so far as the HEPs, no, there wasn't anything done there. The only thing again is a lessons learned. From the expert elicitation effort, my job to my mind was to make sure the scenarios that were selected and described were as realistic and as detailed as possible and that the HRA analyst had as close as this identical understanding of those scenarios in that context as possible.

MEMBER DIMITRIJEVIC: And because when the measurement comes to variability, variability is discussed within this volume. But if you look at the variability between two volumes, then you can see, like, this three order of magnitude differences, like, declaring ELAP, going from 0.5 to 1.0 to the -3. I mean, so there is a big variability in the -- if you compare the HEPs from the different volumes. That's what I want to say.

MS. COOPER: Yeah, I think some of that was due to changes in the industry. I think also having specific details. I mean, although we made some departures from all plant-specific details, it was for a particular plant. So could this be a factor?

Or I remember at my plant, this is a factor. So I'm going to apply that. I try to excise that kind of stuff from the analyst. So some of it I think could be improvements and others could just be that we did a better job of constraining the problem.

MEMBER BLEY: I think we got down to the last 20 minutes. John has some important stuff to get to and we have comments from one member of the public too.

MR. PETERS: And what I would say is maybe, Jing, we should skip the modifications since the last versions of the report. I'd like to propose that. That would save us a few slides and we can just go to a summation. The ACRS members can read those slides and see if they have any questions associated with them.

MEMBER BLEY: I think that's a good idea. I mean, you guys on those slides point out that you had many reviews and that you tried to respond to as many of them as you could. And I think Jing makes a point on slide seven tear downs and rewrites. This report started very rough and has gotten much more coherence. And part of that's due to your very hard work and part due to what you got from commenters.

MR. PETERS: And Jing, if you'd just like to mention briefly the people that did do the comments, that would be great.

MS. XING: Yes, so this is the -- as we said, we have been through many reviews. I just want to take this as an opportunity to express our team's appreciation for all the review input. The review input is not just for improvement. It's actually part of the development of this product.

So for example, one early ACRS recommendation point out this important commodity time effect. That lead to our development of the time a certain model as part of quantification. And a reviewer, Dr. Emily Rothman, had gave us a very useful comment on teamwork. So that solved us a big puzzle of how to model teamwork and lead to the development of the fifth macrocognitive functions, interteam coordination.

And Dr. Mason (phonetic) and Ken, of course, our own NRC staff, they had a very comprehensive comments to say, our 2016 version. That version, I think, had 18 chapters or something like that. They said you need to come up with a cohesive methodology. And that lead us to develop eight steps, IDHEAS-G process and the standalone method for human event analysis.

And at this time, we keep this kind of list in our files. It goes up to several hundred pages. So this is the opportunity want to express our thank you.

And I will not talk about the details of our revision since 2019. But I'd like -- again, I'd like to take this opportunity to thank our -- the comments we received from Mr. John Stetkar. He gave us very thorough, thoughtful -- not just a comment but constructive suggestions and recommendations.

We addressed most of the comments. For the ones we couldn't address at this moment, those are very useful directions for our future improvements. So having said that, I think I can end my presentation.

MR. PETERS: Thanks, Jing. I'd like to share my slides real quick. Oh, wow. I'm on the wrong slide. Sorry, guys. I'll go real quick through here.

So just wanted to go a little bit and talk about our path forward from this point. And the future work that we're going to be doing for IDHEAS is we're going to be finalizing a publication of Rev. 0 of IDHEAS-G. This was already signed out in the December time frame through our offices.

We are also refining and rolling out IDHEAS-ECA. We're including the dependency model. We're looking at improved guidance for recovery. And we are going to be integrating that with the SAPHIRE and SPAR models.

And we're looking at publishing a revision after our public comment period that I mentioned earlier in the April time frame. And of course, we're still completing the IDHEAS-DATA project. You've seen the draft IDHEAS-DATA report.

We're going to be taking the revisions that are from our internal reviewers. And we're going to be sharing this with the public. And we're going to be taking public comments and incorporating revisions based upon the comments plus the new data that we have coming forth.

And other HRA work that you will be seeing coming out also, we have a side project we're working on, on understanding better what environmental and human error probabilities are. We have a lot of work we're working with our international counterparts. We're trying to get more international partners to supply data and exchange data so that we can even put this out in the public domain so we can get work from the rest of the world helping to analyze human error data.

And of course, the last three that we always have, there are big things that are being worked right now. I've seen people starting to work on organizational factors out in academia and in industry. We would love to continue the work that we've been doing on the Commission.

And the Golden Cybersecurity PRAs are becoming of very high interest to the industry as a whole. And the path forward, I think this is the time to get a discussion even after the public comment period here or the public comments we have at the end of our meeting on whether or not we think we can close SRM-M061020 because from the NRC's perspective, from a research perspective, we developed a complete and practice HRA method. We've made significant improvements to the current state of practice and developed some state-of-the-art techniques into the methodology, especially based on timing was one of those that was state-of-the-art that was recommended by the ACRS.

It's human-centered scientific database, so it can be modified to future applications. I think it's a little easier than some of our older methodologies. And we have a program for periodic updates. So that is all, and I'd like to complete the presentation. And thanks to the committee for this time.

MEMBER BLEY: Thanks, Sean. The only thing we didn't talk about today is SACADA, the data. At one time, you were actively seeking additional participants to provide data into SACADA. Is that happening, or are we --

MR. PETERS: We still are. Yeah, we still are. It's always through fits and starts. So it usually takes about a half year to a year to get initiated through a concurrence process and then another half year or so to train the teams up. And there's been a lot of turnover in the industry.

So we will get some industry members that say, yeah, we'd like to participate and then, like, there's a management turnover or a change in operations. And they've decided not to invest money into doing that. But the other side of the business is we have a lot of international interest in it.

So we're currently working through our internal governmental processes to try to get international partners on this also. So more to be heard on that. I'd like to come and present what we have here in another year or so because we're just at the early stages of building of that international relationship.

MEMBER BLEY: Okay. That sounds good. But we'll also have to hear how we adapt international data because there are some practices that are different as you go around the world. But thanks very much, Jing and Sean. I want to get to the public comments. But first, are there any members who want to ask a question or two before we do that?

(No response.)

MEMBER BLEY: I take it this time we'll ask former Chairman of the ACRS and now member of the public, Mr. John Stetkar, to make comments if he's available. And I would ask Chris if we've received Mr. Stetkar's comments in writing too.

MS. LUI: So while Tom is opening up the bridge line, I do not have Mr. Stetkar's upcoming oral statements. But Mr. Stetkar's comments are all available from the ADAMS -- publicly available from the ADAMS.

MEMBER BLEY: Thank you. John, are you there?

(Simultaneous speaking.)

MR. STETKAR: I hope I'm here. Can you hear me okay?

MEMBER BLEY: We can. Please go ahead.

MR. STETKAR: Excellent. For the record, my name is John Stetkar. I'm a former member of the ACRS as Dr. Bley mentioned. And I am speaking today as a member of the public.

First of all, I'd like to add my congratulations to Chris Lui for her new role in research. I have very fond memories of working with her when I was an ACRS member. And I hope, Chris, that you'll have just tons of fun over there in RES.

I'd like to comment briefly on the IDHEAS general methodology in NUREG 2198. I know that the committee has received a copy of all of my detailed comments on the previous version of the report. In my opinion, the current version of the report has addressed a vast majority of those comments, and I very much appreciate the staff's stamina and their extensive efforts to consider my comments and make all of those changes.

I do have a few remaining high level concerns about the methodology in NUREG 2198. Considering the brief time available here, I'll just highlight a couple of those most important issues. First, I'm still concerned about the lack of technical justification for the quantification model that's represented by the equations in that report -- Section 4 of the report.

In particular, I still don't understand why the primary influence on human performance is determined by 3 specific base performance influencing factors while the other 17 factors are cumulative modifiers. I also don't understand why the assumed linear summation of those performance influencing factor weights is justified. I've reviewed the IDHEAS-DATA report, and I understand the committee has received a copy of my comments on that report.

I could not find any compelling

justification in that report for the format of the quantification model. Furthermore, Section 6.3 in Appendix D in the current version of NUREG 2198 have removed examples which were originally intended to support the conclusion that linear addition of the performance influencing factor weights provides the best method to account for the composite effects. The current version of the report relies primarily on only qualitative assertions that the model is justified based on reviews of other studies without any quantitative examples that clearly support that justification.

Second, I think that the examples in Appendix M of NUREG 2198 are very important for prospective analysts to understand how the methodology is applied in practice. Again, because of the time available, I only have a couple of comments on those examples. My first comment is related to documentation of the analysts' decisions that are made in each example.

As been mentioned today, one of the most important objectives of the IDHEAS methodology is to reduce sources of analyst variability in their analyses. As Jing noted on Slide 6 of her presentation, a critical task to achieve that objective is clear documentation of the rationale and justification for a large number of analyst decisions that are made throughout the process. For example, the examples in Appendix M only document those decisions very partially.

For example, they simply list specific cognitive failure modes and performance influencing factors that the analysts have left for each evaluation. They do not document why other cognitive failure modes for performance influencing factors were excluded as being not relevant. It's very important to document the rationale for those exclusions because that rationale can often reveal key sources of disagreement between different analysts and the reasons for that disagreement.

In practice, I found that the documentation process by itself also often prompts each analyst to more carefully consider the basis for their own judgment and selections. The same comment applies to lack of documented rationale for selection of a particular form of the uncertainty distributions for the time estimates and the assignments of specific parameters in those distributions, for example, the 5th and 95th percentile values. So in summary, I think to provide instructive examples that demonstrate the expectations of how the IDHEAS methodology should be implemented, I really think that the examples in Appendix M should better document the rationale -- the analysts' rationales for their decision, including why they excluded particular performance influencing factors and cognitive failure modes as being not relevant.

My second comment on Appendix M is that the quantification example in the current version of Section M.2.6 has been revised, but it's still not correct. If you look at the combined uncertainty distribution in that example, it evaluates the time at which power is restored from a FLEX generator. That distribution shows that there's a small but not zero probability that power is restored before the crew begins to extend -- use the extended loss of AC power guidance.

In other words, there's some probability that power is restored before one hour in that scenario. That's not realistic, and the example should be corrected. Perhaps staff will need to use other forms of the uncertainty distributions to provide a more realistic estimate that's consistent with the physical constraints of the scenario.

Now my comment is not intended to be an

obsessively detailed critique of probabilistic arithmetic. I think it's conceptually important for the methodology because the examples should clearly demonstrate the perspective of analysts. But the uncertainty quantification is not an abstract mathematical afterthought.

The uncertainty should be an integral part of the analyses. They should account for realistic engineering and operational assessment of personnel performance within the physical and functional constraints of the event scenario. If the uncertainty analysis results provide non-physical conclusions, for example, that you can restore power before you start, then something is drastically wrong with those analyses.

And finally, if the committee will indulge me, I'd like to simply emphasize the fact that the FLEX application example in RIL-202013 is a product of several key methods and reports that deserve really careful attention before conclusions are made about that report. The presentations today discuss those. The relationships among the IDHEAS general methodology and NUREG 2198, the IDHEAS-DATA report, and the IDHEAS-ECA application in RIL-202002 are shown on Jing's Slide 7 and 8.

Those relationships are pretty complex and somewhat convoluted. So I think until the committee has an opportunity to carefully examine the IDHEAS-DATA and ECA reports, it may be premature to make specific conclusions or recommendations about RIL-202013. And with that, I think you still have three minutes to go. So I will thank you very much for the opportunity to make my comments and I will go on mute.

MEMBER BLEY: Thank you. We appreciate your comments. Are there any other members of the public or other people sitting in on the meeting who would like to make a comment? If so, please state your name and affiliation and make your comment.

MR. JULIUS: Yeah. Hi, Dennis. This is Jeff Julius with Jensen Hughes.

MEMBER BLEY: Yeah. Hi, Jeff.

MR. JULIUS: And I echo John Stetkar's recommendation or concern that, yeah, we should get some careful look and feedback on the RIL-2020-13 because it is integrating a large amount of data. And so some additional discussions or workshop or opportunities for comment would be useful.

MEMBER BLEY: Thank you, Jeff. I appreciate that. Anyone else like to make a comment?

MR. PETERS: Just to respond to that, this is Sean Peters. Yeah, we will be discussing that in our April workshop with the -- or our April public comment period.

MEMBER BLEY: Thanks, Sean. Last chance for comments if anyone wants to make them. We can close the public line now, Thomas. And I have a question for Sean.

I've been really pulling together a lot of strings on this letter. I won't -- we won't do our deliberations at this point. The committee will get together and talk about this. There's a lot of information provided to us today that goes beyond what I've read.

And the question for you, Sean, is we have on our calendar to write the letter this week. But unless you have a really pressing need, I wonder if it would be acceptable if we did it at the March meeting which would give me a chance to look through the transcript and adjust and chase the information and chase some of the threads. But if you need it at this point, I think we can certainly do that. But what are your thoughts on it?

MR. PETERS: Yeah, I don't think that there's any time crunch from our perspective. As you guys have seen, we have so much work that's going on and the limited resources we have. We're still just trying to process all the comments and the changes and incorporate all the date that we've been gathering and develop the finalized reports that are out on this.

But you guys know that we also still plan to get some new updates, both IDHEAS-G and IDHEAS-ECA, as we get more and more information, more data, and more feedback from the users and more feedback from the advisory committee. So my thoughts are from a timing perspective, I am not aware of any timing restrictions on the SRM. And the SRM is more directed to the ACRS. So from our perspective, the ACRS should have the final say on timing of closing out that SRM.

MEMBER BLEY: Okay. Well the committee will deliberate on this, this week. I wasn't thinking that we'd invite you back in March. We would just include that as part of our letter writing if we skip it until then.

But thank you. We appreciate that. And the revisions you're talking about, are you anticipating that the RIL documents will turn into NUREGs at some point?

MR. PETERS: We haven't made that determination. One of the challenges with the RILs is they are really snapshots in time, right? So the 2018 was a hypothetical plan as hypothetically practiced from what we understood the industry practices were.

The 2019 report was a little more realistic because we were able to actually go to a couple plants and model their behaviors. But of course, those behaviors continue to change. So I think depending on how much feedback and how much industry and public interest is in it, we can take that interest and revise those reports and put it out as a NUREG.

It really just depends on what level of interest there is in those reports because in our perspective, the effects expert elicitation was for a very particular purpose of helping NRR in that interim period before we had a method developed. The second report was to show some of the evolutions in at least how FLEX had been practiced up to that point and to show that we could actually quantify it using our IDHEAS-ECA method.

So to us, it was more of a we're not saying this is the end all, be all of FLEX because FLEX is very dependent on your very particular situation at your site and what type of scenarios are thrown at you. So I don't know -- in the back of my mind, I don't know the full utility of putting that out as a revised NUREG. But that's something I'm willing to be open to.

MEMBER BLEY: Okay. I think it's fair -- I can't tell you what will be in our letter. The committee has to deliberate on that. But I think from what you've heard, it's clear that with a few exceptions, IDHEAS-G report looks pretty good.

The RILs, however, you heard a number of questions raised about them. And the data report, as you said, it's not complete yet. But at least in my opinion, it's got a fair way to go to be not just the data source you want it to be but clearly justified in what it has to say.

I think the last question for Jing is Mr. Stetkar brought up something that slipped my mind. And when I read the new revision of IDHEAS-G, I didn't remember that the statement about the preponderant effect of three PIFs is still included in IDHEAS-G. Is it in there?

MS. XING: Somewhere in the report.

MEMBER BLEY: Okay. That's --

(Simultaneous speaking.)

MS. XING: -- that would be in IDHEAS-DATA report.

MEMBER BLEY: I know, and I've been

through the IDHEAS-DATA report. And I don't -- it's not there yet.

MS. XING: But it's --

MEMBER BLEY: At least I didn't find it.

MS. XING: -- there. But it's embedded in the -- in some lines. So we think of what is important. We probably make a separate appendix to extract all the information.

MEMBER BLEY: If you're going to really claim that's the truth, I think it needs to be really clear and justified because it isn't -- again, it's not transparent yet. So I would like to thank Jing and Sean for all their presentations and the commenters from the public for their comments. We appreciate them. And at this point, four minutes late, I turn it back to the chairman.

CHAIR SUNSERI: Thank you, Dennis, and thank you, staff, for the thorough presentation today. All right. Members, it is a little after 1:00. We are going to recess for lunch until 2:00. At that time, we will resume with a presentation on Advanced Reactor Code, Volumes 4 and 5. So any comments before we recess?

(No response.)

CHAIR SUNSERI: Okay. We are recessed

until 2:00. Thank you.

(Whereupon, the above-entitled matter went off the record at 1:05 p.m. and resumed at 2:00 p.m.)

CHAIR SUNSERI: We'll start with a roll call. Ron Ballinger?

MEMBER BALLINGER: Here.

CHAIR SUNSERI: Dennis Bley?

MEMBER BLEY: Here.

CHAIR SUNSERI: Charles Brown?

MEMBER BROWN: Here.

CHAIR SUNSERI: Vesna Dimitrijevic?

(No response.)

CHAIR SUNSERI: Walt Kirchner?

MEMBER KIRCHNER: Here.

CHAIR SUNSERI: Jose March-Leuba?

MEMBER MARCH-LEUBA: Here.

CHAIR SUNSERI: Dave Petti?

MEMBER PETTI: Here.

CHAIR SUNSERI: Joy Rempe?

VICE CHAIR REMPE: Here.

CHAIR SUNSERI: Pete Riccardella?

MEMBER RICCARDELLA: I'm here.

CHAIR SUNSERI: Vesna Dimitrijevic?

(No response.)

CHAIR SUNSERI: I'll look at the list.

Okay. Well we'll just go ahead. We have a quorum. We will proceed. I'm sure she will join here shortly. So our next topic is Advanced Reactor Computer Codes Volume 4 and 5. Dennis Bley is the subcommittee chair. At this point in time, I will turn it over to Dennis.

MEMBER BLEY: Thank you, Mr. Chairman. I just turned mute off. I take it that didn't affect me.

CHAIR SUNSERI: No, you're okay. Yeah, we hear you.

MEMBER BLEY: Okay. Well we're continuing on our last two volumes of the strategy to implementation action plan, Volumes 4 and 5. And I want to mention, Kim, that I wasn't here for the meeting on Volume 4, but I have had a chance to review the transcripts. And we're looking forward to hearing your presentation. I'll turn it over now to Kim Webber of Division of Systems Analysis in RES. Kim?

MS. WEBBER: Great. Thank you so much. Good afternoon. And I really appreciate your time reviewing our latest volume, Volume 4, called Licensing and Siting Dose Assessment Codes, and Volume 5 which have plans for our Radionuclide Characterization, Criticality, Shielding, and Transport for the Nuclear Fuel Cycle.

I am Kim Webber, and I'm the Director of the Division of Systems Analysis in the Office of Nuclear Regulatory Research. And I'm glad to be with you today talking about our Volumes 4 and 5, which as Dennis said appropriately, these are the last volumes at least that we have planned at this time. Let's go to the next slide please.

Okay. So with me today are John Tomon -- he's the Chief of the Radiation Protection Branch -- and also Don Algama, a senior reactor systems engineer. And both of them are in the Division of Systems Analysis in the Office of Research. Drew Barto is also on the panel, and he's a senior nuclear engineer from NMSS.

As you know, we've been working really hard with staff in NRR and NMSS over the last year to develop these strategies in Volumes 4 and 5. And we believe they represent the most resource effective approach for our codes and code development activities. I'll provide a brief overview of the status of the non-light water reactor code development project which encompasses an introduction and five volumes, and then I'll turn the presentation over to John, Don, and Drew. So can we go to the next slide?

Many of you have seen this slide several times. And really, I keep using this slide because it has the important key message which is still the same, and that is that we're really trying to do the best we can to enable the regulatory offices to be ready to perform their oversight responsibilities such as licensing in a time efficient but safety focused matter. To improve mission value, we're working hard to deliver the tools, the expertise, and the information in a cost effective and efficient manner so that licensing can be completed on time and within the allotted resources.

A key element of our strategy is developing the codes and analytical tools and the approaches to use those codes like the ones you see on this slide and to have those codes ready to go for potential use in safety analysis. Through code development activities in our collaborations with many organizations you see here on this slide, our staff has been acquiring new knowledge about advanced reactor design and phenomena important to safety, thus growing staff expertise and analytical capabilities. Additionally, they've been working really hard to capture knowledge about these reactor designs and the phenomena in the codes and in the code manuals that go along with code development activities. Next slide please.

To facilitate the agency's readiness, NRC's near term implementation action plan was developed in the summer of 2017. And the IAP is the vehicle to execute the NRC's vision to safety achieve effective and efficient non-light water reactor mission readiness. As you know, the IAP includes six strategies, and Strategy 2 focuses on computer codes and knowledge to perform regulatory reviews which is the focus of today's presentation. If we go to the next slide please.

So last year, we completed the introduction in Volume 3. That is the Revision 1 to those. The introduction and the volumes were completed. And they focused on systems analysis, fuel performance, neutronic source term, severe accident progression, and accident consequence codes.

We really appreciate the time you spent reviewing those documents and engaging with us over the course of several subcommittee meetings in addition to full committee meetings. We also appreciate your insights and the feedback that you provided in the letter for those volumes.

(Simultaneous speaking.)

MEMBER BLEY: Kim?

MS. WEBBER: Yes?

MEMBER BLEY: I just wanted emphasize for all the members that the introduction in Volumes 1 through 3 were you reissued -- you revised them after our meeting --

(Simultaneous speaking.)

MS. WEBBER: Correct, yes.

MEMBER BLEY: And at least the introduction is a substantial revision. I've looked at the others and I'm not sure how substantial they are. Maybe you can say something about that.

MS. WEBBER: Well so in general what we presented at the subcommittee meeting during actually 2019, those were all draft documents that we shared with you. And then through the subcommittee meeting, we obtained substantial feedback. And that feedback was considered and incorporated into the January 2020. I think the date is January 20th, 2020.

So those Rev. 1 revisions account for the feedback that we receive through the committee meetings along the way. And then for Volumes 4 and 5, we had a future plant design subcommittee meeting a few months ago where we presented information on our code development plans in the licensing and siting dose assessment area in addition to criticality shielding and accident analysis for the fuel cycle. So each of the five volumes -- and when I refer to the volumes, I'm really referring to numerically Volume 1 through 2, 3, 4, and 5 and not necessarily the introduction.

But the introduction provides an approach for the code development activities that are represented in Volumes 1 through 5. And each of those volumes identifies the computer codes that we plan to use for our independent safety analysis that identifies the gaps in code development capabilities and data. It also has information about verification and validation needs along with specific code development tasks and methods.

And as we did with Volumes -- the introduction in Volumes 1 through 3, we look forward to the interaction today with you. And we also look forward to the letter that we receive from the committee. We'll use that information that we get today and through the letter to revise Volumes 4 through 5. And our intention is to complete those volumes in the springtime. I think in the April time frame is what we're targeting. Next slide please.

So I just wanted to let you know that these activities are really critically important for the readiness, and so to support NRR and their needs. And we also try to communicate what our interim activities are and the completion of those activities. And so if you're interested in, excuse me, having more specific information about our next steps coming up and what we completed in 2020, that information is available on the website.

A kind of high level summary, we talked about the use of reference plant models. And the notion behind the reference plant models is that we build plant models based on publicly available information. With those plant models and the publicly -- excuse me, publicly available information, we're then able to test the codes, validate the codes, get those codes ready so that when we're being called upon -- whenever we're being called upon to perform confirmatory analysis, we hope to gain a time savings when we have to use more design-specific plant DECs.

So that's the whole notion behind this reference plant model approach. And so on the external public website, it does identify several reference plant models that have been completed already. And this year coming -- this year in FY 2021, we'll complete a substantial number of those reference plant models in addition to completing some source term demonstration activities.

MEMBER BLEY: Kim, excuse me.

MS. WEBBER: Mm-hmm.

MEMBER BLEY: Just for the members, if you haven't been up on that part of the public website, it's worth a look. And that schedule is very handy to have. But Kim, I take it an X in a darker color means you're complete.

MS. WEBBER: Yes, so if you look towards the far left and you see the green boxes with the X, that designates that they've been completed. And then the other colored boxes to the right indicate the planned completions. That red line represents nominally the date at which this particular chart was produced. And so you can see as a function of time our plans to complete the various activities that are listed in that first column.

MEMBER BLEY: So if I look at Strategy 2, I see there are three reports you expected to finish at the end of last year but maybe you're not quite done with.

MS. WEBBER: Well actually, no. I think that schedule is pretty up to date.

MEMBER BLEY: Okay. I didn't see an X in those ones, like the reference plant model for the fluoride salt.

MS. WEBBER: Yeah, I think our plans are to complete that this year. So I think you're right. I just can't see what's on the --

(Simultaneous speaking.)

MEMBER BLEY: I got a big copy. I'm sorry. Go ahead though.

MS. WEBBER: I'm working from my laptop and I can't really see where the boxes are right now. But like I said, I think that schedule may be a little bit out of date but not that far actually. I'm not aware of any slips in or schedule. We're really doing really great work and on time work. So I'm really proud of the staff actually.

MEMBER BLEY: Perfect. Go ahead.

MS. WEBBER: Okay. And then if there aren't any more questions, I'd really like to turn the presentation over to John because I know he and Drew and Don have a lot of material to cover.

MR. TOMON: So can everybody see my screen and the slides?

MEMBER BLEY: Yeah, they're up. Hey, John?

MR. TOMON: Yes?

(Simultaneous speaking.)

MEMBER BLEY: I missed that meeting in September when you talked about this. If you can as you go through, can you highlight anything that's changed since that point in time?

MR. TOMON: Sure. There's only like one or two -- I only added like one or two new slides, and I've actually taken some out to pare it down because I have less time this time around. So --

MEMBER BLEY: That's good. Go ahead.

MR. TOMON: Okay. So as Kim said, good afternoon. My name is John Tomon. I'm the Chief of the Radiation Protection Branch in the Office of Research. And this afternoon, I'm going to discuss Volume 4, the License and Siting Dose Assessment Code Plan that my staff developed in collaboration with the program offices and several of our code contractors and developers.

This report describes the vision and strategy to achieve readiness for non-light water reactor designs for the license and siting dose assessment codes. It provides an overview of the technical issues related to the license and siting dose assessment codes and the various non-light water reactor technology and fuel designs that are being considered. The staff and code contractors identified several issues within the current suite of licensing and siting dose assessment codes, which should be addressed for all non-light water technologies while at the same time continuing the code's applicability to the current light water reactor fleet, issues such as the number of licensing and siting dose assessment codes, code function and capability overlaps, and inconsistent and independent code development throughout the years.

Working with our individual dose assessment code developers and the radiation protection computer code analysis and maintenance program, the RAMP contractor, Pacific Northwest National Laboratory, the staff developed the five tasks listed on this slide to prepare the licensing and siting dose assessment codes for non-light water reactor readiness. These tasks included looking at code consolidation and modernization, improved characterization of source terms, improved atmospheric transport and dispersion modeling, updates to dose coefficient values, and updates to the environmental pathway modeling used in some of the codes, and where necessary, include additional radionuclides specific for the non-light water reactor technologies. Licensing and siting dose assessment codes, as shown in this image from Volume 4, we're looking at the possibility of having to make ready approximately 10 licensing and siting dose assessment codes for the various non-light water applications.

Included in these codes are the radionuclide transport removal and dose estimation code or sometimes referred to as RADTRAD, the control room habitability code or HABIT, the atmospheric relative concentrations in support of control room habitability code, ARCON, the ground level relative air concentrations for accidental release code, PAVAN, the gaseous and liquid effluent code, GALE, the normal effluent dose assessment and siting code NRC dose which includes the liquid pathway modeling dose assessment code, LADTAP, and the gaseous atmospheric pathway modeling dose assessment code, GASPAR, the normal relative air concentration and relative disposition factors code, XOQDOQ, the radioactive material transport dose assessment code, RADTRAN, the radiological assessment system for consequence analysis code, RASCAL, the decontamination and decommissioning code, D&D, the residual -- and finally, the residual radioactivity code, RESRAD. In Volume 4, we also included discussions on other computer codes that either the non-light water reactor designers are considered using in their applications code such as the GENII code or GENII code or codes which have inputs to the codes on this slide such as the dose coefficient package code, DCSPAC, the SCALE code, and the MELCOR code.

MEMBER KIRCHNER: John, this is Walt Kirchner.

MR. TOMON: Yes?

MEMBER KIRCHNER: Is it fair to say that the slide you just covered, essentially all those are in current use for LWR applications?

MR. TOMON: Yes, sir. Yeah, they're all used in one form or another and they're kind of stovepiped. And that's going to get to the first task we came up with, the code consolidation.

MEMBER KIRCHNER: Okay. All right. Thank you.

MR. TOMON: One of the -- so the first task we came up with and it was listed on my previous slide, code consolidation and modernization. This was one of the first tasks that became obvious to the staff and it was based upon the number of licensing and siting dose assessment codes and the number of different types of non-light water reactor designs and fuel types being considered. The staff decided that code consolidation where possible was an efficient means of maintaining and writing the codes with the resources available.

Code consolidation and modernization was viewed as a means to help reduce the functional redundancy between the codes, outdated science and technology associated with the design, and the development of those codes. The limited ability of the current codes to assess advanced reactor designs, a history of changing ownership and associated loss of the code development knowledge over time, and the inefficiency of having to maintain multiple codes. Additionally, we were looking to implement this task in phases depending on several factors such as the timing of the non-light water reactor submittals and the availability of resources, both staff and contracting funds.

MEMBER BLEY: John?

MR. TOMON: Yes?

MEMBER BLEY: This is Dennis again and then Joy has something. Have you gotten far enough into this to have some idea of the difficulty of some? From what I read, some of these codes are really dated. You probably don't have much information on them. You almost have to go through it and figure out what it's doing to see what you have to change. It might be easier starting from scratch on some of them. Where do you stand?

MR. TOMON: Well actually some of the codes have been undergoing some kind of maintenance work throughout the years with our developers, our code developers and our contractors. So they're getting -- with trying to keep them up to date and keep them up to date to the various operating system platforms as computers change because some of them were still working in 32-bit systems, they've had to kind of go in and pull them apart a little bit for the light water reactor fleet. So they know kind of where all the skeletons, the faults, the traps, the huge sections of commented code are.

So they have a pretty good idea of what's in there, especially like in the atmospheric codes. So combining them and then making the best use of what's in there to the regulations. We think we have a pretty good idea of that and that we should be able to do it with the existing -- taking the existing codes as a framework to build these consolidated modules.

MEMBER BLEY: Okay, good. Because I read more into what you had written. And so that's encouraging. Joy?

VICE CHAIR REMPE: Yeah, during our subcommittee meeting -- first of all, I want to say I'm really glad to see the consolidation effort going on. And I understand that with the funding uncertainty and timing uncertainty, the incremental approach that you're taking is consistent with what's talked about in the introductory report that Kim mentioned earlier, that you've got a lot of constraints as you make decisions. But in the report, it referred to as I harped on during the subcommittee meeting that it's a common misconception that you couldn't go and take the MACCS code and have it simplified and do what's done with RASCAL.

And before it was over with when I went and reviewed the transcript, I think you said I guess I'm not saying it's impossible. But because of what we wanted to do, this seemed to be -- and I'm paraphrasing -- a better way to go at this time. And I think we're in agreement on that.

But are you planning any -- do we need to put it in a letter to say, are you going to kind of fix the words so it's more accurate? I'm more into a factual correction here, or what's your thought on what you're going to do about the comments that were made during the meeting about this?

MR. TOMON: Well thanks for bringing that up, Joy. Yes, I've spoken with the staff and I've spoken with Kim. And as Kim alluded, we're going to take input from that. And we're going to take inputs from the subcommittee and specifically that section, 2.1.

You're absolutely right. The words that we chose probably weren't the best in there to use that. I mean really what we were thinking about it is what -- and you paraphrased exactly how we're going to change the words to say that we were looking at the limited resources that we have and then looking at the work that's being done on MACCS and being done for codes like MELCOR and SCALE.

And we're going to put what we can from there into RASCAL because basically the user community for RASCAL looks at the code and wants it to act in a certain way, both in time internal to the NRC and external. So we are going to revise that section of -- I think it's Section 2.21 and to take out probably the -- now that I think about it, more and more, the word misconception was probably a bad choice of words. And I think we used it twice in paragraphs following each other.

But yes, exactly what you said. We're going to build on what we -- what other code developers and researchers do in research for the MACCS code, MELCOR, and SCALE and put them into RASCAL. So we're not going to try to go out and do that separately because of the limited resources and because of the uncertainty when certain things are going to come when the certain applications are going to come in. Does that help?

VICE CHAIR REMPE: Very much. Thank you very much.

(Simultaneous speaking.)

MEMBER KIRCHNER: Yes. Joy, also I'd like to observe that if and when they do this that we'll address the recommendations of the last two biannual research review reports on this particular area.

VICE CHAIR REMPE: Right. That's one of the reasons that I wanted to make sure that this was corrected. But I don't think it really merits a paragraph in our letter. It's just a word choice and I think we're all in agreement on that now.

MR. TOMON: Yes, ma'am.

DR. CORRADINI: This is Corradini. I'm a consultant to the committee. Just a quick question. The users of this are not just within the NRC.

They're within the licensee applicant community. Have you gotten input from them on how a consolidation should be done or what they would recommend in a consolidation?

MR. TOMON: We have not, not specific recommendations. But we've had some general recommendations. As part of the RAMP program, some of these code designers and developers have joined the RAMP, the Radiation Protection Code Analysis and Maintenance Program, as a user and they use the code.

And they have given us feedback during the meetings when we talk about what would be best to see. And that's where we got a lot of feedback from the developers specifically with regards to our three atmospheric transport codes and that some of the options in one code they've like to use. But it's not available because -- just because the different -- the way the codes were built individually and kind of siloed. So we are using some of their feedback in our code design, and that's how we went through our thinking process.

DR. CORRADINI: Okay. Thank you. I was going -- I didn't know the name of your user community. So it's RAMP. Thank you.

MR. TOMON: RAMP, yes. Okay. So Slide 5

shows our code consolidation approach. With the assistance of our RAMP contractor, Pacific Northwest National Laboratory, we developed a three-pillared approach to code consolidation, including first, create consolidated engines. This is a set of functional modules or engines that would be developed to perform the regulatory calculations as those performed by the current suite of licensing and siting dose assessment codes.

The functional engine approach improves development flexibility by allowing for future modification and efficient data transfer. Furthermore, separating these capabilities into standalone engines eliminates some of the current code redundancies and inefficiencies. The second was to develop a standard data transfer schema.

Using a standardized data transfer schema such as an extensive markup language for encoding the data for each engine would make data input universal and adaptable while making it easy to pass the output data between the different functional engines. And finally the last pillar was to build a single user interface. The single user interface would be developed separate from the functional engines that would interact with the users and communicate with the functional engines to execute the user defined commands.

The user interface will be designed with the thought that to effortlessly guide the users through the relevant code engine input screens primarily through a series of questions about the desired outputs. The next slide slows the conceptual models for the consolidated code. This figure on this slide is a conceptual diagram of the proposed consolidated code paradigm, showing how the models from the existing siting and licensing codes could be integrated into this new consolidated code. Modules within the consolidated code would be grouped or characterized within this general dose assessment approach.

In addition, the modules will be further broken down into scientific disciplines to account for the unique differences of these fields. The proposed consolidated code would have several modules or components, each of which will contain like phenomenological models from the existing light water reactor licensing and siting dose assessment codes. The eight modules of consolidated codes include the source term, including core inventories, release fractions and timing sequences, the atmospheric transport and dispersion modeling including near, mid, and far field models, the aquatic pathway model including ocean, river, and lake dispersion, environmental accumulation, human biota consequence modeling, non-human biota consequence modeling, dose coefficients and health risk factors, and integrated dose module.

MEMBER BLEY: John?

MR. TOMON: Yes?

MEMBER BLEY: Has your work thus far stayed at the planning stage? Or have you actually begun work on some of these modules?

MR. TOMON: We've actually -- we have just gotten through the source requirement documents from our contractor on the atmospheric -- consolidated atmospheric transport module. So we should start moving ahead now with the consolidated model. We actually -- we took the report and we made sure that NRR -- the meteorologists in NRR, they read through it.

They commented. We addressed the comments. And now we have a path moving forward for that. The source term module, we just started planning. And we expect to get a similar source requirements document from them in the next month or so.

MEMBER BLEY: That's excellent. I'm glad to hear it. Go ahead.

MR. TOMON: My next slide, this goes to the second task, the source term task. The second task is to identify source term input such as fuel inventories, reactor cooling inventories, plant design and operational data, where available, for each of the non-light water reactor fuel designs and fuel types. For normal operations, the radionuclides of interest in the source term include fission products, CAPTCHA products, and activation products produced during normal operation in the reactor cooling system.

For accidents, both severe accidents, beyond design basis accident, and design basis accident work, the primary source term information will be from the work on the MELCOR and SCALE codes as described in Volumes 3 and 5. For transportation source term, the various non-light water fuel types vary significantly from the current light water fuel configurations. In addition, some of the non-light water reactor designs may adopt a mobile reactor type approach where it is likely that the entire core containing spent fuel will be transported in a single shipment. Therefore, the transportation source term module will need to take these issues into account.

MEMBER KIRCHNER: John?

MR. TOMON: Yes?

MEMBER KIRCHNER: This is Walt Kirchner again. One complication, I'm sure you're thinking about it, and I don't know at what step you start integrating it. But when we get to some of the -- particularly the liquid fuel designs and also some of the salt designs, you've got significant -- I'm trying to choose my words carefully -- chemical toxicity issues that are -- how should I say it -- code travelers with any release of the radionuclide inventory to the -- within the actual design, within the plant, outside the plant, and to the environment.

MR. TOMON: So right now, none of the codes that we currently have address chemical toxicity issues, per se, because of the light water reactor. So that is one of the things we are thinking about for the future with some of those particular designs you mentioned. But right now, none of the -- and we have to figure out how to work that in.

That hasn't -- we really haven't gotten very far on that portion of it because none of that is -- we've had to deal with that with the light water reactor fleet. And it wasn't something we were thinking about initially. But it's something we have to probably add to the capabilities of maybe a RADTRAN code or something like that.

MEMBER KIRCHNER: Something that's analogous from the LWR code development, particularly the systems codes, first, the emphasis was on being able to handle two-phase flow. But then it was realized that carrying non-condensable gases or for that matter when you get into a severe accident situation, the hydrogen and oxygen became a consideration for the system codes and MELCOR. So I don't know to what extent the kind of physics methods that were used there would fit into your current code suite. But it's something to be thinking about going forward.

MR. TOMON: We are. It's just that we haven't gotten very far on that. And we plan to try to use, like you said, leveraged research activities from Volumes 3 and 5 as much as we can. Let them do a lot of the work and then when we get into our codes, not spend money twice as it were.

MEMBER KIRCHNER: No, no. That's smart to do that.

MS. WEBBER: Thanks for the comment, Walt. I think that's a good comment. I appreciate it.

MR. TOMON: So some of the source term considerations, like I said, we plan to work with the other code development branches and research to leverage activities from Volumes 3 and 5. We're also working with our RAMP contractor, Pacific Northwest National Laboratory, to leverage their source term work and activities with the National Reactor Innovation Center, including the National Reactor Innovation Center fission product modeling approach using publicly available information on the various non-light water reactor designs and fuel types to create categories of general reactor types.

And finally as an aside note, some of the current licensing and siting codes we have now are flexible in their current configuration to accept source terms outside light water reactor designs. For example, as currently constructed RADTRAD under SNAP, the code will allow users to enter user defined source term release fractions and timing sequences. However, this is a little bit more involved process than just selecting from the current hardwired pressurized water and boiling water reactor options already in the code.

Additionally, the NRC dose code can allow for the import of user defined normal or routine source terms. However, there is currently no code that will perform normal affluent reactor coolant source terms for non-light water reactor technologies like the GALE code does for light water reactors. The next slide is a new slide you asked me to point, and this is just recently from some work that we've done with our contractor, Pacific Northwest National Lab.

And this slide depicts kind of the methodology and the general concepts and strategies that our contractors have mapped out for developing a normal or routine source term for the various non-light water reactor and fuel designs. The proposed methodology for the normal or routine source term will draw again on that National Reactor Innovation Center fission product modeling approach and will be similar in concept to how the GALE code calculates normal source terms for light water reactors. The methodology will use built-in source -- built-in origin source term data for each non-light water technology and fuel design coupled with code features to determine the fuel isotope concentrations, calculate fission product release fractions to the primary coolant based on the ASME 18.16 nuclide classes or more if we need to develop more based upon the actual coolant, the fission products in the coolant.

Determine activity concentrations in the primary coolant, both from fission and activation products and also in the secondary coolant if that happens to be applicable to the design. And then last, determine the liquid and gaseous waste streams for each reactor design to include rates, activity, and waste stream cleanup mechanisms such as hold up. Additionally, the normal source term methodology, when we initial develop it and then I imagine it'll stay throughout, we plan on it to being very flexible to allow for user defined parameters wherever possible.

The third task in Volume 4 for non-light water reactor readiness involves the atmospheric transport and dispersion modeling. Most of the license and siting dose assessment codes have use or have atmospheric transport dispersion models which are typical Gaussian plume models. For example, ARCON PAVAN, and the XOQDOQ code uses straight line Gaussian models with different correction factors such as building wake effects, wind direction, wind speed, atmospheric stability class, location of release point, stack down wash, and plume rise to adjust for the code use.

The staff is looking to consolidate ARCON PAVAN codes into a single atmosphere engine in a phased approached. Phase one would be to integrate the atmospheric engine that would have the capability of performing near field, mid field, and far field calculations, thereby the user could perform the regulatory calculations relevant to any of these three distances. Phase two would involve adding capabilities to the consolidated atmospheric engine to support non-light water reactor technology siting such as in remote areas with different atmosphere stability class diffusion and dispersion characteristics.

What we -- this next slide is kind of the general outline that we've got for our atmospheric engine prototype. It shows examples of user inputs and features that will be incorporated to the atmospheric engine prototype developed during phase one along with the data flow between the interface and the engine. After selecting a dispersion distance model, i.e. near, mid, or far field, the user could provide source receptor inputs such as distance, intake height, direction, using 2D and 3D graphical displays.

The user would then choose a meteorological file and visualize the wind distribution. Train data could be imported from a public database such as the National Elevation

Dataset. Also train heights for source receptors could be extracted from elevation data and provide the input to the atmospheric model.

Once the inputs are set up, the data shall be transferred to an extensive -- using extensive markup language schema to the atmospheric engine where calculations are performed. And then after the calculations are complete, the atmospheric dispersion engine will allow the users to select various output options for both reporting and plotting the results. The fourth task involves the dose coefficient module, developing a dosimetry module that has the flexibility to use different integers, dosimetric models, and dose coefficient values, and examining the dose coefficient models with respect to aerosol particle size since non-light water reactor technologies could release particle size smaller than the one to ten micron range that are typically considered in the current code.

Currently, the dose coefficients and dosimetry models are hardwired into most of the codes. And the user has few options to edit or change these values. An important element of this task is to design the module with the understanding of different dose endpoints of siting and licensing of non-light water reactor designs. The other dose coefficient consideration is that this module will be flexible that it would allow the user to select from Federal Guidance Report 11 and 12 dose coefficients which are used by the current regulations, as well as future federal guidance report dose coefficients such as those in FGR 15 and possibly 16 when that is released.

Another part of this module will consider options to allow the user to select aerosol particle sizes for the radionuclide which could directly impact the calculated dose. And as I said, many of the existing dose assessment codes with the exception of the RADTRAD code do not possess for the user select user defined dose coefficient values. We have a couple codes like NRC dose and RASCAL which does allow the user to choose between different dose coefficient values from different hardwire dosimetric models such as ICRP 26, ICRP 2630, ICRP 2, and ICRP 6072.

MEMBER KIRCHNER: John?

MR. TOMON: Yes?

MEMBER KIRCHNER: At this point, how much of that you just covered is already in MACCS?

(Simultaneous speaking.)

MR. TOMON: I'm not sure. I mean I don't know how much of MACCS actually uses DCFPAK. We're planning to -- I'm sure they do. But I don't know to what extent and to what vintage that MACCS actually has. I wouldn't be able to answer that. I'm not really sure. I'm not a very fluent MACCS user.

MEMBER KIRCHNER: Well MACCS went through a lot of effort to incorporate HYSPLIT, the atmospheric model developed by NOAA. Maybe I misunderstood, but I thought most of the engine you're describing already existed in MACCS and that you would extract that and --

MR. TOMON: Well --

MEMBER KIRCHNER: -- make it compatible with your data and user interfaces. It seems to me that you have put a tremendous amount of effort into MACCS. What am I missing here?

MR. TOMON: Well that's -- I was talking about the dose coefficients. And previously, I was -- the previous task was talking about the atm, which was you're referring to. But you're right. I mean they are also exploring in MACCS, I think, in changing the near field modeling.

But a lot of what -- I think they're planning to use some of the models that are in ARCON for the near field modeling. Those models obviously are in ARCON already, and they are also because ARCON was developed in the same -- at the same contracting place, Pacific Northwest National Lab, as RASCAL was. A lot of those are already in RASCAL itself.

But we will -- if there are significant changes to the far field modeling that are different than what we use in a code like MACCS or further out like XOQDOQ, we would definitely look to employ them into the atmospheric consolidated engine. And that's one of the thing we hope is that using the data schema -- the XML data schema, it'll be more flexible and we'll be able to do drop in and replace models as work is done. And we find that model more efficient than the current model we're using.

MEMBER KIRCHNER: Well maybe this is a question for Kim and can be deferred. But in our review of the RES efforts in the systems analysis area, we spent a fair amount of time going over MELCOR and MACCS and their attempts to use the same kind of approach you're using, John, in terms of separating the development of the physical models from the development of the solvers and such so that you had the equivalent of your engine packages. I'm just a little concerned right now because our recommendations in this area were to take the best estimate practices and tools that were developing for MACCS and see if you could extract those engines out of that particular code and use them to backfill all of those specific user codes that you have that you mentioned previously. And I guess I'm missing something here if MACCS -- is MACCS going to continue as a standalone code?

MS. WEBBER: Yes, it is. So MACCS is going to continue as a standalone code. The real benefits of MACCS are to support a lot of precise kind of detailed analysis that's needed to evaluate consequences. And so the application of the radiation protection codes and the codes that John is talking about really go to ease of use of these codes.

Not to say that MACCS isn't easy to use, but it does require a level of understanding of a lot of input parameters in order to get some analysis that kind of makes sense. So there's definitely a substantial amount of skill that's needed to run the MACCS code. And it is used external to the agency as well.

So it definitely has a place not only in doing research studies such as SOARCA and other studies. But it also has a place with some of our external vendors or developers as well. But these codes, John's codes, these RPB codes, they also have their place. And a lot of people choose to use those because of the ease of use.

And so I can't really answer the detailed question, Walt. We'll have to take that one back. But I think your message really is where we have capabilities in other codes regardless of the code, we should leverage those capabilities to our benefit.

MEMBER KIRCHNER: Well yes, and I think that was the theme of our recommendation over the past two biannual research reviews in this particular area. So --

MS. WEBBER: Yeah, it's a good one.

MEMBER KIRCHNER: Yeah, it's just a concern on my part because your MACCS code is evolving to be the state of the art, so to speak --

MS. WEBBER: Yeah, yeah.

MEMBER KIRCHNER: -- for atmospheric dispersion and consequence analysis. So it would seem to me if it's modularized, then you could take the engine from that effort and plug it into some of your legacy codes. And as far as the user is concerned, the user doesn't have to know the --

MS. WEBBER: Correct.

MEMBER KIRCHNER: -- detailed physics of the solver and for MACCS. Okay. I've made my point, I guess.

MS. WEBBER: Yes.

MEMBER KIRCHNER: Just I got a little confused here because it seems like the efforts are redundant with what's already going on for the MELCOR MACCS modernization efforts.

MS. WEBBER: Yes. So we definitely will take a look at that. I appreciate you raising it.

(Simultaneous speaking.)

VICE CHAIR REMPE: Go ahead. I'm sorry. I thought you were done, Walt. Walt?

MEMBER KIRCHNER: I'm done. No, I think --

VICE CHAIR REMPE: Well during the subcommittee meeting, we spent a lot of time discussing it, and it's a different approach. One could have a simple user interface with MACCS and try to take that on. But there are these other codes that are simpler and consolidating them so you don't have 10 of them and go down to a fewer number. My impression --

(Simultaneous speaking.)

MEMBER KIRCHNER: No, I agree with all of that, Joy. My point was if indeed the internal engines, to use John's terminology, of MACCS are state of the art, it would seem to me -- and they functionally equivalent of the -- and I'm not going to get all the acronyms right, ARCON, PAVAN, XOQDOQ, et cetera, with the HYSPLIT addition from NOAA. Now maybe that's too much to put in these other legacy codes. Maybe it would not function. But it's just a concern.

VICE CHAIR REMPE: Yeah. Well again, I think two different paths could've been taken. Again, as long as you get there and there is -- what can you do with a little bit of money if you aren't sure it's going to continue? Those kind of factors seem to come into play too.

And so yeah, maybe there is some redundancy. But as long as they are making progress is why I kind of -- I wanted to make sure you didn't say it was impossible to do the other path because I don't think it is. It's just --

MEMBER KIRCHNER: No, no.

(Simultaneous speaking.)

VICE CHAIR REMPE: -- a lot of money, do it for a long period of time, I would be pushing harder to say let's go with MACCS and just have a simpler user interface because ultimately you might save money in the long run.

MEMBER KIRCHNER: No, I understand and

appreciate fully. You've got a user community out there. You've got immediate needs. And this path that John is outlining may be -- especially to get the flexibility you need for the non-LWR concepts may be the best approach with all the boundary conditions applied. But it just strikes me a little bit different than the conversation we had when we did the research reviews.

VICE CHAIR REMPE: Yeah, I agree. And it's not totally clear to me, but I get what they're saying.

MR. TOMON: Just to throw one other little wrinkle in it is that ARCON, PAVAN, and XOQDOQ really derived a lot of their equations and how they'll do it from several reg guides. And the reg guides haven't been updated in years, and that's one of the functions that we want to do with consolidating the code. We didn't put it on here, but work with the meteorologist too because their fallback is the reg guides tell the licensee how to do these calculations for. And that's what PAVAN, ARCON, and XOQDOQ are set up to do.

But they can be revised since they haven't been revised in a while. So going forward having this one consolidated engine may be in the revisions of the reg guides. We don't want to get too far in front of the reg guides. We want to make them come at the same time.

But it might be pulling in the better or different models from MACCS. They're more state of the art and they can do the same functions. And that's agreed upon with the meteorologists and their licensing activities.

MEMBER BLEY: Are the same people going to be working on the reg guides as they're working on the codes then?

MR. TOMON: I'm going to -- well the plan right now is talking to then -- in talking with NRR is, yes, to have the contractor that's PNNL that's working on the consolidated ATD code as once they get close to having the consolidated code is to work on doing the updates to the reg guides with, but making sure that NRR is actively involved in any updates and revisions we do to those codes, so yes.

MEMBER BLEY: Okay. Thanks.

MR. TOMON: So I only have I think two more slides left. So hopefully, I'll get through them quickly here. So my next slide, Slide 14, is it shows the last task, the environmental pathways.

And this is going to be a task that we're going to accomplish in the future down the road. It's not really dependent upon the non-light water reactor designs and fuel types. So we're looking at a time frame of greater than five years to actually look and explore changing some of the models and the environmental pathway.

This task will also look to explore feasibility of radionuclide particle size as we discussed before. And the task will also leverage models from the GENII code and decommissioning codes like RESRAD. My final slide shows some of the -- and this is a new slide to answer that question -- shows some of our near term planning and milestones for license and siting dose assessment code readiness.

The staff determined that the dose assessment codes would have to be updated for the various non-light water reactor designs and phases based upon the availability of resources and the time frames of application. In our phased approach, we are considering near term to be now through the next three years, an intermediate phase three to five years, and longer term greater than five years, with the ultimate long term goal of reducing the 10-plus siting licensing codes down to two or three by that five-year point that accomplish the same regulatory functions as the existing suite of codes.

MEMBER BLEY: Hey, John?

MR. TOMON: As a matter of fact -- yes?

MEMBER BLEY: Could you go back a slide?

MR. TOMON: Sure.

MEMBER BLEY: You mentioned particle size and behavior. Where do we stand on knowledge base for those kind of chemical-related effects for some of the new designs?

MR. TOMON: I really haven't seen an environmental source term for any of the new designs yet. So I'm not really sure. It just could be I haven't seen it yet. But I know that -- I know they've come up with generic kind of inventories for the National Reactor Innovation Center. But I don't know if they've come up with environmental inventories that get at -- whether it's a normal or an accident and what those -- what the radionuclides are in that release and then basically what the particle size. I haven't seen that as of yet, so I'm not really --

(Simultaneous speaking.)

MR. TOMON: -- sure where that it.

MEMBER BLEY: It strikes me that we really need some experiments on this. Maybe Dave or somebody has some thoughts on that.

MEMBER PETTI: Yes, so Dennis, I'm not too worried down to half a micron. The equations are all there, whether or not there's corrections as you get smaller. So they're not -- so things could just be not very difficult to add has to do with the size of the particle relative to (audio interference) things like that.

In terms of what is actually emitted from the reactor design, that's going to be partly due to -- on the shoulders of the applicant where there is some data, for instance, on dust in a pebble bed reactor. And I think it's probably reasonably adequate they went and they got a distribution and mean size, all the stuff you expect. I'm not so sure about some of the other -- this stuff being done.

MEMBER BLEY: Yeah, I know the ACGRs have looked at that a lot. But yeah, the other areas are suspect.

MEMBER PETTI: Well, in the sodium, if there's a higher -- we know what particle size it is. There were tests done years ago. The only one is salt. That's where things are a little bit less clear.

I just had a question, John. My sense here that there's a huge value in the consolidation of the existing fleet. And let's call it the existing regulatory infrastructure, all the stuff that happened by people, whether it's the applicant, the NRC, even I'd assume EPA and some of these other organizations that we would need that. And so although a lot of this has to do with the advance of the non-LWR designs, this should be leaning into the 21st century, if you will, for the LWRs as well. Is that fair?

MR. TOMON: Yes, that's the way we're looking at it as well. Because yeah, it goes back to what we said before, limited resources and everything being built in kind of silos before and now trying to get them all into the 21st century. Making this consolidated code would make things a lot easier for the existing fleet as well as -- and making it flexible to add things for the non-light water reactors as well.

And then the only other thing I wanted to point out on this slide is that we are planning for the development and piloting of the consolidated atmospheric transport engine by the end of the second quarter of fiscal year '22. And we will continue to meet and collaborate with our code developers, our contractors, and the counterparts in the program offices in developing and coordinating implementation plans for code consolidation. And that's my last slide. And if you have any additional questions, I'll be happy to answer them.

MEMBER BLEY: Thanks, John. I think we can go ahead with the next talk.

MR. ALGAMA: Howdy. My name is Don Algama. Oh, sorry, Ken. Let me know when you're ready.

MR. ARMSTRONG: I'm ready, sir. Can you see it?

MR. ALGAMA: Oh, yes. Thank you very much, Ken.

MR. ARMSTRONG: Perfect.

MR. ALGAMA: Hello. My name is Don Algama, and I'm here with Drew Barto, NMSS. I'd like to present the staff's draft approach to develop insights into fuel cycles from non-LWRs. It's actually for non-LWRs and understand computer code performance. And I want to make sure, as everyone understands, is as we learn more, we might update the process, particularly from information from the DOE and vendors. Next slide, please.

I'd like to acknowledge a lot of great people who helped produce this document from the program offices, NRO, NMSS, and Research. And within Research is Oak Ridge, in particular, Dr. David Luxat and Dr. Will Wieselquist who were crucial in this report. Next slide, please.

I won't spend too much time. This is a summary of what Kim spoke about earlier today. Next slide, please. The goal of the plan is to apply and understand the performance of existing NRC tools to support fuel cycle evaluations. And the hope is in doing this we'll demonstrate our computer code performance and readiness, and also staff will gain an understand of what to expect or some insights into the non-fuel cycle processes.

And the plan is intended to be updated as we learn more from DOE and the industry of both the designs and what we might expect from the actual operations of these designs. The plan takes on a delta approach using the existing LWR fuel cycle as a reference. It's basically an incremental approach comparing the candidate non-LWR design against existing fuel cycle capabilities and developing on the same spectrum hazards and accident scenarios.

As we are taking LWR approach, this means in practice we will also be coordinating closely with internal partner groups when the scenarios demonstrate the need such as those in Volume 3 and Volume 4 and NRR and NMSS teams. As in Volume 3, the input decks and analysis notes will be made available to the public upon completion. Next slide, please.

As I mentioned, the objectives -- the results -- the reports ultimately demonstrate computer code readiness and to understand how they perform. To achieve this, we will have to look at developing scenarios to identify potential hazards to assess against. For this, we will look at both existing guidance as well as anything available from the DOE and design information that's public.

We intend to be flexible in our approach and the plan will evolve as we implement as mentioned before. The following list are some documents that we intend to leverage to support criticality safety, radionuclide inventory characterization, decay heat estimation, radiation shielding, and radionuclide and non-radionuclide hazard evaluations. As noted earlier, anytime we have to deal with consequence assessment areas, et cetera, they'll be raised to the appropriate team at NMSS, NRO, and within Volume 3 and 4 as they occur. So we'll make sure to coordinate.

With 6410, the focus is on understanding characteristics of releases of radionuclide material and/or hazardous chemicals from non-reactor facilities. Particularly, it includes a description of process hazard analysis and other structured event scenario development approaches that can be used to support integrated safety analysis. That handbook covers actual scenarios, including criticality events, release of materials, the in-facility transport depletion processes, and leak path factor estimation.

Table 2-2 of that report provides a range of scenarios that we can evaluate. NUREG-1520 complements 6410 and covers 10 CFR 20 and 70 applications. The focus of this SRP is to ensure quality and uniformity of reviews, and it provides us with further insights.

With NUREG-2215, we move from facilities to storage, Part 72. This focuses on certificate of compliance for dry storage systems for use at a general license facility, and two, a specific license for a dry storage facility that is either an independent spent fuel storage installation, ISFSI, or a monitored retrievable storage installation, an MRS. This SRP provides us with insights into what to look for in storage conditions such as margins to subcriticality, how it would prevent releases, et cetera.

In NUREG-1567, this complements 2215 as it applies to wet storage. With NUREG-2216, we move to transportation. That covers shielding, criticality. And Table 1-2 provides an example scenario to demonstrate subcriticality. And Attachment 2A of that report provides staff expectations for computer codes.

Complementary DOE documents, one is an example, it may be useful for developing hazards as presented. But there are other DOE documents such as DOE Standard 102792 which is for hazard evaluation techniques; DOE Standard 30072007 which covers SER, non-path facilities; and DOE Handbook 30101-94 provides airborne release fractions for non-power facilities. These will all be reviewed in the implementation phase to understand how best to evaluate this scenario. Next slide, please.

This slide captures the basics of Volume 3 approach for non-LWR analysis and an illustration of how we plan to apply each for Volume 5. As before, we start with fundamental data processed by SCALE and then passed as input to the severe accident source term code MELCOR. Anything to do with consequence analysis will be handled by either Volume 3 or Volume 4 as appropriate. Next slide, please.

With a scenario and understanding of what is interesting, we can investigate existing code performance in the areas of criticality safety, radionuclide inventory characterization, decay heat estimation, radiation shielding, and radionuclide, non-radio, and hazard evaluations. Areas such as mining, milling, long term storage and disposal, consequence, radiation protection, chemical toxicities will be covered elsewhere. As with Volume 3, we expect to reasonably apply comprehensive and methodological approach from starting with scenario definition, identification of items of interest, identification of dominant phenomena we need to capture through to V&V and appropriate documentation.

The design selected in Volume 3 will be used as a driver for Volume 5 analysis approach. And here we're looking at HPR, HTGR, FHR, SFAR, and MSR classes. Next slide, please. Thank you. Right now, we anticipate ten reports, as before we're flexible on this. They're not shown in order and we are flexible.

As we learn more from the DOE and its partners, we will adapt. This includes how we prioritize work. The ten reports are broken down into five reports looking at non-LWR specific fuel cycles and five reports that cover common fuel cycle activities.

The reason for this is to try to make use of efficiencies and commonalities. For example, look at HTGR and FHR, we anticipate that Reports 6, 7, and 10 will be common. So once we do it for one, it'll be ready for the other one. Next slide, please.

So this is how we plan to begin our approach. As mentioned, the LWR fuel cycle will be used as a reference to understand the anticipated non-LWR fuel cycle. To make the task tractable, we broke down each of the steps into six major steps and several sub-steps.

These are labeled with the first letter of the stage and a number with a sub-step. So fabrication, for example, can be broken down to two sub-steps, identified as F1, fabrication of UO2 facilities for example, and F2, fabrication of fresh fuel assemblies. This work right now will not look at scenarios of interest in the T3 and S1 steps due to less information available on what DOE and industry intentions are. We will revise as we learn more. Next slide, please.

This is an example of what we anticipate the stages will look like for an HTGR fuel cycle report. The HTGR concept has been developed for decades with experimental reactors starting from DRAGON from 1963 to 1969, AVR from 1967 to 1998 to HTGR which is 1998 and still operating, HTGR-10 from

2003 to the present, and through to commercial operations from Peach Bottom 1 which operated from 1967 to '74, the THTR, Thorium High Temperature Reactor, I like saying that, from 1986 to 1989 and even Fort St. Vrain from 1976 to 1989.

For this work, as based in Volume 3, we chose the PVR-400 to drive this class of analyses. And there are two basic types of this reactor which is pebble bed and prismatic. And they're using a pebble bed type reactor.

We can expect there are hundreds of thousands of pebbles in the reactor core, tens of thousands of TRISO particles and online refueling and helium as the coolant. So those are the basic characteristics of this design. We've learned a lot from the NGNP base.

So with our approach for this fuel cycle that covers this reactor design, it'll be in a series of products. So for example, in Report 6, we will tackle the generic E1 and T1 activities which cover UO6 enrichment in transport. We anticipate maybe some primary hazards there with the enrichment facility with chemical hazards through the release of UO6 and the criticality hazards associated with enriched uranium.

In a trial phase of UO6, we will look at different configurations of canisters and overpacks to understand how the system responds. And Report 7 which is the F1 step, we will look at -- we will cover TRISO fabrication. We will look at the various fabrication steps and look for criticality and radionuclide and non-radionuclide hazards that may arise.

In Report 10 which is the F2 step and T2 step, we will look at fabrication of pebbles and their transport to the utilization facility. In Report 4, this report is expected to cover the utilization step. Sub-steps U1, U2, and U4 stage, the U2 step will also be coordinated to the Volume 3 report as it leverages the work performed there. The U3 -- oh, excuse me. The U3 step which is spent fuel pool shuffling as seen in the reference cycle is not covered here. In the U4 step, we will look at onsite discharge of pebble storage -- for pebble storage. Next slide, please.

So in conclusion, we believe that we have a reasonable approach in the reference to delta strategy. With the LWR fuel cycle used as a reference to understand the non-LWR needs, we believe that the development and assessment work being performed under Volume 3 will cover the needs we expect to have in

Volume 5. We believe that sufficient experience in the application of SCALE and MELCOR to non-reactor facilities exist to start the process.

This experience will be developed and refined as we get more experience and information with DOE and its partners. To develop experience in the future we are also developing reasonable scenarios to apply the codes. And we will leverage other NRC teams including those in Volume 3 and Volume 4 as the scenario dictates. Thank you. That's the end of my presentation.

VICE CHAIR REMPE: Don, this --

MR. ALGAMA: Yes, ma'am.

VICE CHAIR REMPE: -- is Joy. During the subcommittee meeting, I know I emphasized a lot about there's a lot of real world examples that weren't covered by the sources that you indicated even on this slide earlier in your presentation. And that was similar to what I saw in the report, as I recall. And after the meeting and maybe even during the meeting, Amy Cubbage mentioned, well, we actually have started to ask the laboratories to do some research to give us some real world examples.

And after the meeting, we were sent some reports. I note the level of depth varied considerably for the different reactor types. But I just wanted to acknowledge that that's the kind of detail I was looking for because the DOE report on your slide was very outdated and old and had limited information. And so I was glad to see that you're starting to do that because -- and you might want to think about updating this report before it's issued to acknowledge those references and that effort that's ongoing with the advanced reactor folks.

MR. ALGAMA: Yes, ma'am. Thank you for the pointer. I appreciate that.

MEMBER BLEY: Don, I don't know if this is for you or for Kim or someone else. In the conclusions of your report, you list the ten reports that are expected in the future. And they were numbered that way, one way in the report and another way on the slide to the last time I saw them.

MR. ALGAMA: Yes.

MEMBER BLEY: But that isn't my point.

MR. ALGAMA: Oh, okay.

MEMBER BLEY: In the report, I think at the time of the subcommittee, we were told the enrichment -- and you have swift handling up to 20 percent was available now. The TRISO fuel form of fabrication was available as well as the table TRISO fabrication. Do you have a schedule for the other seven reports?

MR. ALGAMA: Right now, apologies if I misspoke at the subcommittee meeting. Those -- we don't have those reports available yet. We haven't done the work. There are some complementary work that we can leverage, for example with the UO6 transportation packages we're looking at for the LWR ACS HLU work. That -- we have a report available for that. But that only covers part of what we anticipate we'll need to cover non-LWR activities.

MEMBER BLEY: Okay. So it'd be my misunderstanding.

MR. ALGAMA: I apologize if I misspoke.

MEMBER BLEY: Do you have a schedule for them, and are you planning to bring them to our Committee?

MR. ALGAMA: We can. Yes, sir. We don't have a schedule yet, but we can bring it in once we do.

MEMBER BLEY: Okay.

MR. ALGAMA: The first task is to try to figure out what Joy was saying, bring all the available knowledge together to understand what we should look at and how to develop the scenarios to apply the codes.

(Simultaneous speaking.)

MEMBER BLEY: I'm sorry. Go ahead.

MR. ALGAMA: No, no. I apologize. Go ahead.

MEMBER BLEY: Have you thought about the priority of which ones you want to get done first and why?

MR. ALGAMA: Yes, sir. We're using Volume 3's approach is which is coordinate with NRR to dictate which designs we would pick first. So the first one will be the HPR, the HTGR, and the FHR. Those are the first three we're going to look at.

MEMBER BLEY: Okay, great. Thank you. And I think you would find a lot of interest on the Committee to get a look at that.

MR. ALGAMA: Yes, sir.

MEMBER BLEY: Any other members have a question?

MS. WEBBER: Can I just comment on that?

MEMBER BLEY: Oh, please.

MS. WEBBER: That's a good question, Dennis. I mean, so what Don and the staff and Drew and the staff have really done is outlined an approach. And so maybe -- this is a suggestion.

Maybe in terms of writing the letter, you write a letter based on the overall approach and some other things that you noted, Joy, in terms of references and so forth. And then maybe we finish that report, make it a Rev 1 or whatever like we did with the other ones and then come back to talk about some of the details because I think there is quite a lot of important technical detail that would be included in those subsequent ten reports. So I think we need to just think about it.

MEMBER BLEY: I got a little confused from what Don told me. And looking at this last slide, it does say that in this numbering system, 6, 7, and 10 are already available. And that's true?

MR. ALGAMA: No, it's not.

MEMBER BLEY: That's not true either? Okay.

MR. ALGAMA: No, I'm afraid not. We haven't actually started the work. So none of these --

(Simultaneous speaking.)

MEMBER BLEY: That's what I thought you said. Okay.

MR. ALGAMA: Yes, sir. Yeah, I may not be helping with this in a --

MEMBER PETTI: I doesn't mean you have enough information that you could start. That might be what you meant to say.

MR. ALGAMA: Yes, we believe we have enough information to get something going to provide some kind of scenarios to assess our codes against. We believe there's enough knowledge out there.,

MEMBER PETTI: So in terms of the first five volumes, just in general the priority is going to be what month are we asking because things are fairly volatile. But DOE issued some big money to a pebble bed design and a sodium fast reactor design. So actually number 3 there might move up in priority whereas the fuel cycle analysis for the FHR may not be all that different than a pebble bed in terms of the fuel cycle per se. The reactor analysis will be different. So there's some things that could flip this stuff around.

MS. WEBBER: And to your point, Dave, thanks for raising the question of priority. I mean, all along since we've been developing these volumes, there's been so many changes with the non-light water reactor community. And notably, DOE's funding of these two advanced reactor demonstration projects and at a substantial level, really does help with prioritization of activities.

And so as best we can, we do try to pivot, if you will, towards the priority du jour. And it does seem that, again, with last year's awards -- DOE awards, there seems to be some substantial interest in those particular reactor types. So it's a good comment.

MEMBER KIRCHNER: Don, this is Walt Kirchner. Following the kind of fuel cycle from mining to disposal approach, of your codes, if we put aside for the moment the utilization aspect, pretty much I would think that your workhorse tools are fairly flexible and available to analyze certainly all those parts of the fuel cycle with the exception of the utilization. Is that a good summary? I mean, I'll pick on something. I'm assuming --

MR. ALGAMA: Yes.

MEMBER KIRCHNER: -- you're going to use the Monte Carlo code for MCNP for criticality --

(Simultaneous speaking.)

MR. ALGAMA: It'll be SCALE. So this will be --

MEMBER KIRCHNER: Or SCALE? Okay.

MR. ALGAMA: Yes, sir.

MEMBER KIRCHNER: I misspoke. But pretty

much aren't the tools -- I think the tools as I know them, and my experience now is quite dated, have the flexibility to address pretty much on both sides of the utilization.

MR. ALGAMA: Yes, sir. And we're using it in some parts of even U2 power production phase to provide in Volume 3, so where it makes sense for containment analyses or --

(Simultaneous speaking.)

MEMBER KIRCHNER: I'm thinking transport -- the codes available for structural analysis and thermal analysis of transport, for example, probably are flexible enough to accommodate these different designs. Is that a fair statement?

MR. ALGAMA: I believe so, sir. That's our starting-off position is that we have the capability.

MEMBER KIRCHNER: Yeah, okay. So then the real rub comes into the utilization area with some of these advanced concepts.

(Simultaneous speaking.)

MEMBER BLEY: Any other members of the Committee have anything you'd like to raise?

(No response.)

MEMBER BLEY: Thomas, can we get the

public line open? We'll be opening the public line. Any member of the public who would like to make a comment in a moment, we'll ask you to state your name, affiliation, and give us your comment for our consideration. Thomas, are we open yet?

MR. DASHIELL: Lisa, coming up live. Going live. Public line is open --

MEMBER BLEY: Thank you, Thomas.

MR. DASHIELL: -- for public comments.

MEMBER BLEY: Anyone out there on the public line who would like to make a comment, please state your name and give us your comment.

(No response.)

MEMBER BLEY: I guess we have no one. Thomas, we can close the public line. And Mr. Chairman, I can turn it back to you.

CHAIR SUNSERI: Thank you, Dennis, and thank you, staff, for that presentation. It's 3:22 right now. Our next presentation is scheduled to start at 3:30. It's an informational briefing on Post-Halden plans.

Since that is an informational briefing, what I'm going to do is I'm going to call for an eight-minute break here. We will resume at 3:30 because we need to respect the research group's time on this. They're expecting to start, and we should abide that.

However, since this is an informational briefing, members will be -- I'll ask that members can come and go as you determine your needs are being met. So we will take a recess till 3:30. We'll reconvene at 3:30, and members are free at their will to take their break however they want. Thank you.

(Whereupon, the above-entitled matter went off the record at 3:23 p.m. and resumed at 3:33 p.m.)

CHAIR SUNSERI: We will proceed with the meeting. This is a session on post-Halden plans, informational briefing by RES. I'll turn it over to Subcommittee Chair Joy Rempe, who's also Vice Chair of the full Committee.

VICE CHAIR REMPE: Thank you, Mr. Chairman. Colleagues, this briefing pertains to our efforts to address the 1997 SRM to the Commission to examine the need, scope, and balance of the Reactor Safety Research Program and follow the Commission's directive that ACRS consider how the Office of Nuclear Regulatory Research, or RES, anticipates research needs and positions for the changing environment.

In our 2020 review and evaluation of the NRC Safety Research Program, we observed there were several research topics of special interest for additional briefings. In subsequent interactions with Ray Furstenau, the Director of RES, he indicated that the Committee's review on such topics would be of more value to RES than the quality reviews of selected projects that we previously performed for RES.

In September 2020, we were briefed about the future-focused research project efforts by RES, and today we're going to hear about a second topic of interest, RES activities to address the gap associated with the closure of the Halden boiling water reactor that was used to obtain data to assess the irradiation performance of fuels and material.

So at this point I'd like to ask Ray Furstenau, the Director of RES, to begin today's meeting.

MR. FURSTENAU: Thank you, Vice Chair and Chairman, for having us come in and provide this information briefing. It really is my pleasure to introduce this part of your agenda today.

I know it's been a long day, but I think you'll find this pretty interesting. I know it is for me, and I do appreciate Matt, both you and Joy in working with us to come up with topic areas. I really think this will be very beneficial to the NRC's research program to provide these briefings and get feedback from you. So thank you for that. Next slide, please.

Here's the agenda. I'll provide some brief opening remarks, but I really want to have time for, you know, some really top quality researchers that we have on our staff to talk about the fuels activities and strategies and then the material, structural material strategy. Looking ahead, a vision of the future, our Engineering Director, Louse Lund, will talk about that, and then I'll have some brief closing remarks. Next slide, please.

And Dr. Rempe already talked about our motivation for doing these information briefings, so I won't spend a lot of time on that. This post-Halden planned discussion will only be for the fuels and materials research. There was a separate activity as part of the Halden project called the man-technology organization interface, and that's still going on and we are participating in some of those activities. Next slide, please.

This is kind of a hard one to see, but this just kind of shows you the timeline of recent Halden events and the shutdown, the decision announced permanent closure of Halden and some of the early activities that have went on since that occurred.

And I'd like to point out we've been participating in the INL workshops and the NEA activities related to post-Halden activities as well. And we'll be getting into much more detail on these in some subsequent presentations. The next slide, please.

And you'll hear also, there's been a lot that's been happening. You know, we've -- a lot, you know, Halden was a nice total package, and I think in some respects we were fortunate to have it as long as we did. It was a very good deal for the NRC and the rest of the international community, but once it shut down we -- you have to move on. And we have to fill those gaps the best we can.

And I'm very optimistic that we'll be able to do that. Halden did a lot of good things, it was a bargain to us. But we -- we're going to find ways to fill those gaps. And you'll hear much about that today again.

And our NRC staff have been in a leadership role in many of the initiatives, both domestic and international. We've been kind of spearheading the effort, along with DOE, on the FIDES framework, that's the framework for irradiation experiments, which is kind of the life after Halden on the international end for the NEA.

And we've been working on that framework. That agreement is almost in place. I think probably within a month we'll be ready to go and there'll be several JEEP activities that we'll be able to get started. And those'll be talked about later as well.

So these are the types of things we'll talk about. Archiving of the Halden data, which we think's important. The new research projects we're going to be doing, both with participants domestically and internationally. Retrieving of some of the Halden materials so it doesn't get disposed of as they're decommissioning that facility. And the new domestic capability -- new experimental capabilities.

And we do have some -- we're going to be talking about some of the DOE programs. And so if there are any questions regarding the DOE partnerships, we do have some people that can help answer questions on that. So next slide, please.

And the benefits and the challenges, I think you're aware of those. The benefit of having a diverse network of research facilities can be positive so we're not vulnerable to facility closure like what happened with -- single facility closures like what happened with Halden.

And I think the investment in US facilities, DOE's really stepping up in investments in their research reactors, hot cells. The NRIC program, which is the Nuclear Reactor and Innovation Center program that kicked off in the last couple years.

They're building capabilities, like a molten salt thermophysical examination capability in Idaho, the LODIS facility and DOME (phonetic) facility in Idaho to really be able to do demo activities that we can take advantage of the work that's being done there as well.

So, but the challenge obviously is these multiple research activities will probably be a higher cost than the Halden project was. But we have been working with DOE. DOE's picking up more of the cost of the FIDES framework and the projects coming out of FIDES. We are able to join as participating members of JEEP projects when they're domestically located in the US at no cost to the NRC.

So we're trying to look at a lot of different avenues of how we can best utilize the funding we have and participate in research activities for fuels and materials. Next slide, please.

VICE CHAIR REMPE: Could I stop you for a second?

MR. FURSTENAU: Sure.

VICE CHAIR REMPE: The situation about the Halden gap was brought up during our December meeting with the Commission. And after we discussed it, one commissioner said as you -- eventually we were going to have this briefing and we were going to be evaluating it. And they mentioned that they were concerned about having diverse test facilities, that it might cause some differences in the data that might be more difficult to explain.

And it's my opinion, and I didn't have the opportunity the way the comment was offered, that if you have adequate instrumentation, you can overcome such difficulties. And so your point about having multiple facilities might be good because we won't be so dependent on one facility.

But on the other hand, this challenge you've brought up about the cost of multiple research initiatives is going to be most likely higher. And one of the nice things about Halden was they had standardized test rigs.

They knew what they were doing by always having the same kind of test rig go in for a particular type of test, so they didn't have to expend resources for designing a test rig, which I know from your background at ATR you understand that that is quite expensive. But we don't worry about cost, we worry about safety --

MR. FURSTENAU: Yes.

VICE CHAIR REMPE: If resources are still an issue for ACRS, because it prohibited us from getting -- from advising how the staff can get what they need to address safety issues.

So one, I'm interested in your thoughts about the instrumentation overcoming differences in facilities. Then two, as you interact with these various facilities, is there a push to say hey, let's try and have some standardized tests and everybody realized that this is what we're going to do? Because that was a nice benefit of Halden.

MR. FURSTENAU: Yeah, okay, Joy, I'll comment on that and I'll try to cover. If I miss something, please let me know. As far as standardized tests, I think, at least my understanding of like what's being done with ATR, for example, if they took a I-Position loop and some of the treat testing that's -- has the capabilities that are being developed and standardized tests at Holgers (phonetic) and instrumentation allows for more economical testing, and maybe quicker testing as well.

And the instrumentation challenge, I, you know, I think the national labs get -- trying to learn the benefits, the lessons learned from like Halden and from international test reactors on how do you instrument these things, whether it's material or fuel. And how do you know what you're measuring. And that's always important in any of the tests.

And then how do you somehow make sure you get consistent measurements like using, I don't know, using the same type of thermocouples. Where do you put them. And same way with pressure caps and things like that.

So I think those are things we have to stay aware of in the integrity of the data and how we pedigree that data is very important. And, but I think that happens whether you're at one facility or multiple facilities, Joy. I think it's just harder when you do it at multiple facilities. But I think it can be done.

VICE CHAIR REMPE: I agree with you. You need to be cognizant of how the facilities are run, because Halden is, for example, a type C thermocouple, which might be difficult to -- which transmutes, by the way, due to the radiation and you can't quite use that at ATR because, you know, at Halden, they always brought it up to the same power level.

MR. FURSTENAU: Yeah.

(Simultaneous speaking.)

VICE CHAIR REMPE: -- controlled runs that you move because of other tests. And so you're going to have to be cognizant of some of the specifics of the facility. But I do think it's a challenge that can be addressed.

MR. FURSTENAU: Yeah, it certainly is. I would agree with you, Joy, yeah. Anything else?

VICE CHAIR REMPE: Nope, thank you very much.

MR. FURSTENAU: Okay, next slide, please. And I won't spend a lot of time on this because we've really already talked about it, about these things. I did want to point our university, integrative university program offers another mechanism where we can maybe get some more research done by the universities, especially in the more future-focused type research.

Some of you may or may not be aware, in Fiscal Year '20 funding we receive from Congress for the Integrative University Program, we normally fund fellowships, scholarships, and faculty development grants. But in FY '20 we broadened the scope of that a bit and we created two funding opportunity announcements, one for the traditional faculty development scholarships and fellowships.

But we did a separate FOA that really asked the universities in particular areas to propose multi-year research projects up to three years and up to $500,000 per project. And the response was really overwhelming. We have, oh, in the neighborhood of 140, more than 140 qualified applications. And we chose 15 out of that, and maybe we can brief you on those sometime.

But it was really -- and so we really want to take advantage of the university program for good ideas on how to help with our emerging research needs. So it's really a kind of exciting time in research, I think.

So with that, I would like to turn it over to Michelle Bales and Lucas Kyriazidis and James Corson to talk about our activities in the fuels area.

So Michelle, you've got it. Oh -- I'm sorry.

VICE CHAIR REMPE: I have a question. Just at a high level, when I think about gap, are there any ongoing activities for the staff where because right now you've got limited locations to conduct irradiations where something might be at risk.

Is it like the Accident-Tolerant Fuel Program if someone came in, or is it the high assay enriched uranium, is there -- do you think you've got a couple of years and adequate time to get data that you need for regulatory decisionmaking? Maybe it's, you know, subsequent license renewal. But what's the one with the least margin that might be a close concern?

MR. FURSTENAU: Well, I think I'd ask maybe the subsequent presenters here. And if they don't answer the question, Joy, we'll answer it in the end.

I think some of the programs that are going to be subsequently talked about, they'll -- like accident-tolerant fuel, for example, I think Michelle, I'll put you on the spot that you can kind of talk what you see are maybe some of the experimental gaps. And then Lucas, James and then subsequently Matt, if you could kind of express where you see the nearest term.

Because I think we're, in my opinion, I think we've got a good path forward, Joy. I don't see anything where we're -- we just can't proceed forward without it. But I really like our researchers that are going to present subsequently that give their opinion on it too.

VICE CHAIR REMPE: That sounds great. Thank you, I just would like to have that emphasis, is there anything with the least margin.

MR. FURSTENAU: Yes, good question, Joy. So we'll try to cover that with subsequent talks here, so. Anything else?

VICE CHAIR REMPE: I'm good. Colleagues or consultants, do you have any questions.

CHAIR SUNSERI: I don't have any questions or comment. I will just, I note that there are some comments in the chat line that are kind of supportive of the meeting. So I just request that people do not use the chat line for meeting content. It's outside the scope of the transcript and the public disclosure. So only use the chat for coordination or Teams communication problems. Thank you.

MR. FURSTENAU: Michelle.

MS. BALES: Okay, thank you. So Joy, just to answer your question since I don't want to forget to address specifically with ATF. I think what we're seeing is that there's a lot of restrategizing how to get the same data that might have been obtained at

Halden through other means.

And so I don't see a bottleneck of data that was going to be coming from Halden just not being able to be obtained through any other means. I think we're going to see a lot more reliance on information from LTA, lead test assembly examinations.

And while that might not be as detailed or as independent as Halden might have been, I think for the near term decisions that we're going to be faced with at NRC, we're going to have the information that we need. So --

VICE CHAIR REMPE: For something like thermal conductivity degradation also?

MS. BALES: Yes, I mean, I think that there's going to be technical issues where, when the staff is presented with an application, they are going to, you know, be used to seeing certain things that might have been at Halden and they might ask about those. But so thermal connectivity might be an example of where an online measurement really made a big difference, rather than a end-of-life post-irradiation examination kind of situation.

And I think eventually those kind of capabilities, one of -- as I go through the presentation and I share some of the work that DOE has done, I think we'll see that that type of capability to make measurements of thermal conductivity is going to be brought online in the near future. And I think it's just, you know, how the vendors choose to deal with the near-term applications.

VICE CHAIR REMPE: These things don't happen overnight, as you know. And so I'm pushing, trying to push the envelope that are we thinking and making sure everybody knows that, again, you're just the regulator, but if they come in and they say, okay, we'd like to do it. And maybe it's not ATF, maybe it's something else.

But I'm just kind of bringing it up because that one comes to mind. But is there some place where we're conveying to them that you better have data and, you know, for regulatory decisionmaking we're going to need that data or you won't be able to do something.

And that's where I'm going to be pushing during this conversation to make sure that we've identified not just the gaps for today, but the gaps for a couple years, three years from now, or whatever it is, to get the data we need. Okay?

MS. BALES: Yeah, no, that's a great point. And I think, like I said, specifically with

ATF we have -- the staff is really working with vendors in real time and ahead of their submittals to express our data needs and to talk about what kind of expectations we have. That's part of the ATF project plan where we talked about this new paradigm where we need to get data early and often.

And I think it's working pretty well, but you know, that's -- the applications aren't in yet. So I think that there'll be opportunities to prove that that really works.

VICE CHAIR REMPE: Okay, thank you.

DR. CORRADINI: This is Corradini, can I ask Michelle just one last way of asking the question. To the extent that you're always in communication with the DOE and the potential applicants, I assume that you early on point out things that you're going to need so that they figure it into the budgetary considerations. Because in terms of expenditures of funds, they're the largest expenditures of funds with some of this fuels and materials testing.

MS. BALES: Yeah, you know, I mean, I'm going to try to speak to this at a high level. But really the questions that you're both getting at are complicated because when we talk about what data is needed for licensing, and I'm going to very high level reiterate some conversations that are happening amongst the staff and the Licensing Office in Research, so much of the data needs are defined by the licensing strategy.

What the vendors are going to seek to take credit for, or how they're going to impose limitations and conditions when they don't have certain types of data. How they're going to deal with uncertainty. And we just don't know those full licensing strategies yet.

And so I think in the -- in NRR, they are thinking about data needs in a very particular way. And it's a little bit different than how Research, when we're trying to develop our fuel performance code and want to get a best estimate solution for fuel performance behavior. You know, their thoughts are going to be a little different than ours.

And so I think in the context of research and in the context of Halden, we have a certain way of thinking about the data that was produced and how we used it. This is a gross oversimplification, but NRR is just thinking about it differently. And I think it largely is because the licensing strategy has so many options for dealing with varying amounts of data at different times.

VICE CHAIR REMPE: But even earlier this week we heard about the accelerated whatever licensing strategy. But it finally comes down to got to have an integral test.

MS. BALES: Yeah. Yeah, and I'm excited to tell you some of the slides that I'm going to have here because I think we really -- there's really exciting developments going on to ensure that we still have those integral test capabilities.

So maybe with that I'll get started, and then as there's more questions about this I can certainly -- we can certainly return to it if we're not giving you the right information.

MR. FURSTENAU: Joy, could I jump in with something real quick?

(Simultaneous speaking.)

VICE CHAIR REMPE: Go ahead, Ray.

MR. FURSTENAU: Yeah, regarding integral test, I think is very important. But I think what we're trying to do with the collaborations and stuff, as we all know, integral tests are expensive. But you know, we've come a long ways with modeling and simulation capabilities. And so we can really maybe zero in better on what those integral tests ought to look like so we don't have to maybe do as many, you know.

And I think getting some data to help validate our codes in areas that they haven't been used before is I think some of the data that we'd be looking for as well. So I think targeted integral tests is what we really want to work with DOE on as well.

VICE CHAIR REMPE: Okay, thank you. And I apologize for dragging this out so much with our questions, but I do want to kind of keep that focus on not just where you're at but where we're going. So go ahead. I'll try to contain myself. Michelle.

MS. BALES: No, it's great, I appreciate the questions. So I'm going to start my presentation, which is going to focus on the fuels area specifically by reiterating what Ray said, that in the two years since Halden announced that they were officially shutting down, a lot has happened.

And so in the slides that you'll hear from myself and from my colleagues, we'll speak specifically to the fuels research, and you'll hear after us what some of the developments in the materials world.

And I'm going to start my presentation with some significant investments that have been made by DOE to address the gaps left by the Halden reactor shutdown. I'm going to then turn it over to my colleague James Corson, who will speak to NEA's progress in launching the FIDES framework, which is designed not only to connect a network of experimental reactors, but also reestablish the valuable technical community that was formed under the Halden reactor joint project.

And you know, listening to your questions, Joy, I think this is an important point, because the Halden reactor project wasn't just a way for multiple countries to leverage their resources dollars-wise. But also, the Halden reactor project formed a peer review body with a really immense knowledge base that would scrutinize the Halden results and ask tough questions as data was coming out. They weren't just customers, in other words, they were really part of the fabric of the program.

And so I think with the FIDES program what we're going to see is that reestablishing that technical community I think might get to some of, you know, what you were pointing to about ensuring that this diverse network has the same pedigree and that maybe Halden would have had. But there's a lot of smart people who will be at the meetings and poke holes when they see something that doesn't seem right or have the knowledge to point out some of the different ways that you can mess up an experiment.

So I think it's important to just point that out, that it's not just the leveraging of dollars but the leveraging of expertise.

And then finally my colleague Lucas Kyriazidis will explain Studsvik nuclear proposal to rescue unique and valuable irradiated material samples from Halden so that they can continue to provide value to the nuclear community in the future.

And I'll say this throughout, but I just want to say here at the onset that in each of these areas, NRC staff and management have played a pretty active role to influence the initiative. So even though they're not directed by us, you know, we've been very engaged.

So as I said, I'm going to start with information on DOE's investments to address the capability gap left by Halden. But I want to explain that DOE didn't do this in a vacuum. DOE brought together experts from around the world to inform their strategy.

They brought other research reactors to the table, from MITR, BR2. They had a number of regulatory bodies giving feedback through their workshops over the summer following the announcement. Industry representatives including fuel vendors and utilities were there to help talking about what kind of capabilities they needed to support the design of new fuel materials.

And NRC was very engaged in these workshops that were held. You know, on Ray's slide you could see the timeframe. Sometimes months after significant news on Halden, DOE was having a workshop to collect the opinions of these key stakeholders.

So the report picture on the left is the culmination of a month-long conversation that DOE led with key stakeholders. And it was published just six months after the reactor officially announced its shutdown.

And the report declares that the primary recommendations for addressing the capability gaps left by Halden and that were really necessary to sustain the US nuclear fleet were, first, to transfer unique technologies and knowledge for testing, refabrication and instrumentation from Halden to relevant facilities.

I think, Joy, this gets also to your point about Halden's pedigree. And I think there was a great recognition that what they had developed shouldn't go unused, that we should really try to capture that in transferring knowledge and technologies to other facilities.

Another conclusion in the report is the need to expand LWR irradiation capacity in test reactors, both steady state and transient testing capabilities. A third conclusion was the need to establish fuel rod refabrication and re-instrumentation capabilities at DOE facilities. This is something that Halden was particularly strong on. And so ensuring that that can be replicated is a key recommendation.

Complementing in-pile testing capabilities with reliable in-pile instrumentation, similar to what was available at Halden was another finding. And then finally to establish a domestic center of excellence consolidating irradiated -- irradiation testing activities in a way that reduces schedule and shipping costs but also simplifies data acquisition to ensure that no facility becomes a single point of failure. Sorry, I merged two points there. That simplifies data qualification.

And I think, again, this gets to your point, Joy, that when you have a really diverse network and you have to qualify data at a variety of places, that that sort of can be a downside. So spreading out the testing capabilities, but not so much that you've diffused efforts that are necessary to qualify data as important.

DR. CORRADINI: Can I ask a clarification? You said blue is what was expended in those years and yellow is what's planned?

MS. BALES: Yes, so on the slide --

DR. CORRADINI: So in FY '21, has it come to pass what they need versus what they got?

MS. BALES: So I created this slide, and in the weeks that have passed since the slide was created there may be news. But I would have to ask DOE to speak to that specifically.

DR. CORRADINI: Okay, all right -- sorry.

MR. McCAUGHEY: Would you like this -- would you like me to address that? This is Bill McCaughey with the Office of Nuclear Energy.

DR. CORRADINI: That's up to the Chairman. I'll let Dr. Rempe decide that.

VICE CHAIR REMPE: Sure. And as you're addressing it, I'd like to add on a question: what does that get me if we get out to 2023? Do I have the I-Positions? Do I have something at MIT as well as the I-Positions? What do I have by 2023 if I get all this funding that's shown here?

MR. McCAUGHEY: Okay, so I'm Bill McCaughey, I'm the Director of the Advanced Fuels Technologies Office at the Office of Nuclear Energy.

The yellow are, that's estimates still. For 2021, yes, we did get the appropriations. We also got an, also another bill, an authorization bill. We are still working out the funding that flows from that, and that's why it's yellow. So the, starting with 2021, that's still an estimate, and we're working out the details on how we're going to allocate our funds.

DR. CORRADINI: Okay, thank you.

MR. McCAUGHEY: Dr. Rempe, for your question, what this is going to get is pretty much along the lines of what Michelle just went through in the -- what was needed. So it's going to get -- we're working on a new flowing water loop in the advanced test reactor in one of the I-Positions.

We're also working on refabrication capabilities in the hot cells at Idaho National Labs so you can take irradiated fuel from reactors elsewhere, bring them into Idaho Lab and refabricate them to fit the test vehicles that you want and also to instrument them for insertion into either the transient reactor test facility or the advanced test reactor.

And then you're also getting the LOCA test capabilities at the transient reactor test facility. And also advanced instrumentation along the lines of what Halden was capable of.

VICE CHAIR REMPE: So by 2023 I'll be able to put a fuel rod in a -- that's been previously irradiated, and put it into the standardized test grid and get thermal conductivity degradation, get crud deposition? What all can I get?

MR. McCAUGHEY: Well, now you're getting into some details that I don't want to go out on a limb. But we do have Dan Wachs from Idaho Lab who might be able to answer that, some of those specifics.

MS. BALES: Well, can I say just the next couple of slides actually talk about the plans. And so maybe after I go through that, Dan, you can then sort of just say, okay, what Michelle just said will be ready or won't be ready by 2023. Because --

VICE CHAIR REMPE: And it's more money that's needed too. Because this, just knowing how much things cost I just am curious. Because again, there's a lot of -- I want to, yeah, understand how soon.

PARTICIPANT: Yeah, that sounds find, Michelle, that will work well.

MS. BALES: Okay, because I'll -- I've worked with DOE to extract a lot of the planning here, so I have slides that speak to it a little bit. And then in terms of timing and budget, I think that'll be more meaningful once you see what kind of plans there have been -- what plans have been made.

So I mentioned on the previous slide that one of the main recommendations from the report is to expand LWR irradiation capacity. So to fill on the expansion of steady state capabilities, DOE is designing I-Loops, which, you know, have just been mentioned in the ATR and the INL. And the I-Loops are designed to provide additional BWR and PWR water loop testing capability at prototypic linear heat generation rates.

The in-pile tubes will allow for highly instrumented testing. And further, the I-Loops will support power ramp testing using helium-3 screens to allow independent control of rod power and full hydraulic control to allow for things like dry-out testing.

And power ramp test data is really

critical to address many reactor safety questions. And these testing capabilities have not only been impacted by the Halden reactor closure, but prior to the Halden reactor closure, the closure of the OSIRIS reactor in France and the R2 reactor in Sweden left big holes in the ramp test capabilities. So the establishment of ramp capabilities at INL truly is fulfilling a major capability gap.

So on the slide it says that this testing capability is expected to begin operation by 2023. I'll at the end turn it over to Dan to say whether that is funded and -- or not, with the graph that I showed on the previous slide. But you know, in speaking to the plans, I think it's a really exciting capability development.

In addition, INL is developing LOCA testing capabilities in treat. So there's been a lot of hot cell LOCA testing capabilities developed around the world in the last decade. But the closure of Halden eliminated a heavily used in-pile LOCA testing capability. The transient water irradiation system for TREAT, or TWIST, provides a truly unique testing capability.

Cask fill and rodlet pressure can be measured by the same LVDT Bells (phonetic) approach that was employed by Halden. Water, fuel, and cladding temperature can be measured with thermocouples and pyrometry. And post-test neutron radiography can reveal details of fuel relocation and conditions after testing, similar to what was done at Halden.

But an exciting expansion beyond Halden's capabilities will be available at treat, which is that fuel motion monitoring in real time can be accomplished in the treat facility. And that will allow us a much more sophisticated look at fuel relocation fragmentation relocation and dispersal phenomena.

And as this slide indicates, commissioning tests are planned for the TWIST capsule in 2022. Again, I'll leave it to Dan to say at the end whether that is something funded with the allocations requested to date.

So two other of the recommendations from DOE's reports were established -- to establish fuel rod refabrication and re-instrumentation capabilities at DOE facilities and to compliment in-pile testing capabilities with in-pile instrumentation, similar to what was available at Halden.

So DOE has worked with Halden directly to transfer the world-class technologies that they had developed, transferred those to INL. An instrumentation device for drilling and preparing rodlet ends was procured from Halden, and INL has developed a remote welding system, the so-called in-cell weld under pressure systems shown in the upper middle of the page.

And these tools will make it possible to allow previously irradiated fuel rods to be repurposed for follow-on R&D with additional irradiation, transient, or other experimental purposes.

Replication of Halden's in-pile instrumentation capabilities has also been achieved, thanks to extensive knowledge and technology transfer from Halden, including technologies for measuring plenum pressure, fuel elongation, center line temperatures, and local neutron flux.

And there's plans to innovate even beyond what Halden was capable of using optical fibers for measuring in-pile temperatures, pressures, imaging, deformation, etc. So these capabilities are really critical for assessing interval performance data that we have really relied on Halden for in the past so that we can develop models that track these parameters of the function of time and burnup.

So I mentioned earlier that there might be in the immediate timeframe some increased reliance on lead test assemblies for fuel performance data. And that's great, that's fully representative, commercially irradiated material is really important. But you only get one data point at the end of life from some of these exams that require destructive examination.

And so having in-pile instrumentation capability is really what's needed to follow parameters over the course of irradiation and over the course of life, so that when you go to your modeling and validation exercises that you have more than one data point. You really have a history.

So these investments bring world leading capabilities to US facilities, and once complete will represent a huge step towards replacing some of the more unique and relied-upon features of the Halden reactor.

So I actually have one more slide before I turn it over to my colleague, but maybe, it's on a separate topic, so maybe this is a good time for Dan to address the question posed by Dr. Rempe earlier about the capabilities that I spoke to on these last two slides and their relationship to the 2023 funding request so far.

VICE CHAIR REMPE: Sounds good to me.

MR. WACHS: Thanks, Michelle. Yeah, I think the key point to highlight when you look at the Halden gap report is we reviewed the existing capabilities in the United States already as a part of that -- as a launching point.

So you mentioned things like the MIT reactor, you know, work that's going on there. We actually think that's a great place to do some of the corrosion studies and things like that. And we've seen that utilized effectively by a number of the vendors in the United States.

We had a pressurized water -- or we have a pressurized water loop in ATR already, a center flux trap that's being used extensively by a number of different sub-parties. And we have separate effect site testing capabilities at both HIFER (phonetic) and ATR is one that we're using.

So in that report we're really focused on the places where we were relying on the complementary capabilities available at Halden to fill in our, the spaces that we were missing. So we really -- these are the things that we came up that we needed to have to -- in order to move technology forward in like a general sense.

So as Michelle mentioned, so we're adding the pressurized water or the extra LWR loop to the ATR. That could be operated at either a BWR or a PWR mode. We have conceptual design for a second loop so that we could have both operating simultaneously. But the funding to build that infrastructure, infrastructure for both of those is not currently in our near term plan.

However, we are running the installation of that new loop in the I-Positions as a capital project. It has a, you know, a project execution plan associated with it, all those kind of thing. It's monitored closely at the DOE level. So assuming the funding allocations, you know, follow what our plan is, we should have that up and running in 2023.

Now, that does need to be complemented by an experiments program that's planning to use that, and that plan is incorporated into many of our, the ATF vendors' programs. So we expect that complementary to be there. It is a little bit --

VICE CHAIR REMPE: Dan, slow down for just a second. You said that basically the DOE Fiscal Year '21 programmatic or whatever funding doesn't cover the yellow bar that we were shown earlier. It's going to come out of the facilities?

MR. WACHS: No, no --

VICE CHAIR REMPE: Is that what I heard you say?

MR. WACHS: No, the budget line there is the funding allocations from the ASB program direct funding. It's, there's -- and there's a little bit coming in from the advanced sensors and instrumentation program for some of the refab work. So that is the program funding --

VICE CHAIR REMPE: So that's still not 2021, it's just the programmatic funding. But to get the loops where you could put something in the reactor, unless you fight with existing PWR loops, which is another thing because you've got a lot of people competing for it. To get those two I-Loops, you're going to need to have infrastructure funding. So we don't --

MR. WACHS: No, no, I don't think so. The facilities funding is -- so this is the funding to have the up -- the loop up and running and available. The additional funding is simply for a user to provide their sample and do their experiment-specific analysis.

VICE CHAIR REMPE: So I'm sorry, I guess

I'm slow here. So the 20 -- the yellow bar for the facility funding that you hope to have --

MR. WACHS: It is the advance fuel site -- advance fuels campaign allocations to building the experimental infrastructure that would go into the existing infrastructure at the reactors.

VICE CHAIR REMPE: So it's the standardized test loop with some instrumentation, what's shown here on the yellow bar. To get the I-Loops, you've got to have another pot of money.

MR. WACHS: No, no, that is for the I-Loops.

MR. McCAUGHEY: Can I interject here? This is Bill McCaughey again. So Joy, this is funding the hardware, the design, the installation of the I-Loop, as well as the refabrication upgrades and the instrumentation upgrades and the LOCA test capabilities at treat. And it's all getting funded out of the fuels campaign, not the facilities budget but the fuels campaign.

VICE CHAIR REMPE: So then I might say, back to the original question, if I got all the yellow bar money, then I would have two I-Loops with instrumented test rigs.

(Simultaneous speaking.)

VICE CHAIR REMPE: Is that what I'm hearing?

MR. WACHS: No, this is -- we'll have the center flux trap pressurized water loop and one I-Loop on that, this funding.

VICE CHAIR REMPE: Okay, that's -- and so, again, you're on track. You got what you wanted, I guess, in 2019 and 2020 to do things? And then you're hoping to have a big plus-up coming here in 2021 and on out. And then you'll be ready to go with one extra I-Loop, the existing PWR loop, and a lot of test rigs and instrumentation.

And can I do diameter gauge, can I get crud as a function of time as well as thermal conductivity degradation?

MR. WACHS: So those, some of those detailed experiment pieces would go into the experiment-specific design. We'll have a loop with the penetrations that support that branch of experiments, but we're working with the ATF vendors for the design of their specific experiments.

VICE CHAIR REMPE: So you'll have the infrastructure but maybe not the instrumentation to get the data.

MR. WACHS: Yeah, I think the test train

-- so we broke the test train design off into a separate piece from the experiment platform. And we are designing experiments for these currently, but it's not included in this cost. This is just for all the permit infrastructure that would be in those facilities.

VICE CHAIR REMPE: Okay, again, cost isn't my thing, my purview here as an ACRS member. I'm more interested will NRC have what they need to get the data they need for decisionmaking. And this is a partial story is what I'm hearing.

MEMBER PETTI: So Dan, is it fair to say that this, the yellow bars in the blue represent what sort of enables an experimenter to come in and execute an experiment but they have to pay for their experiment?

MR. WACHS: Yeah, I think that's a good way to describe it, Dave.

MEMBER PETTI: Okay, thanks.

VICE CHAIR REMPE: True, because having instrumentation takes a little bit more than -- it takes a few years. As you know the GR -- test right. It's, you guys paid for it but it took several years in advance to get it qualified.

MR. WACHS: That's correct. And I think

the -- you have active collaborations with the advance centers and the instrumentation program now that are being executed in parallel to the design of the experiment. So we are providing enhanced access to the experiments. We're making some modification to the plan in order to support that.

So we should be able to see the timelines that you've historically seen associated with instrumented experiments shortened substantially in these. So we expect these to be fully instrumented. We recognize the primary objective of this was to add access to dynamic testing, and not just the start-and-end type testing that we would see with LTAs and things like that. So instrumentation is a core principle for these test rigs.

VICE CHAIR REMPE: Okay, the other question I have is we all, many of us live in Idaho. We have the difficulties that are political in nature. Are they being addressed so people can send irradiated fuel to Idaho to have them re-instrumented? How's that going along?

MR. WACHS: I know Bill, do you want to answer that, or would you like me to make a stab at it?

MR. McCAUGHEY: Well, it's being worked,

Joy. It's, you know, it is tied to the operation of the integrated waste treatment unit, with the PM program. We still have a linkage to that with the state of Idaho, and that's being worked. The virus has pushed back some schedules at Idaho. And so it's just something that we're working and it's not totally resolved yet.

MR. WACHS: But I would say our goal is to have a functioning LWR materials library to use in support of these capabilities. We've identified the first handful of materials that we would like to acquire for that library, but it's waiting for obviously some of those things to be resolved.

VICE CHAIR REMPE: I just am looking for risks that might affect the NRC's ability to get what they need in a timely fashion. Thank you. Go ahead. Or I guess you're done and it's back to Michelle, right. Unless, colleagues, do you have any other questions? Go for it, Michelle.

MS. BALES: Okay, thanks. I'm glad that the DOE folks are here to help because I definitely would not have been able to field some of those questions. But I'm glad that we were able to get some more details.

CHAIR SUNSERI: And since you've made that comment, let me make an interjection here. And I don't mean to be overly restrictive here, but this meeting was noticed to the public as an interaction between ACRS and NRC staff, so any guest interaction needs to be specifically requested or otherwise acknowledged by the Chairman of the Subcommittee leading the discussion.

And I don't mean to be rude on this thing, it's just protocol because we are a FACA group and we have rules and we have to abide by them. So I would appreciate that. Thank you.

MR. FURSTENAU: No, that's a fair comment, thanks, thanks for that reminder, Matt. We appreciate it.

MS. BALES: Yeah, so I'm going to actually transition to a different topic and then turn it over to my colleagues to talk about other topics.

But what I want to say before we go on to some of the other international, new international collaborative research that you're going to hear about is to say that one of the important lessons learned from Halden's closure is that we need to be more deliberative about capturing metadata for nuclear fuel and material research.

And by metadata I mean information about experimental design, the details of the experimental design and experimental protocol and various factors that are crucial for interpreting experimental results. These pieces of information are critical to putting experimental results in the appropriate context for use by regulators and industry.

And I think when the closure of the Halden reactor was first announced, part of the panic that reverberated around the nuclear fuel research community came from a realization that the institutional knowledge housed at Halden might be lost.

So it wasn't so much that obviously the continued use of the facility was a big deal, but that also we wouldn't be able to call up Halden anymore and say hey, I finally got around to using this data that you sent me five years ago and I don't really understand how it was collected. Can you remind where the neutron detection meter is and how does that affect what I'm seeing in these results.

And so DOE's efforts to transfer technology and expertise to the US will go a long way. Later this afternoon, you'll hear from my colleague about how a significant piece of the continuing Halden research project effort since the shutdown is really dedicated to capturing historic data knowledge, data and knowledge and, quote, metadata.

But importantly, this lesson is being applied in current -- in future research programs that are being proposed now. New research proposals are emphasizing the need to capture data and metadata and make them accessible for long-term use. And so as I turn it over to my colleague James, I'll point out that you'll hear that point as a pillar of the FIDES project.

So with that, I will turn it over to James.

MR. CORSON: As Michelle had said, she gave a nice overview of the US activities. And now FIDES is the international community's response to the closure of Halden. And as she had mentioned, it's not just a way to connect a network of experimental reactors, but to retain the Halden community itself and the vast knowledge that they have on fuel and material research.

So FIDES encompasses both the joint experimental programs, so the actual experiments that will be run, as well as cross-cutting activities that make the most of those experimental results. And as Michelle had just mentioned, you know, one of the main cross-cutting activities is this issue of data preservation and quality assurance. And so FIDES is really trying to focus on that issue.

Cross-cutting activities also go into training and education, the next generation of fuels researchers. And also looking to make the most of advances in modeling and simulation to help guide experiments, and as well as have experiments help validate these tools.

So the joint experimental program, that's really the crux or the main point of FIDES, is to do these experiments. And the -- which experiments get proposed and funded and so on are guided by the governing board of FIDES. And so each organization that's involved has a say in this in the United States -- sorry, is there a question? Okay.

So in the United States, the NRC has been heavily involved, as I believe both Michelle and Ray have said. Ray has been serving or leading the establishment board for FIDES, and has led some of those meetings. We're also working with the Department of Energy on this. A lot of these efforts, we're working in close coordination with them to establish FIDES.

So again, yeah, I'll talk about a few

fuels-related JEEPs in just a second. But this is a way to leverage funds from the international community to do this work. So the core group, which are the people who are actually doing the experiments and making the sort of day-to-day decisions, they're the ones who fund half the work roughly. And then the rest comes from the larger pot of FIDES funds.

So that's the idea behind this new effort. And now I'd like to talk about three of the upcoming fuels JEEPs that have been proposed. Next slide.

MEMBER PETTI: James?

MR. CORSON: Yes.

MEMBER PETTI: What's the green colored boxes, the light colored boxes?

MR. CORSON: So, the green colored boxes, those are the ones that are the most mature proposals at this point. So, they're the ones that would most likely be funded in the first round of FIDES. The white ones represent less fleshed out proposals at this point.

And I have to say, for the white ones, they may be slightly out of date, just because I think this is taken from older FIDES materials. But, certainly, the green boxes are the JEEPs that are moving forward at this point.

So, the first JEEP that I'd like to highlight is on high burnup experiments in reactivity-initiated accidents. And this is primarily led by the United States, at the Department of Energy, EPRI, and the NRC is also a core group member for this. And so I'd like to give some recognition to Bill McCaughey and Dan Wachs for including us in this activity and letting us have our say here. And this also involves our colleagues at IRSN in France and JAEA in Japan.

So, this JEEP is going to look at the effect of pulse width deposited energy in PCMI, pellet-cladding mechanical interaction, failure in reactivity-initiated accidents. So, this sort of gets to Dr. Rempe's earlier question about differences between reactors. For RAI testing, it's been done at several different facilities, as highlighted in this slide.

So, this JEEP, part of the goal is to look at TREAT versus NSRR in Japan. What are the differences? Does the pulse width make a difference in the behavior that you see? So, it's trying to address some of these issues about having distributed facilities. So, next slide, please.

So, the second JEEP I'd like to highlight is power to melt and maneuverability, or P2M. So, this is being conducted at the BR2 reactor in Belgium, and also involves CEA and EDF in France. And so this is looking at the margin to fuel centerline melting. And this is important when you're talking about higher power operations. Specifically, this test is going to look at higher burnup fuel, so it will indirectly address things like thermal conductivity degradation that Dr. Rempe has mentioned several times. So, it will also look at other issues, like fission gas release when you get into these power ramp situations. So, next slide, please.

And then the last JEEP I would like to highlight is in-pile creep studies of ATF claddings, or INCA. And this is being conducted primarily in the Czech Republic at the LVR-15 reactor. So, for this JEEP, they'll be looking at the effects of chromium coating on zirconium alloy cladding and how that impacts creep behavior.

And so, for the first round of tests, it's primarily going to be capsule tests, where they stick in a bunch of samples, irradiate them, and then take them out and, you know, do their creep measurements. But also as part of this first round they're looking to qualify MELODIE device, which was previously developed in the OSIRIS reactor in France, for the

LVR-15 reactor. So, this is an example of using a standardized test rig in multiple reactors, which is something else that Dr. Rempe was interested in.

So, those are the three JEEPs, or three fuel JEEPs, that I'd like to highlight. My colleagues will be talking about the materials-related JEEPs later. But, right now, I'd like to see if you have any questions before I turn it over to Lucas Kyriazidis.

VICE CHAIR REMPE: So, I'm not hearing any questions from my colleagues, so I'm going to ask you the same question I've been asking others today. Do you see any near-term, or even maybe longer-term, needs that take a while to get addressed because of the need to get facilities and instrumentation and test rigs qualified and you think will have less margin and maybe we ought to be looking at? Or do you have enough tests in the queue that you think things are going okay?

MR. CORSON: I mean, I think, for the most part, things are going pretty well. Michelle highlighted a lot of the things that are going on in the United States. Similarly, in the international community, there is this recognition to look at advanced instrumentation, to look at high burnup fuel behavior, and to look at ATF cladding behavior. There's a lot of talk about, you know, what instrumentation do you use and what's appropriate? So, I think we're on a good path right now. So, to answer your question, I don't see any major issues right now.

VICE CHAIR REMPE: If some of these proposals don't go forward, is it going to be a catastrophe? Or are you betting on these things all happening?

MR. CORSON: Yeah, I wouldn't say it's going to be a catastrophe; it'll just mean we're going to have to adjust. But I think, you know, Ray brought up this point at the beginning, the fact that we have more of these distributed facilities, that if any one of these proposals doesn't go through, I think there's backup plans. And there might be slight delays, but I wouldn't say it would be a catastrophe.

So, that's the benefit of having this distributed network now, as well as the framework, like FIDES, that can help fund these distributed network of reactors.

VICE CHAIR REMPE: Okay. Thank you.

Colleagues, anything?

(No response.)

VICE CHAIR REMPE: Okay.

MR. CORSON: Okay. I'll turn it over to Lucas.

MR. KYRIAZIDIS: So, good afternoon, everyone. So, today, we talked a little bit about facility upgrades that DOE is doing and some international collaboration work through the various JEEPs that James has highlighted, but another important area that we need to discuss is where this irradiated material is going to come from.

So, immediately after the Halden closure, the nuclear community recognized that efforts should be made to save the valuable irradiated samples accumulated throughout the many years of testing at Halden.

So, here, Studsvik Nuclear Laboratory had proposed a new international project called SPARE. And here SPARE would fund the transport of the highest priority fuel samples from Norway to Sweden. And, early in SPARE's proposal, NRC staff have been heavily engaged in prioritizing the selection of fuel specimens that would be transported and potentially saved from final disposition and disposal.

So, here, NRC staff prioritized fuel segments with enrichments greater than five weight percent U-235, fuel segments with burnups above the current U.S. limits, and many fuel segments subjected to power ramps and interval testing.

But I do want to highlight that SPARE only focuses on the actual transportation, and any future research on transported segments would have to be proposed and funded separately. But SPARE members would control the release and future use of transported fuel for a fixed period of time.

So, that's all I have that I wanted to talk on SPARE. Maybe I'll give it a few seconds for questions.

MEMBER PETTI: Yes, just a question. So, these will be stored somewhere.

MR. KYRIAZIDIS: Yes.

MEMBER PETTI: I assume in Sweden. And then, say the U.S. wants to have a specimen and, you know, money is paid to ship it, and it's destructive, so it doesn't go back. Is there some sort of body that will say, yeah, it's okay that you can destroy that one, but if Country X comes in and says, well, I don't think that's the right thing, is there going to be a steering committee, do you know, to kind of adjudicate all this stuff?

MR. KYRIAZIDIS: So, there will be a

working group with all the signing members of SPARE that will discuss this. But maybe -- I don't know, Michelle, if you want to handle part of this question?

MS. BALES: Sure. Yeah, so, the members who pay for the transport have a say in what material can be used, especially when destructive testing is involved. And they have that right for a period of five years from the last transport. After that, they can renew it, but after that, it's up to Studsvik to weigh those proposals.

But I think, importantly, for the five years, and then if they choose to renew it, everybody who pays into SPARE to transport the material gets to determine the acceptability of specific proposals and whether the transfer of material to another organization for testing is valuable enough to justify the potential destructive test transfer.

MEMBER PETTI: Yeah, okay.

MR. KYRIAZIDIS: So, I don't know if there's any more questions. If not, we can go on to the next slide.

VICE CHAIR REMPE: Please do.

MR. KYRIAZIDIS: Okay. So, here, I want to wrap up some of the fuels work that we talked about. So, with all the activities happening throughout the U.S. and through international collaboration, the nuclear community as a whole is now a lot less vulnerable to a single future facility closure.

Going forward, fuel safety testing will be supported through a well-equipped, diverse, and dispersed network of research facilities. And today, we've heard of just some examples from my colleagues of work being done here within the U.S. at DOE facilities, but also overseas through various international facilities, such as the JEEPs that James had mentioned.

So, this work, specifically the investments being made in the U.S., will provide significant autonomy and add significant value for the whole nuclear community, but also especially for U.S. embassies. These investments will allow the NRC a firsthand look and an early opportunity to get involved, provide feedback to test plants, and become intimately familiar with the research being proposed and conducted at these facilities.

Even though the future outlook is robust, one feat that Halden did offer the nuclear community that the nuclear community will deeply miss was its economy of scale. And this has been mentioned a few times now, but Halden was a dedicated research reactor and research center with a relatively large footprint for performing nuclear fuel research for many, many years. Halden provided the required real estate and expertise for performing these long-term steady state irradiation campaigns. And Halden was also equipped with nearby PIE facilities, fuel fabrication capabilities, and offered a robust suite of in-pile instrumentation and measurements.

So, many of these replacement capabilities will now be housed at various facilities with various ongoing missions. And these facilities are also typically separated by distance, sometimes organizations, and sometimes staff. This will inevitably introduce competition and inefficiencies for performing safety research.

So, it's recognized that the balance between cost and testing capacity will have to be considered when investing in future upgrades and funding new projects. And one example that comes to mind was Halden's ability in performing long-term steady state irradiation, but also its robust suite of in-pile instrumentation.

It is known that this is quite difficult and costly to reproduce, whether in the U.S. or overseas. The community as a whole will have to be smarter and innovative in how we go forward, but we do recognize the innovations and the aggressive plans made to date from both DOE and the international community.

And, lastly, I just want to state that the community's response to the Halden closure has been robust and swift. That's what I had on this slide. I don't know if there's any questions for either myself --

VICE CHAIR REMPE: When I go back and think about the replacement facilities being used right now, the Czech Republic reactor is pretty small, with respect to it's got like one loop location, and the MIT reactor has one loop location, I believe. You have a loop at the ATR, but a lot of people want it. And, yes, there's something in Russia, but it seems to me that might be more difficult for things of interest to the NRC to get. It sure sounds like making sure that you have the ATR loop being established is going to be important.

But maybe it isn't, maybe you can rely on sharing the limited number of international capabilities. The Jill Ford (phonetic) I guess I've heard now is not going to go up and run until 2030. So it seems like locations are going to be very important. But, again, I'm just looking at it as a reviewer. Do you have the same impression?

MS. BALES: So, I can respond to this, because we've talked about this a lot with Lucas, and also I think Ray mentioned it at the beginning. I think, with the capacity being substantially less than Halden, we have the requirement to be smarter with what testing we're going to do and be really precise about what data we really need. And so I'm hopeful that the lower capacity will be met with innovation in test planning and really thinking through what we really need.

In some ways, the Halden capacity was a luxury that we might have taken for granted. And I think, going forward, we just have to be smart. And I think that that's sort of what Lucas's third point gets at, is, if we wanted to have the capacity that we had at Halden, we could probably do it, if we had infinite resources. But it just means that cost and testing capacity are going to be in competition, and we have to look for the right balance between those to ensure that we're getting the data that we need for a cost that is feasible.

VICE CHAIR REMPE: Unless other colleagues have questions? Please go on, then.

MEMBER KIRCHNER: I have an observation, Joy. I was going to save it for the end, but maybe it's appropriate with this viewgraph.

I think, positively, the shock of losing Halden -- which we were comfortable with, I think was just described as a luxury -- it's going to force a sharpening of minds, pencils, and budgets. That's not a bad thing. And I see there's opportunity here to reinvigorate both the fuels and materials research communities, as a result, instead of just coasting along as we perhaps were with the luxury, quote/unquote, of Halden. So, I take what I've heard so far very positively.

VICE CHAIR REMPE: Thank you. Any other members want to make a comment?

Let's go on, then.

MR. KYRIAZIDIS: Thank you for those comments. So, I think going on, we're going to transition into the structural materials section. So, with that, I will pass it on.

MR. HISER: Thanks, Lucas. My name is Matt Hiser. I'm a materials engineer in the Division of Engineering in the Office of Research. And I've been working on irradiated materials and, specifically, involved with the materials work at Halden for about the last ten years, working alongside Michelle and some of the other folks in the fuels area looking at Halden. So, maybe go ahead to the next slide, Michelle.

So, the first slide, I'm sort of taking this in a chronological order and setting the scene for where we were prior to the reactor shutdown. And so Halden was a key aspect of the irradiated materials research that NRC was doing. It wasn't the entirety, or necessarily even a majority, but it was a key piece. And Halden offered some unique capabilities, relative to other facilities, for materials research. It also, as has been mentioned before, offered excellent value and leveraging. And so I just want to note that Halden has contributed in the materials research area quite a lot.

So, just touching on the capabilities, and particularly the in-reactor testing capabilities for stress corrosion crack growth rate testing and instrumented creep and stress relaxation testing. Those are, to my knowledge, fairly unique, to have those in an in-pile, and those were some of the capabilities we were using while the Halden reactor operated.

On the value and leveraging side, as I note there in the sub-bullet, we split the funding with other countries, other U.S. organizations, and even our other research areas at NRC, to make this program very cost-effective.

And then, finally -- and I'll come back to this, and we'll come back to this through the materials slides -- there were three key specific materials research activities that we were pursuing at Halden. And I think we have sort of a strategy to continue those specific activities, so I'll just touch on them here. And then you'll hear more about them in future slides.

But they were are further irradiation and testing of ex-plant harvested stainless steel welds, SCC crack growth rate testing of high dose harvested ex-plant stainless steel base materials, and then creep and stress relaxation testing of baffle-former bolt materials. And so I think we'll, as we get into these slides, see how our strategy sort of addresses some of those specific activities, as well as the larger capability development. Next slide.

So, as we move into the post-Halden materials research strategy, cooperation is a key aspect of it. And, as with the Halden reactor, we're looking to focus on the value that we can get for NRC interests, particularly relevant to U.S. nuclear plant operations.

So, following the reactor shutdown, NRC staff did look at, you know, what were the values and what were the gaps that were created by losing the Halden reactor, and how can we mitigate those impacts? And so we identified three approaches that would help to address our needs going forward and mitigate the impacts from the reactor shutdown.

So, first was preserving knowledge from Halden. And I'll just point out here, you'll notice the color-coded text on the right side of the slide, and you'll notice that carried through in the remaining materials slides. So, you can map back the red referring to Halden activities, blue referring to DOE activities, green for FIDES JEEP activities, and then orange for harvesting activities.

So, the first one is preserving knowledge from Halden, which is being addressed by a combination of activities through the Halden project, as well as some DOE initiatives.

Performing some of those high priority research items that I identified on the prior slide. That's being addressed both through the Halden reactor, the finishing up of work at Halden, a couple of proposed JEEPs, materials JEEPs through FIDES, as well as harvesting.

And then, finally, developing new capabilities is also a key sort of long-term piece of our strategy. And the FIDES JEEPs, as well as some DOE investments and coordination, is critical there.

And so I'd just like to point out one aspect when it comes to the irradiated materials, particularly high dose materials, while we look to cooperate wherever we can, and we have found good international cooperation through Halden and some of the other things that we'll discuss on these slides, I will note that this is becoming increasingly a sort of U.S.-focused concern, as other countries in Europe, in particular, are not necessarily looking at operating plants out to 80, 100 years. Some of these really high dose effects and very long-term aging of reactor internals become a little more of a U.S. focus. And so developing domestic capabilities is probably a prudent long-term strategy for the NRC and for the U.S. as a whole. So that will be part of the theme as well in these slides. Next slide.

So, just the first key piece of the strategy. And this slide is just going to sort of touch on the strategy, as well as by really going over what's planned at the Halden reactor post-shutdown. So, there are three key aspects of their post-reactor shutdown activities, and these are true both for the materials and the fuels research.

So, first was the orderly completion of ongoing work. This means finishing post-irradiation examination on samples, obviously not getting any more radiation dose once the reactor is shutdown, but finishing up any testing that was planned or characterization after irradiation. Preserving key samples, fuels and materials samples, that are of research value. Lucas touched on the SPARE program, and I'll touch later on this slide on the plans in the materials area. And then, finally, documentation and capture of past Halden data, which also got mentioned during the fuels presentation.

So, I'll just note, in the materials area, some of the key ongoing experimental work that was being wrapped up is nearly complete. I don't know that we have final reports, but I think the work has largely been completed. And our main interest was some of the SCC crack growth testing of high dose ex-plant materials, high dose stainless steels.

Then, the second bullet, we have to credit our colleagues at the Department of Energy. Through the Nuclear Science User Facilities, they have a fuels and materials library. And they have graciously stepped up to acquire, and are planning to acquire, some of the high-value irradiated materials samples that are at Halden and would otherwise be disposed of in the decommissioning of the Halden facility.

So, the intention is that will happen within the next two to three years and be transferred into DOE and then be available for research use. So, NRC has supported that through our role as a Halden member, and we're pleased that that looks like it's on track to take place and not lose valuable research specimens.

And then, finally, Halden is, as Michelle indicated in the earlier slides, they are putting quite a bit of effort into capturing prior data and knowledge, and, particularly, developing a legacy database and doing some analyses on some of the key fuels and materials issues, to sort of synthesize the data that has been collected over the past 60 years of Halden reactor operation.

So, maybe I'll just pause for a moment and see if there's any questions on these first few slides before I turn it over to my colleague, Eric Focht, to present on the FIDES JEEPs.

MEMBER KIRCHNER: Joy, this is Walt again. I'd like to try something on the presenters. I understand the value of having the high dose samples. I'm sure and hopeful that you're going to harvest those. I don't know the details in terms of actual fluences and such. Is there enough information to be gleaned from the Halden operations and samples to kind of address the kind of issues that come up with going plus-20, and then another plus-20, in terms of fluence?

So, it's a general question: do we have fluences that capsule samples for stainless steel and other materials used for reactor internals and vessels that encompass, say, an 80-year exposure?

MR. HISER: So, the materials from the Halden that we're talking about preserving from Halden, no, those alone do not do it. So we have other initiatives that we're planning, some of which we'll touch on on the later slides, on new harvesting.

And just to be clear, in the materials area, Halden would often get specimens from commercial reactors that may have been harvested, in some cases a baffle bolt or other pieces from internals. And so they were not necessarily very super-high dose, but they had been tested and characterized. And, in some cases, specimens weren't tested and could be available for further irradiation and testing. So that's part of the reason we wanted to preserve them.

Maintaining the metadata, if you will, for these specimens is an important piece that DOE is focused on and making sure that they -- you know, they may not be able to get all the materials, but they will focus on the ones that they see as having the most research value in the future.

But, no, this is sort of a housekeeping activity we think is important and it's not going to be tremendously costly. But, no, it's definitely -- these Halden materials preserved from Halden are not going to cover us to 80 years for reactor internals aging by themselves.

MEMBER KIRCHNER: Okay, thank you.

MR. HISER: Okay. So, with that, I'll turn it over to Eric to talk about the FIDES JEEPs.

VICE CHAIR REMPE: Real quick on the in-pile stress corrosion crack growth. Wasn't MIT the one where they were doing some testing for in-pile capabilities in that area? And I, again, have not kept up with some of the things, but how far along are they in getting data?

MR. FOCHT: I'll touch on that. One of our JEEPs is going to benefit from that work.

VICE CHAIR REMPE: Okay.

MR. FOCHT: I can't speak specifically about it, but I can give you some idea --

VICE CHAIR REMPE: That sounds fine.

MR. FOCHT: Okay. Well, good afternoon, everyone. My name is Eric Focht from the Division of Engineering in the Office of Research. And, as Matt mentioned, I'm going to be talking about the FIDES JEEPs.

And the Halden program definitely offered some unique and valuable testing capabilities. After the program shutdown, the NRC and EPRI sought options for obtaining stress relaxation data on baffle-former bolting materials, which, as Matt mentioned, was testing originally planned to be performed under the Halden program. We also recognized the need for in-core mechanical testing capabilities, specifically, as we just said, stress corrosion cracking crack growth rate testing.

Thus, there are currently two structural materials JEEPs proposals being developed by INL for consideration by the FIDES program. INL will be the operating agent for both JEEPs, and the NRC will be a part of the core groups, along with EPRI, for both JEEPs. And that will allow us the ability to provide input into the projects.

The objective of the stress relaxation and creep research JEEP, or STRETCH JEEP (phonetic), is to obtain irradiation-induced stress relaxation and creep data on baffle-former bolting materials. To get EPRI the data they need as quickly as possible, the testing will be performed in the MIT reactor, which can produce the dose needed in a PWR environment and will utilize stress relaxation testing rigs developed by INL.

This JEEP leverages resources from the DOE Advanced Sensors and Instrumentation Program and the Nuclear Materials Discovery and Qualification Initiative, or the NMDQi. And I should mention that the support from these programs will enable this JEEP, both JEEPs, actually, to begin sooner than they otherwise would have without their support.

DR. CORRADINI: Just one question. Does the MITR exposure, is it a one-to-one time or is it accelerated?

MR. FOCHT: I think it simulates PWR conditions pretty well, so I think it's -- I'm not an expert in that area, but I think it's -- maybe Ron could chime in, or Matt -- it's on the order of a couple DPA per year. So they're going to be exposed for several years to get the data they need.

VICE CHAIR REMPE: I think Ron's been trying --

(Simultaneous speaking.)

MEMBER BALLINGER: It's one-to-one.

MR. FOCHT: Okay. Thank you.

MEMBER BALLINGER: There's no acceleration.

MEMBER KIRCHNER: I was going to ask Ron or Pete, if they're online, this is Walt, how many plants still use the baffle bolts versus welded?

MEMBER RICCARDELLA: Almost all.

MEMBER BALLINGER: Yeah. My guess is almost all of them. APR1400 uses welded. AP1000, I think is welded. That's about --

MEMBER KIRCHNER: I was just curious whether, in the life extension space, they were replacing the baffle bolts design with the welded baffle-former.

MEMBER BALLINGER: Pete probably knows well, but I don't think a U.S. plant would replace the shrouds, or whatever they call it, the barrel.

MEMBER RICCARDELLA: I think that would be prohibitive, Walt. But they are replacing baffle bolts.

MEMBER BALLINGER: Yeah.

MEMBER RICCARDELLA: They can do that when they find them, but --

(Simultaneous speaking.)

MEMBER RICCARDELLA: And I would say, probably 90 percent of PWRs right now have baffle bolts.

MEMBER KIRCHNER: Still have them? Okay, thank you.

MEMBER BALLINGER: And I think one of the Studsvik reactors, and maybe one of the Japanese reactors, have replaced shrouds or core barrels, but not in the U.S.

VICE CHAIR REMPE: So, let's go ahead and keep going, because I'm a little worried about time, because --

MEMBER BALLINGER: Okay.

MR. FOCHT: Sure, thanks. The development of in-core mechanical testing capabilities, or the ENCORE JEEP, is focused on developing in-core testing capabilities to benefit both light water reactors and advanced non-light water reactors. The goal is to develop testing capabilities at the ATR that not only retain those lost due to the Halden program shutdown, but to go beyond that, with capabilities for testing in non-light water environments, such as at elevated temperatures and in coolants such as molten salts.

An important aspect of this project is that developing these capabilities at a DOE lab will provide access and expertise over the long-term to meet the data needs of both the U.S. nuclear community and the NRC, particularly the need for data on structural materials performance in advanced non-light water reactor environments.

The ENCORE JEEP will focus initially on stress corrosion cracking crack growth rate testing, and takes advantages of previous work at INL and MIT performed to develop an SCC crack growth rate testing rig based on the Halden design. And, as I mentioned, just like the STRETCH JEEP, this JEEP also leverages resources from the DOE ASI Program and the NMDQi.

So, yes, Dr. Rempe, we are using the test rig very similar to the Halden design that was being developed at MIT.

VICE CHAIR REMPE: Yeah, I think --

MR. FOCHT: They did a performance test on that, I think, and in their -- it may have been an autoclave -- no, actually, it was in-core, they have done in-core testing --

VICE CHAIR REMPE: I'm pretty sure Joe Palmer got this with the MIT reactor. I don't know how it turned out, but I know it went in.

On the prior one, with the LVDTs, has that ever been irradiated or is this the first time? I'm sure they've done autoclave testing, but I don't know if they've ever irradiated it. So, it's kind of interesting that this is a JEEP where, unless it -- did it go in a reactor yet, or do you know, Eric? On Slide 25.

MR. FOCHT: I don't think so. I think it's been autoclave tested. I don't know if Colin Judge is on the line, he could confirm that.

MR. JUDGE: I know the rig's been put into MIT and they've done testing. I'm not sure if they've done them with the LVDTs in place.

VICE CHAIR REMPE: Okay. Because I just was curious. So, the JEEP might be helping to fund some of this instrumentation development in a way, because it's putting it in a reactor the first time, which I hadn't caught on from what I've read. But, anyway, go ahead, because, again, I'm delaying you.

MR. FOCHT: No, that's okay. I appreciate the questions. So, I guess, one thing I'd like to point out -- I don't know if Matt will follow up with this -- but, traditionally, it's been my understanding that the Halden program was a balance of materials, as well as fuels testing. So we feel these JEEPs are important for the FIDES program to help kind of maintain that balance of fuels and materials testing. So, hopefully they'll agree and we'll get these JEEPs funded.

So, with that, if there's no other questions, I can pass it back over to Matt.

MR. HISER: Thanks, Eric. So, I just have a couple slides on harvesting, and then we'll wrap things up on the materials side.

So, I just want to introduce the sort of final pillar, if you will, of our materials post-Halden research strategy, is looking at ex-plant materials harvesting. And just to clarify terminology, this means taking previously or service-irradiated pieces of material and reactor internal components out, and then doing testing and characterization on them to confirm our understanding of their performance.

And so, you know, harvesting can be done both on irradiated and unirradiated materials. We've actually put quite a bit of time and energy into harvesting over the past few years and trying to do it strategically in a way that will give the most value.

So, again, it can provide highly representative aged materials for research. And this is particularly true for irradiation effects on materials. It can be challenging to replicate 30, 40, well, 50, 60, 70, 80 years of operation in irradiation, and, particularly, flux effects and neutron energy spectrum through test reactors. So, if nothing else, harvesting provides a good validation and confirmation of what we learn through other types of irradiation studies.

And so I just want to note, on the broader topic of harvesting, NRC staff has spent some energy developing harvesting priorities. And that's for not even just metallic components or irradiated components, but also for concrete and electrical components, which are also in the scope of license renewal and subject to long-term aging effects.

We've also been working to identify harvesting opportunities and been engaged with partners, both DOE and EPRI, as well as the international community. We've hosted a couple of international workshops focused on harvesting, one at NRC headquarters about four, almost four years ago, in

March 2017, and then another one at NEA headquarters just about a year ago, just before we stopped being able to meet in-person.

And so, just to shift this discussion back to the focus of this meeting, in the irradiated materials arena we've identified a few key harvesting priorities from an NRC perspective. So, the first one is high fluence stainless steel welds. The second one is high fluence and high temperature stainless steel materials. And you'll note the high fluence is defined a little differently, and this has to do with where welds -- the doses that welds see in most plants versus just base materials. And then, finally, irradiated cast austenitic stainless steel materials.

So, those are some of the key irradiated materials harvesting priorities that NRC has. So, maybe, Michelle, you can go to the next slide?

So, just shifting gears from the broader materials harvesting discussion, there is a key international cooperation that is getting ready to kick off here known as the Studsvik Materials Integrity for Life Extension Project. And this is a planned cooperation through the NEA that's being led by Studsvik, which is also involved quite a bit in the fuels research worlds, as you heard earlier.

The program is structured similarly to the Studsvik Cladding Integrity Project. It's a five-year scope of work, anticipated to begin this year. And we think SMILE will provide a lot of value to some of our key priorities for metallic light water reactor components, both irradiated and unirradiated materials.

So, it includes the harvesting, characterization, and testing of metallic components from both a BWR and a PWR in Sweden. And from a materials standpoint, it covers an array from the reactor pressure vessel low alloy steel to stainless steel internals, including the core shroud and barrel, respectively, in a BWR and a PWR; the baffle plate and baffle-former bolts from the PWR; and then, finally, nickel alloy penetrations, piping, and alloy-690 steam generator tubes are also a part of this planned program.

And just to give a little information on the reactors that the harvesting will be done from. The first, the PWR is Ringhals 2, which is a Westinghouse design three-loop PWR with about 30 EFPY. And then the second is Oskarshamn 2, which is a ABB Atom design BWR with approximately 30 EFPY.

MEMBER BALLINGER: This is Ron. I'm glad

to see you're working with that Studsvik Materials Laboratory. It is outstanding. It's really outstanding.

MR. HISER: Yes, we've been involved with some previous projects that just wrapped up on some of those irradiated materials with Studsvik. Yes. We've had good experience with Studsvik.

MEMBER BALLINGER: Yeah, you can stick a block of irradiated material in one end and out comes specimens and TEM and everything at the other end. It's really very highly integrated.

MR. HISER: Any other questions on this slide? Or we can move on to the next one, which sort of burrows down a little further into SMILE.

So, just, again, to the scope of this meeting, focused on irradiated materials, this slide just gives a little more information on the irradiated materials that we see of most interest. So, we're primarily interested in some of the PWR materials that are higher dose.

And so this table gives a little flavor of the grade of stainless steel, as well as the maximum dose that's estimated from some of the different components, the baffle plate, baffle bolts, core barrel, which is where you're going to see your highest dose stainless steel welds, and then some of the other internal components.

So, we're particularly interested in the very high doses on stainless steel plate and baffle bolt materials, which would be about the highest we're aware of being harvested from an LWR where we can have enough material to do crack growth rate testing, as well as the fairly healthy dose on the stainless steel welds with 30 years of thermal exposure as well.

And I'll just note, lower in the slide, we have both characterization, microscopy, retrospective dosimetry, and hydrogen helium content, as well as mechanical testing, tensile, crack growth rate, and fracture toughness is all planned as part of the scope of this program.

So, if no other questions on SMILE, we can move, and I just have one last slide to wrap up the materials part of the presentation.

So, again, just to echo back to our strategy on Slide 23, sort of some key aspects are preserving knowledge from Halden, and that's being done both through the Halden activities, as well as the DOE initiative to preserve samples and move them into the DOE library. And then for performing high priority research, we have contributions from SMILE, from the FIDES JEEPs led by DOE, as well as some of the Halden activities that are wrapping up.

And then developing new capabilities is really focused on the DOE-led FIDES JEEPs, and we see those as hopefully providing valuable research in their programs, but then also the capability to provide benefits down the road.

And I don't know if it got emphasized earlier, but we also see these capabilities as being important for non-light water reactors, too. That's part of the plan that DOE has in place, is to first demonstrate some of these capabilities with light water reactor conditions, but with the vision to expand. And that can truly be a value to the NRC and to the U.S. nuclear research community down the road.

And then, finally, just long-term testing of highly representative materials is how NRC is focused, particularly for irradiation effects and long-term aging of reactor internals. And so harvesting is going to be a key aspect of that. We try to be selective and make sure we're -- harvesting is very challenging and expensive, and so we try to pick our spots and identify the highest value items. But we also see the value of pursuing that where it makes sense, and SMILE appears to be a good example of that.

And so, in summary, just to wrap up on the materials side, we think the closure of the Halden reactor has caused some delays and will probably increase costs modestly to fill some of our short-term needs, but it's really just accelerated probably some transitions and adjustments that we were going to need to make anyway, because Halden was not going to operate forever and we need to have domestic capabilities on some of these things.

And so this is really giving us a push into the direction that we need to go to be prepared for non-light water reactors, and the long-term aging of light water reactors as well.

So, any questions?

MEMBER KIRCHNER: This is Walt Kirchner. What are the major codes that Research holds or maintains and develops to actually take this information and use it to benchmark and verify and validate the codes so that if, indeed, we cannot get 80 years of fluence, we have a reasonable feeling about the codes' abilities to project performance under -- I'm thinking first of the LWR fleet, and then I'm thinking of the higher irradiations that you'll see in some of these fast reactor designs and such.

Is there a close coupling between your different branches on this aspect?

MR. HISER: So, I would say that -- you're talking about, like, modeling and simulation codes, I presume?

MEMBER KIRCHNER: Yes, exactly.

MR. HISER: Yeah, I was going to say, we don't -- particularly for reactor internals, there have not -- I think DOE has developed some codes, you know, with challenges in validation, for irradiation effects. It's really a challenging phenomenon to model. And the safety significance is -- you know, it's not insignificant, but these are not pressure boundary components. So, there have been failures of baffle bolts, for instance, and these things have tended to be managed through experimental research, engineering judgment, and then inspections, has been generally the strategy that the industry has followed and that we have found acceptable.

Now, we certainly are open to looking at validating and benchmarking, and developing codes that could be validated and benchmarked, but that hasn't been really the industry or NRC approach in this area.

MEMBER KIRCHNER: No, I appreciate that, and I appreciate the value of having the empirical evidence. I'm just thinking that, as we go forward, or as research goes forward -- and I hope the industry is thinking of this, because if they're not prepared to do the integral testing at representative fluences, et cetera, and prototypical operating conditions, then they need some kind of convincing and validated tools to make the projection that the particular design aspect is going to meet the requirements and satisfy you, the staff, in a review, in a licensing review, that, in the absence of an integral test with many years of irradiation, this is an acceptable design.

Otherwise, it throws you back on saying, well -- and this is making it too simplistic, but you need to have a prototype, which was the old way of going forward on advanced reactors.

MR. HISER: Right. Well, and what I will say is, you know, when you look at the spectrum of dose on reactor internals, you have the re-entrant corners on baffle plates, and those see a significant acceleration in dose relative to even just the exterior-facing corners of the baffle plate. And then there's a significant reduction in dose out from there. So, through harvesting, you can harvest sort of the highest dose corners and really be able to bound a large fraction of the internals out to a significant lead factor, if you will. So, there are approaches. We're not --

MEMBER KIRCHNER: Well, the whole basis for PWR -- and it's true, I think, also for the BWRs -- to give confidence and conservativism in terms like the boiling pressure vessel code, and so on and so forth, I mean, you design the reactor with the baffle for a number of reasons, flow as well as having a space there that's filled with water that reduces the fluence on the vessel.

But as we go forward to some of these advanced concepts, they're not going to have that, how should I say, buffer baffle kind of effect, and we're going to see fluences at high temperatures, much higher than you would see in a LWR fleet.

And that's where I was going with this. If we're not going to see with these advanced reactors the kind of integral testing out through the exposure, lifetime exposure, then it suggests that they're going to have to rely on some kind of means to extrapolate performance, and that sooner or later gets you either to a kind of simplistic estimates of exposure and all the other factors, or you have some kind of physical-based code to project performance further out.

So, that's what I was thinking about when you were presenting this material section of the presentation.

MR. HISER: No, and that makes sense. And I have to say, I personally have lived more in the LWR world and been focused more on, yeah, the current fleet. I know that there are other staff in my branch that are more focused on the advanced reactor piece. And I'm sure that, yeah, probably modeling and codes will need to be a bigger piece of the puzzle on that side.

But I will say, I think the ENCORE JEEP is designed to develop some of the experimental testing capabilities, which there will at least need to be some experimental testing, I'm sure, but maybe not as much, as was stated earlier.

VICE CHAIR REMPE: So, we are kind of short on time. And so, if my colleagues will let me, I'd like to go ahead and go to the next presenter directly. I believe this is your last one, right? Your last slide?

MR. HISER: Yeah, that was my last slide. Yeah.

MS. LUND: Yeah, good afternoon. And we very much appreciate the opportunity to discuss this important topic with you this afternoon. And, summarizing what you've heard today, while we recognize the tremendous research benefits we've gained by our participation in the Halden Reactor Project, and are grateful for its uniqueness and longevity, we're committed to being ready as an agency to meet our future regulatory challenges.

The closure of the reactor has certainly caused us some short-term pain and has led us to refocus and broaden our efforts to fill those immediate research gaps that were planned to be addressed by Halden.

One immediate focus is, as you've heard today, the orderly termination of the Halden Reactor Project to best preserve the knowledge gained over the course of the project. And also consistent with what you've heard today, the reactor's closure has spurred us to rigorously reevaluate our research and the associated regulatory needs, and has accelerated our strategic planning to meet those needs, for both the existing fleet of light water reactors and future reactors that will have a broader array of characteristics and capabilities. Future fuels and materials challenges will require experimental facilities beyond those possible with Halden.

So, these expanded research needs, coupled with economic realities that make it infeasible for the NRC to independently support extensive and expensive fuels and materials irradiation and testing, are the principal factors driving our current pursuits of focused, innovative, aggressive, and diversified activities.

To focus even sharper on identifying and addressing the most safety-significant concerns through our research portfolio, technical innovation is imperative to better couple advanced experimental techniques with state-of-the-art modeling and simulation tools to optimize experimental programs and more intelligently mine the results. This innovation is necessary in our pursuit of aggressive goals to both accelerate fuels and materials qualification and certification and implement experimental findings more efficiently in technical practice and associated regulatory requirements.

Diversification is imperative in realizing these goals. We will need a variety of domestic and international partnerships, which you've heard about today, some of which are well-established, but others that are still conceptual, to best leverage funding, capabilities, and expertise going into the future.

An array of programs are being planned to address our more immediate research needs. Some of these are leveraging existing programs at DOE, and some activities have been initiated to fill the void left by Halden. An array of experimental capabilities will be needed to address future needs, and those needs are being individually matched to the optimal facility to create a dispersed research network that will allow us to nimbly adapt to the expected accelerated future pace of change.

DOE's investment in U.S. infrastructure is central to our entire post-Halden strategy. These past investments have allowed us to mitigate the near-term impact of the Halden closure. However, continual investment is critical for our long-term success. NRC hopes to work closely with DOE to align on an optimal investment strategy.

In closing, as we look to the future, we realize we can't do things exactly the way that they've been done in the past, and I think that's already been mentioned many times in this presentation. However, we believe that the activities we've presented today illustrate how we will continue to meet the agency's fuel and materials research mission going forward, despite the loss of the Halden reactor.

And that closes my remarks.

VICE CHAIR REMPE: Thank you, Louise.

Colleagues, does anyone have a question for Louise?

So, not hearing anyone, I'll ask a question. My earlier comment about the need for some domestic locations are tied to this bullet that you have on the far right, the lower one. And I often mention the fact that when they reorganized the Atomic Energy Commission, that there's wording in that act that discusses the fact that the head of what is now the Department of Energy, as well as other federal agencies, are expected to provide the Commission the facilities that it needs to accomplish their mission.

And so I assume that this point is being conveyed to the Commissioners and to the DOE and decision-makers, because I'm not even sure if DOE (audio interference) affect that, right?

MS. LUND: There was an interruption in your last sentence.

VICE CHAIR REMPE: Well, I assume that this bullet is being conveyed to the Commissioners, because -- I think you got the point about what I'm saying is --

MS. LUND: Yes. Yes.

VICE CHAIR REMPE: It's important that decision-makers that affect the DOE investments are aware and communicate that to people who affect what the DOE does, right?

MS. LUND: Yes. I think that, to the extent -- especially as the planning for this evolves and there's communications -- Ray, with his periodics, with the Commissioners -- and we have, Ray and Stephanie, as do others, we have a lot of coordination discussions with DOE to try to make sure that the decision-makers on both sides are aware of the plans, the needs, what it takes going forward.

So I think, to your point, we are trying to make the needs and what it's going to take to get us there clear to everybody involved.

VICE CHAIR REMPE: Thank you. And I think now it's time for Ray to do his last --

(Simultaneous speaking.)

MR. FURSTENAU: I'll just wrap it up really quickly here. Chairman and Vice Chair, I really appreciate you taking time out of the busy ACRS schedule to allow us to come in and make these informational briefings. I hope we plan to continue that in the future on different topics. These are some potential ones, but we can add further discussions on what others might be appropriate.

Just the conversation and the discussion and the questions we get are just valuable to us to kind of think about -- causes us to think more where we may need to do better or do more or do less. So, thanks for your support of us on the briefing.

VICE CHAIR REMPE: And I need to thank you and your staff for taking time and to prepare the presentation and give it to us, because it helps us to accomplish what we're supposed to be doing as an Advisory Committee.

Colleagues, do you have any last minute comments before I open the public line?

MEMBER BALLINGER: Yeah, this is Ron. Ray, I'll put you on the spot. Is the NRC a paid, active member of the ICG-EAC group?

MR. FURSTENAU: You did put me on the spot, Ron.

MEMBER BALLINGER: It was intentional.

MR. FURSTENAU: Okay. Is there any of my staff on the line that can help me on that? Otherwise, we'll take it as a look-up, Ron.

MR. JUDGE: I can tell you that, yes, they are, speaking as an ICG member.

MR. FURSTENAU: Okay, good. Sorry, Ron,

you got me. I'll be better prepared next time.

MEMBER BALLINGER: No, you're fine.

MR. FURSTENAU: Okay.

VICE CHAIR REMPE: Tom, can you verify that -- oh, Dave, are you trying to say something? You're flashing.

MEMBER PETTI: I just wanted to thank the staff for the slides. Very informative, nice view of the lay of the land and the challenges and the opportunities going forward.

VICE CHAIR REMPE: Okay. Let's open up the public line.

MR. DASHIELL: The public line is open for comment.

VICE CHAIR REMPE: So, are there any comments from members of the public? Please state your name and provide your comment.

(Pause.)

VICE CHAIR REMPE: I think we've given then the ten-second rule, right? So, let's close the public line.

And, Ray, with respect to your potential topics, we'll talk and plan and do this. I also wanted to remind you that we need to get going on our biannual review. And so we'll be talking to you and your staff about that, too, okay?

MR. FURSTENAU: Okay. All right, sounds good.

VICE CHAIR REMPE: And thank you, again, very much. It was very informative and it was exactly what I wanted to hear.

MR. FURSTENAU: Yeah, my staff did all the work, Joy. It was a pleasure, so, thanks.

VICE CHAIR REMPE: Okay. And then I'll turn it back to you, Mr. Chairman. We're only a couple of minutes late.

CHAIR SUNSERI: Thank you, Joy. And let me extend my appreciation to Ray and your team for the thorough and comprehensive and informative presentation. It's clear that you all are staying on top of this matter and applying a lot of details. So, appreciate that.

Okay. Members, you will thank me tomorrow for what I'm going to do right now, but we're going to roll right into the GEH containment letter. I'll give five minutes or so, time for you to take a break, as we transition to get the letter report up.

Jose March-Leuba, the lead member for this, is prepared to go, we've got other people standing by, so we need to get this done. The goal will be to read in the letter, have high level comments, and we should be able to end by around 6:00 per our schedule.

So, let's start that transition right now.

(Whereupon, the above-entitled matter went off the record at 5:33 p.m.)

Post-Halden Research Strategies & Activities in Fuels and Structural Materials

A briefing from the Office of Nuclear Regulatory Research

to the Advisory Committee for Reactor Safeguards

February 4, 2021

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Agenda

- **Opening Remarks** – R. Furstenau
- **Post-Halden Research Strategies & Activities in Fuels** – M. Bales, L. Kyriazidis, J. Corson
- **Post-Halden Research Strategies & Activities in Structural Materials** – E. Focht, M. Hiser
- **Vision for the Future** – L. Lund
- **Closing Remarks** – R. Furstenau

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Motivation & Scope

- **Motivation:** Replace the general "RES quality reviews" with briefings on targeted technical subjects

- **Scope:** Post-Halden plans for the Fuel and Material's research areas. The Man-Technology-Organization area, including human factors and digital I&C, was not impacted by the reactor closure and will continue as a stand-alone OECD joint project.

Closure of Halden Reactor caused swift, significant and broad response around the world

2011-2018
Funding challenges, significant reduction in revenue from bilateral projects

March 2018
Costly maintenance work identified, requiring prolonged shutdown

Spring 2018
NRC, DOE, EPRI, and fuel vendors, expressed support for continued operation of the Halden reactor into the mid-2020s to support development of ATF

May 2018
- US-Norway Government Mtg
- NEA-Norway Government Mtg
- NRC, DOE, EPRI, NEI Mtg
- DOE seeks impact assessment from ATF fuel vendors

June 2018
Halden Reactor announces permanent closure

July 2018
INL hosts “Halden Capability Gap Assessment Workshop” with participation from U.S. national laboratories, Halden, DOE, NRC, NEI, EPRI, NEA, SCK-CEN, NRG, MIT, and industry teams from Westinghouse, GA, GE, Framatome, and Lightbridge

October 2018
NEA hosts Workshop on "Building Multinational Material and Testing Capacities for Science, Safety and Industry

December 2018
INL issues “Post-Halden Reactor Irradiation Testing for ATF: Final Recommendations

March 2019
NEA hosts “Introduction to the Multinational NEA Framework for In-Pile Fuel and Materials Testing “

A lot has happened in the two years since the Halden Reactor shutdown

- Innovative solutions, new ideas and collaboration have been abundant in the two years since the Halden Reactor shutdown
- NRC staff have been in a leadership role in many of the initiatives
- *Presentations from the staff will provide exciting details of what's been accomplished to date* including:
  - Archiving of Halden data
  - New collaborative research projects
  - Retrieval of valuable Halden test materials
  - New domestic experimental capabilities

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The new fuel and materials landscape offers many benefits, but some challenges remain

- Benefit: The dispersed network of research facilities is overall positive, leaving the nuclear fuel and materials community less vulnerable to a single future facility closure
- Benefit: The investment in US facilities will provide significant autonomy and value for the US nuclear community
- Challenge: Cost of multiple research initiatives will likely be higher than Halden Reactor Project for the near future
- *Presentations from the staff will elaborate on these benefits and challenges*

The closure of the Halden Reactor isn't the only factor driving change in fuel and materials research

- Fuels and materials testing is complex and expensive – it's becoming increasingly difficult for NRC to sponsor irradiated research projects alone, we need partners and collaborations
- DOE's NEUP and NSUF programs are offering opportunities for NRC to easily partner with DOE Labs and Universities for meaningful, timely research
- The Integrated University Program (IUP), offers another mechanism to align university research with NRC emerging research needs
- As the industry pursues innovative fuel and materials, to improve economics in the LWR fleet and design advanced reactors, there is a growing demand to optimize the number and types of experiments needed to qualify fuel and material
- *Presentations from the staff will elaborate on our vision for the future and explain why the future calls for more creativity and more partnerships*

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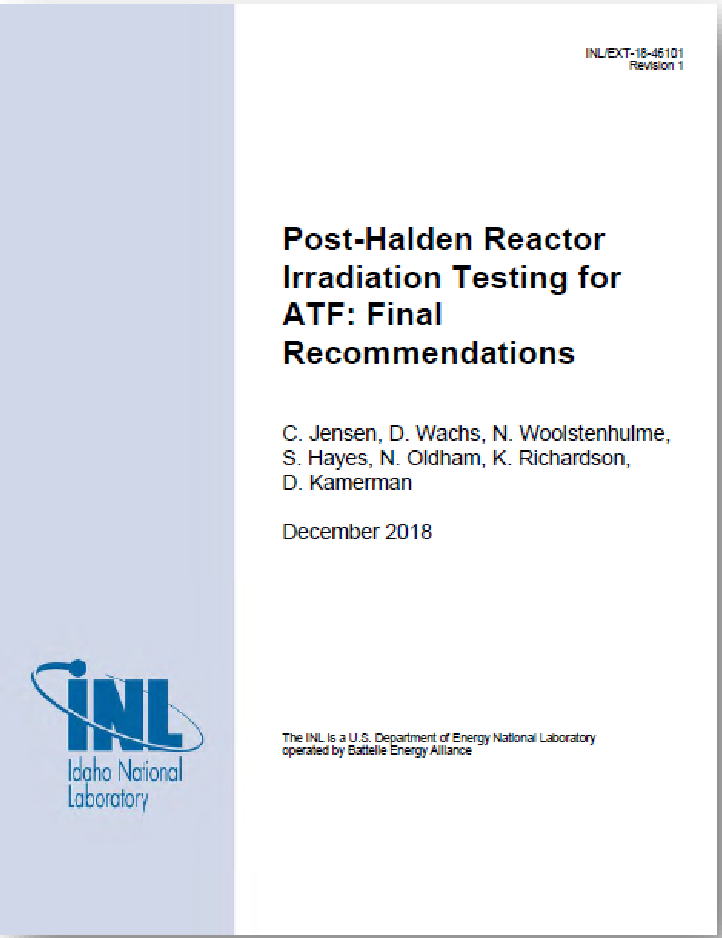
A lot has happened in the two years since the Halden Reactor shutdown

- DOE has made significant investments to address Halden capability gap

- NEA has launched the FIDES Framework, which is designed to connect a network of experimental reactors and re-establish the community formed via Halden research

- Studsvik Nuclear Laboratory has proposed a small program to recover valuable fuel specimens from the Halden Reactor

DOE has made significant investments to address Halden Capability gap


INL/EXT-18-46101
Revision 1

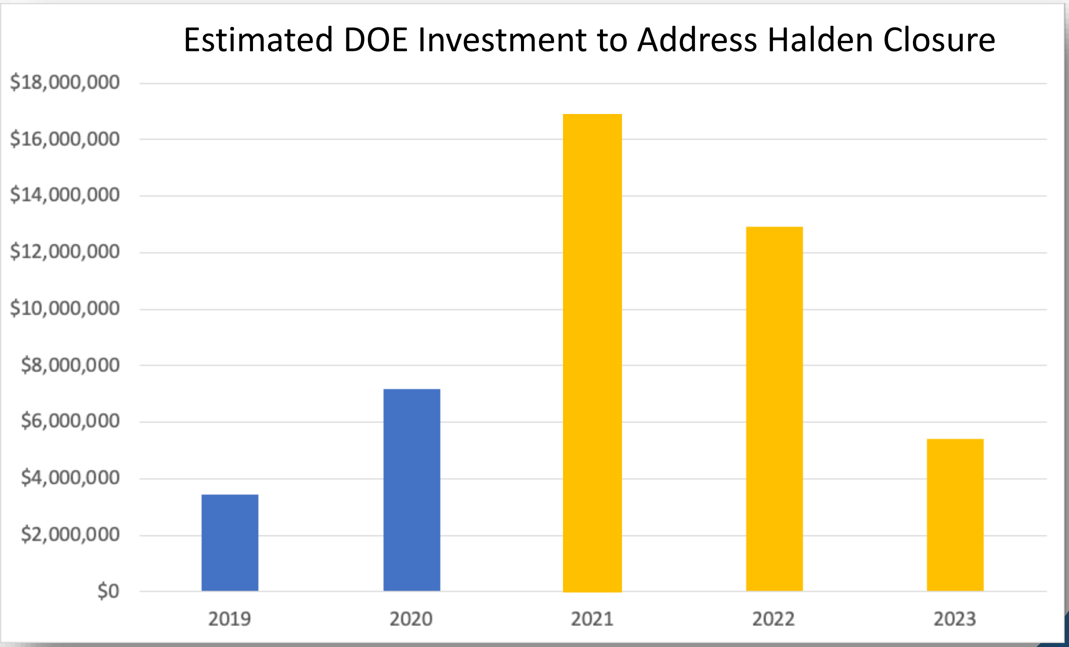
Post-Halden Reactor Irradiation Testing for ATF: Final Recommendations

C. Jensen, D. Wachs, N. Woolstenhulme, S. Hayes, N. Oldham, K. Richardson, D. Kamerman

December 2018

INL
Idaho National Laboratory

The INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance



Blue is spent in previous FYs
Yellow are estimates, subject to Congressional appropriations

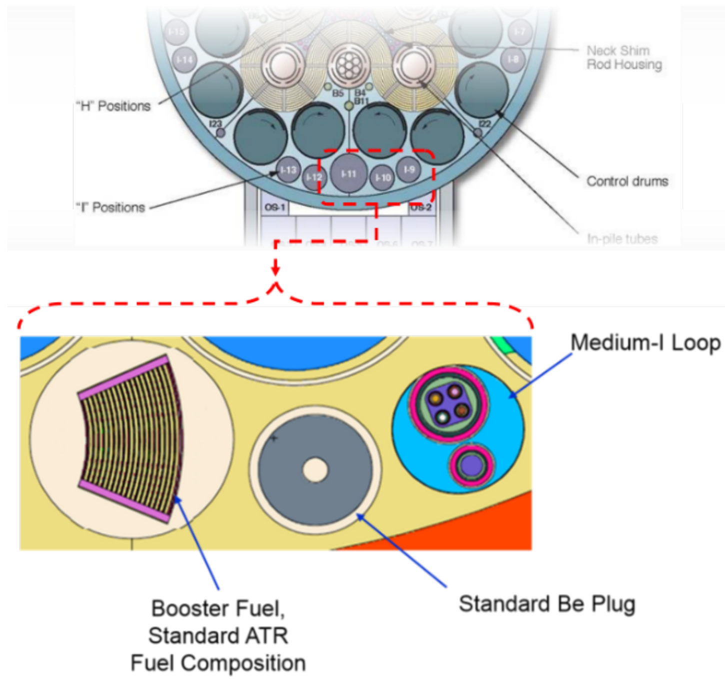
DOE has made significant investments to address Halden Capability gap (continued)

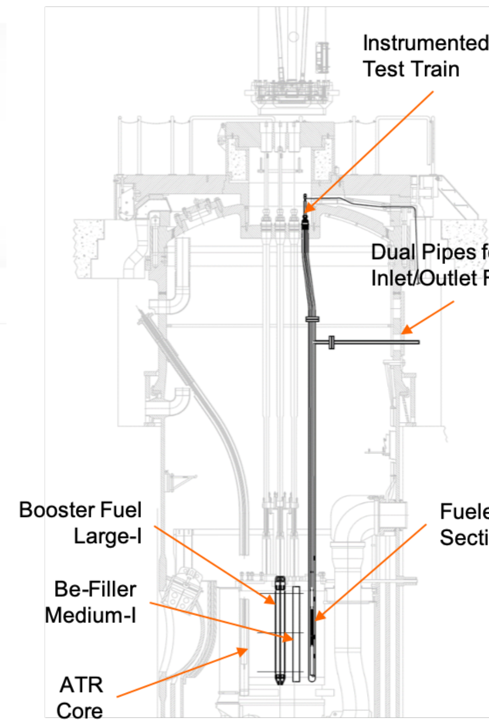
Establish additional LWR test loops in ATR

- Design of I-Loops underway, loop operating is expected to begin 2023

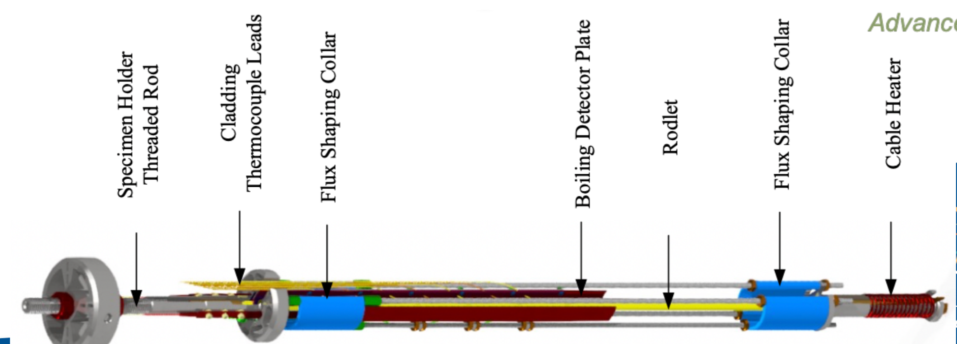
Establish LOCA testing capability at TREAT

- Commissioning tests for a Transient Water Irradiation System for TREAT (TWIST) planned for 2022





Advanced Test Reactor



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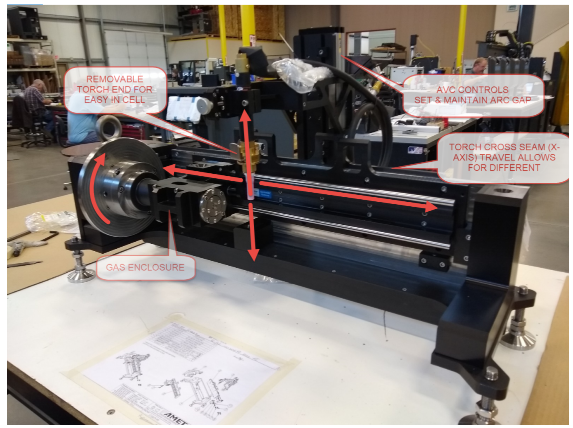
DOE has made significant investments to address Halden Capability gap (continued)

Establish refabrication capabilities

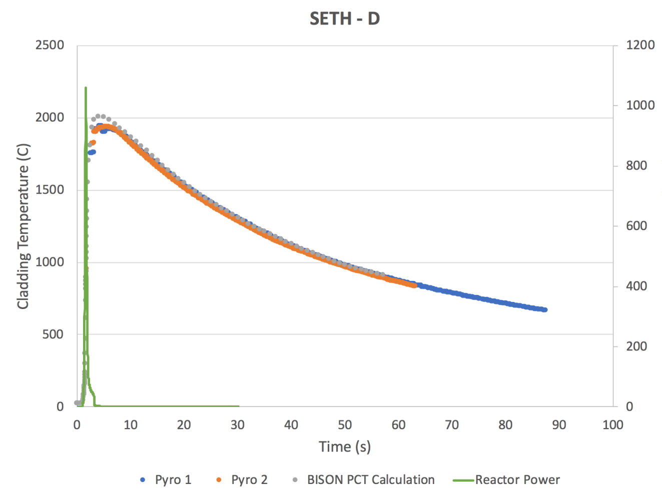
- Remote welding and instrumentation installation

Develop advanced in-pile instrumentation capabilities

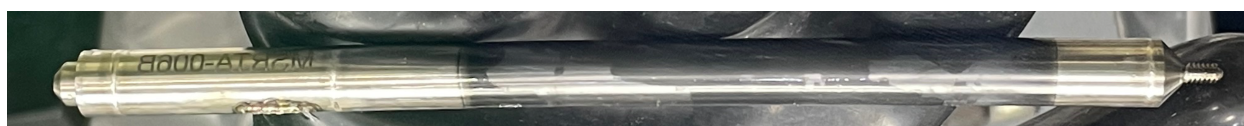
- Replicating Halden's capabilities and pushing further



INL Developed Remote End Welding System for fuel rod refabrication, currently undergoing out of cell testing.



In-pile temperatures data from temperature measurement during RIA Transient Test at TREAT.



Above: Fuel pin from recently completed RIA transient test at INL which included advanced instrumentation (LVDTs, boiling detectors, TCs, Optical Pyrometry, Fuel Motion Monitoring System)

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Lessons Learned on capturing experimental metadata

- The closure of the Halden Reactor clarified: we need to be more deliberate about capturing the "metadata" of nuclear fuel and materials research
  - Metadata includes experimental design details and key parameters
  - These are critical to putting the results in appropriate context for use by regulators and industry
- This lesson is being applied in future research programs
  - New research proposals are emphasizing the need to capture data (and metadata) and make them accessible for long-term use

FIDES is designed to connect a network of experimental reactors and retain the Halden research community

Framework for Irradiation Experiments (FIDES)

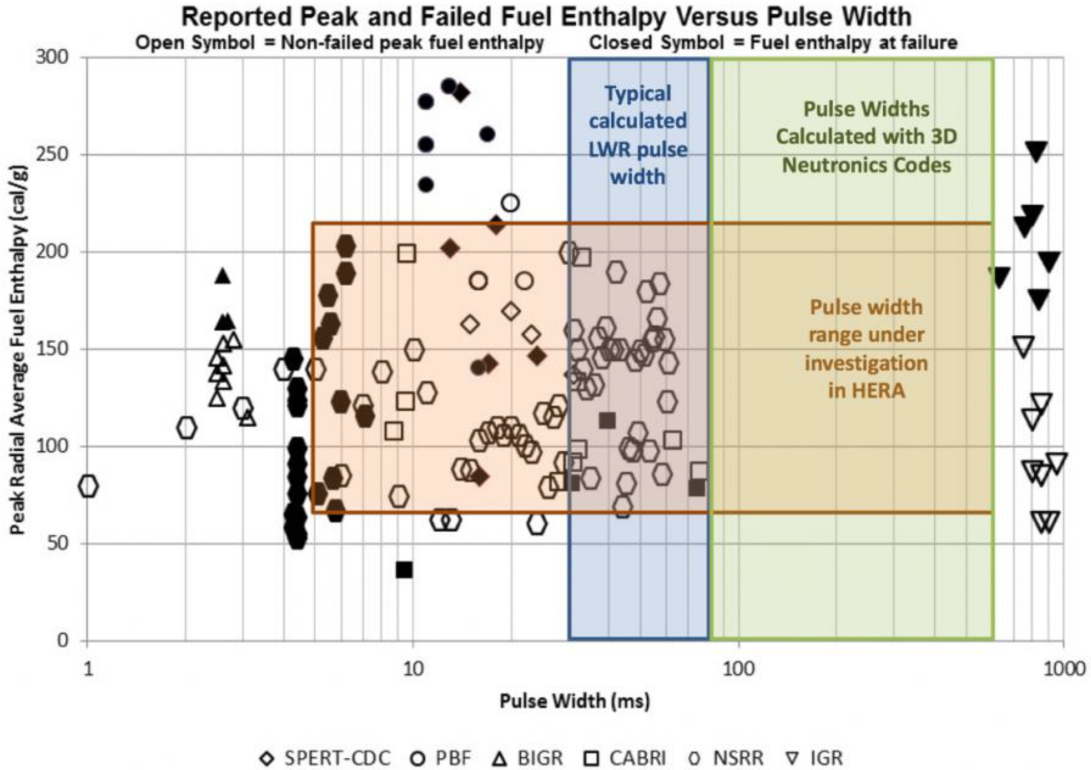
- Encompasses **Joint Experimental Programmes** and the following **Cross-cutting Activities:**
  - **Data preservation and QA**
  - Training and education
  - State-of-the-art modelling & simulation and instrumentation for efficient design, performance and analysis of experimental campaigns

Joint Experimental Programmes (JEEPs)

- **P2M**: Tests in BR2 & PIE in CEA. Proposed by CEA, SCK•CEN, EDF — Belgium, France
- **LOCA MIR**: tests in MIR.M1. Proposed by RIAR and ROSATOM — Russia
- **INCA**: Cladding creep tests in LVR15. Proposed by CVR, UJV, VTT, CEA, Alvel — Czech Republic
- **HERA**: RIA tests with high burnup fuel in TREAT. Proposed by INL — USA
- **LOCA**: tests in CABRI. Proposed by IRSN and CEA — France
- **INSTEP**: RIA tests in NSRR. Proposed by JAEA — Japan
- Tests for validation of 3D M&S. Proposed by INL
- Potential new proposals for existing RR and RR under construction

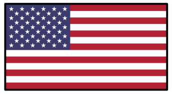
FIDES JEEP

High-burnup Experiments in Reactivity Initiated Accidents (HERA)



In-Pile RIA Testing Database as a function of Pulse Width.

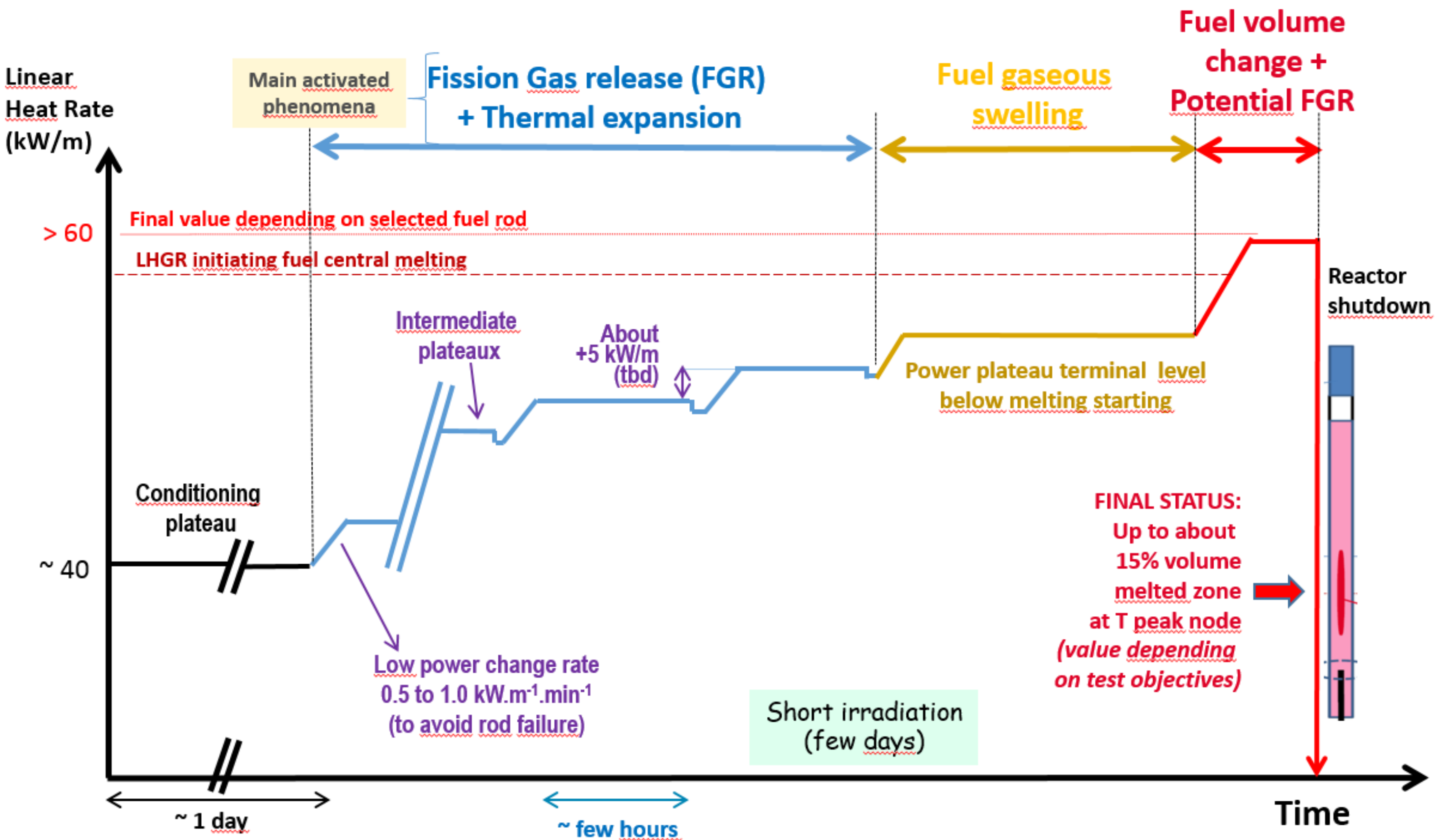
✓ NRC Core Group Member



TREAT Reactor
United States

FIDES JEEP

Power to Melt and Maneuverability (P2M)

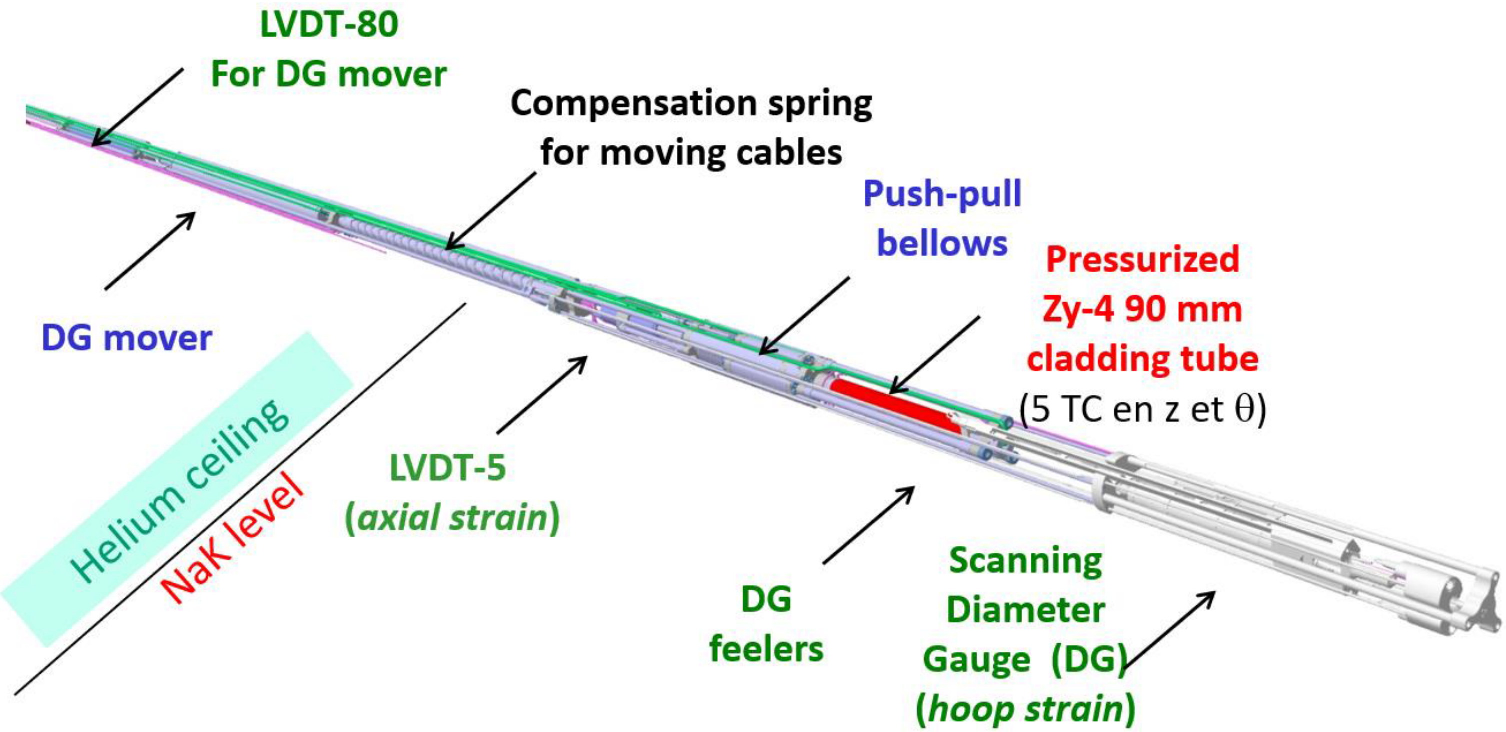


Schematic of the envelope configuration of the slow transient that the Project proposes to investigate

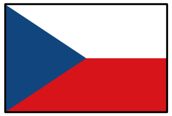
BR2 Reactor
Belgium

FIDES JEEP

In-pile Creep Studies of ATF Claddings (INCA)



Melodie sample holder



LVR-15 Reactor
Czech Republic

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Transferring the valuable fuel and material library at Halden to other research facilities has been a priority for the entire nuclear community

Studsvik Nuclear Laboratory has proposed project *SPARE* to fund the transport of the most valuable fuel specimens from Norway to Sweden

The dispersed network of research facilities is an overall positive, but also presents some challenges

- Less vulnerable to facility closure
- The investment in US facilities will provide significant autonomy and value for the US nuclear community
- Halden offered significant economy of scale that will be hard to replicate – a balance between cost & testing capacity will have to be considered in the dispersed network
- Long-term, steady-state irradiation of instrumented fuel and materials is difficult to replace

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Halden was a key aspect of NRC 's irradiated materials research prior to reactor shutdown

- Unique Capabilities
  - Multiple in-reactor testing loops dedicated to materials research
    - In-pile stress corrosion crack growth rate (SCC CGR) testing
    - In-pile instrumented creep / stress relaxation testing
- Excellent Value / Leveraging
  - Halden funding split with other countries, US organizations, and other NRC research areas made research very cost-effective
- Specific Planned Materials Research Activities
  - Further irradiation and testing of ex-plant stainless steel (SS) welds
  - SCC CGR testing of high dose ex-plant SS materials
  - Creep and stress relaxation testing of baffle-former bolt (BFB) materials

NRC's post-Halden materials research strategy emphasizes cooperation

- Following the Halden reactor shutdown, NRC staff assessed the impacts to NRC interests
- Focused on addressing needs and mitigating impacts by:
  - Preserving knowledge from Halden → Halden 2018 – 2023 / DOE
  - Performing high-priority research → Halden 2018 – 2023, FIDES JEEPs, harvesting
  - Developing new capabilities → FIDES JEEPs / DOE

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Halden Materials Research 2018-2023

- Halden activities post-reactor shutdown focused on:
  - Orderly completion of ongoing work
  - Preserving fuels and materials samples of research value
  - Documentation and capture of past Halden data
- Ongoing experimental work is nearly complete
  - Included high-priority NRC interest of SCC CGR testing of high dose ex-plant SS materials
- DOE is expected to acquire high-value irradiated materials samples from Halden
  - Will be available to the research community through the existing Nuclear Science User Facilities (NSUF) process
- Halden focused on capturing historic data and knowledge by developing a legacy database

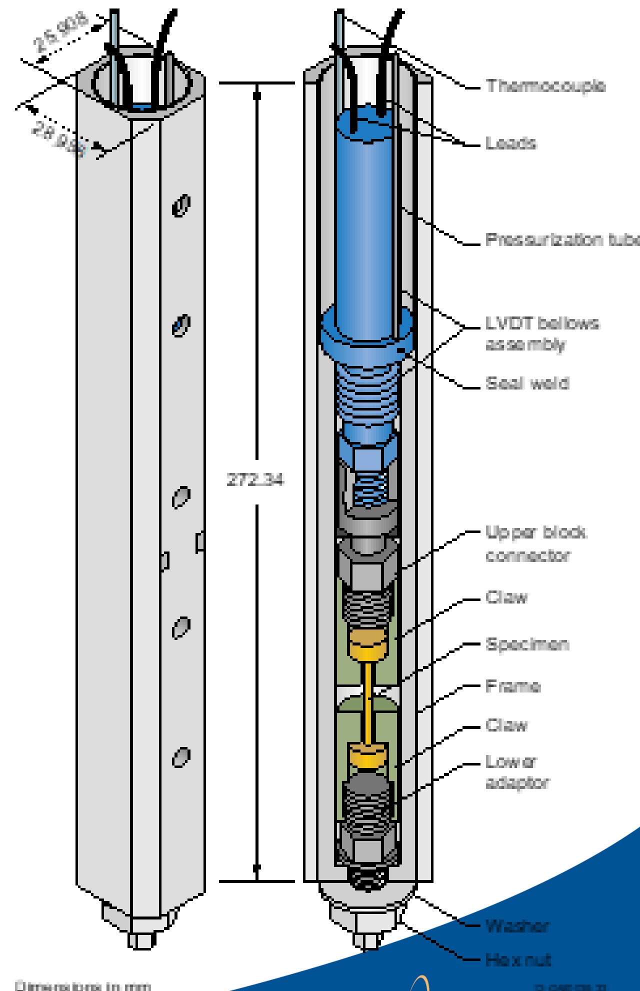
NSUF Nuclear Science User Facilities

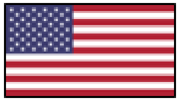
Proposed FIDES Structural Materials JEEP

INL Proposal (under development)

Stress-Relaxation and Creep Research (STRETCH) JEEP

- **Obtain irradiation-induced stress relaxation and creep data for baffle former bolting materials**
- **Testing previously planned under Halden program**
- **Leverages DOE projects at INL and INL-MITR working relationship**





MIT Reactor
United States

Proposed FIDES Structural Materials JEEP

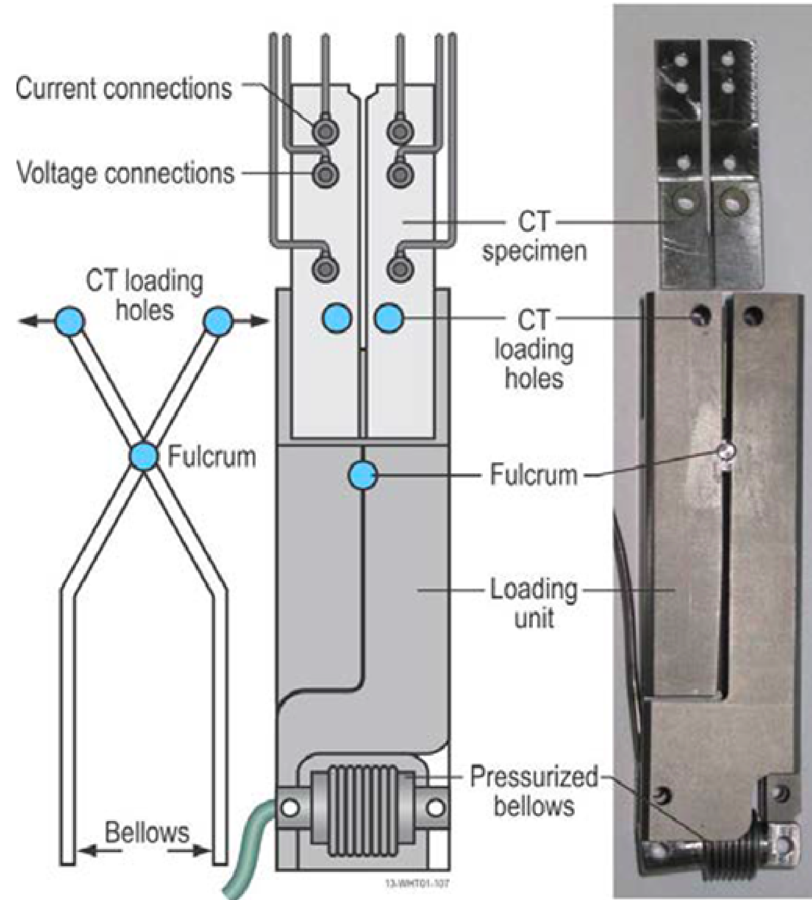
INL Proposal (under development)

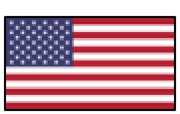
Development of In-Core Mechanical Testing Capabilities (ENCORE) JEEP

Develop in-core mechanical testing capabilities at INL Advanced Test Reactor (ATR)

Long-term solution to retain and expand lost Halden capabilities

SCC crack growth rate testing in LWR and ANLWR environments





ATR
United States

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Ex-plant materials harvesting is important for understanding long-term aging

- Harvesting provides highly representative aged materials for research
  - Particularly valuable for irradiated material research

- NRC staff has developed harvesting priorities, identified opportunities, and engaged partners
  - International harvesting workshops held at NRC HQ in March 2017 and OECD/NEA HQ in January 2020

- Key irradiated materials harvesting priorities for NRC:
  - High fluence (>2 dpa) SS welds
  - High fluence (>30 dpa) / high temperature SS materials
  - Irradiated cast austenitic SS materials

SMILE will address key long-term aging issues for metallic LWR components

- Studsvik Materials Integrity for Life Extension (SMILE) project is a planned international cooperation through OECD/NEA
  - Structured similarly to Studsvik Cladding Integrity project (SCIP)
  - 5-year planned scope of work beginning in 2021
- Harvesting, characterization and testing of metallic components from decommissioning Swedish BWR and PWR
  - Reactor pressure vessel low alloy steel
  - SS internals: core shroud / barrel welds, baffle plate, BFBs
  - Nickel alloy penetrations, piping, and steam generator tubes
- Reactors:
  - Ringhals 2: Westinghouse 3-loop PWR with ~30 EFPY
  - Oskarshamn 2: ABB-Atom BWR with ~30 EFPY

SMILE Irradiated Materials Research

- SMILE addresses multiple high-priority NRC interests:
  - Very high dose SS plate and BFB materials
  - High dose SS welds

Table 6
Materials and maximum dose for Ringhals 2 components.

	Component	Material	Max Dose dpa
INTERNALS	Baffle plate (various doses)	304	71.1
	Baffle bolts (various doses)	316 CW	71.1
	Baffle former plate	304	32.3
	Core barrel (various doses)	304/308	6.95
	Flow mixing device	CASS	
	Fuel alignment pins (surface treatment)	304	
	Upper and lower core support column, 290 & 325 °C	CASS	low dose
	Guide tube support pins, various ages and doses	316 (X-750)	various doses

- Scope includes:
  - Microscopy, retrospective dosimetry, H/He content
  - Tensile, IASCC CGR, and fracture toughness (FT) testing

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Materials research strategy focuses on supporting regulatory decision-making

- Preserving knowledge from Halden
- Performing high-priority research
- Developing new capabilities
- Long-term testing of highly representative materials

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Vision for the Future

Closure of the Halden Reactor has accelerated strategic planning to address our future fuel and materials research needs

The closure of the Halden Reactor isn't the only factor driving change in fuel and materials research

Economic trends are driving change

- Growing need to pursue more focused, innovative, and aggressive campaigns, i.e., Accelerated Fuel Qualification

The future will require more partnerships

- Domestically: NEUP, NSUF and IUP Grant Programs
- Internationally: FIDES, QUENCH-ATF, SMILE and SPARE

Diversifying, partnering, and enhancing the U.S. infrastructure are the tenets of NRC's post-Halden strategy

- Preserving the knowledge gained during the Halden program
- Utilizing array of ventures to address our short-term research needs
- Developing new experimental capabilities to address our long-term needs
- Significant investments in U.S. infrastructure made by DOE are critical to meeting future needs

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Potential Topics for Future Meetings

- Updates on the Future-Focused Research Initiative
- Updates on Integrated University Program grants for mission-related R&D
- Non-LWR research activities

Closing Remarks

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Oral Comments by Mr. John Stetkar on IDHEAS
Agenda Item 6 at the 682^{nd} ACRS Meeting

February 4, 2021

1. My name is John Stetkar. I am a former member of the ACRS, speaking today as a member of the public.

2. I would first like to comment briefly on the IDHEAS general methodology in NUREG-2198. I understand that the Committee has received a copy of my September 24, 2020 detailed written comments on the previous draft version of the report. The current version of the report has addressed the majority of those comments. I very much appreciate the staff's stamina and their extensive efforts to consider my comments and make those changes.

3. I have a few remaining high-level concerns about NUREG-2198. Considering the brief time available for these oral comments, I will highlight only a couple of my most important issues.

   - First, I remain concerned about the lack of technical justification for the quantification model that is represented by Equation 4.6 and Equation 4.7. In particular, I do not know why the primary influence on human performance is determined by three specific "base" performance-influencing factors, while the other 17 factors are cumulative modifiers. I also do not understand why the assumed linear summation of those performance-influencing factor weights is justified. I understand that the Committee has also received a copy of my November 2, 2020 detailed written comments on the IDHEAS-DATA report. I could not find compelling justification in that report for the format of the quantification model. Furthermore, Section 6.3 and Appendix D in the current version of NUREG-2198 have removed examples which were originally intended to support the conclusion that linear addition of the performance-influencing factor weights provides the best method to account for their composite effects. The current version of NUREG-2198 relies primarily on qualitative assertions that the model is justified from reviews of other studies, without quantitative examples that clearly support that justification.

   - Second, the examples in Appendix M of NUREG-2198 are very important for prospective analysts to understand how the methodology is applied in practice. I have two comments on those examples.

   - My first comment is related to documentation of the analysts' decisions that are made in each example. One of the most important objectives of the IDHEAS methodology is to reduce sources of analyst-to-analyst variability in the human reliability analyses. As noted on Slide 6 of Dr. Xing's presentation, a critical task to achieve that objective is clear documentation of the rationale and justification for numerous analyst decisions that are made throughout the analyses. The examples in Appendix M only partially document those decisions. For example, they simply list the specific cognitive failure modes (CFMs) and performance-influencing factors (PIFs) that the analysts selected for each evaluation. They do not document why other CFMs and PIFs were excluded as not relevant. It is very important to document the rationale for those exclusions, because it can often reveal key sources of disagreement between different analysts and the reasons for that disagreement. In practice, the documentation process by itself also often prompts each analyst to more carefully consider the basis for their own judgment and selections. The same comment applies to lack of a documented rationale for selection of a particular form of the uncertainty distributions for the time estimates and the assignments of specific parameters in those distributions (for example, the 5th and 95th percentiles). So, in summary, to provide instructive examples that demonstrate the expectations of how the IDHEAS methodology should be implemented, I think that the examples in Appendix M should better document the analysts' rationale for their decisions.

- My second comment on Appendix M is that the quantification example in Section M.2.6 was revised, but it is not yet correct. The combined uncertainty distribution in that example evaluates the time at which power is restored from the FLEX generator. That distribution shows that there is a small, but non-zero, probability that power is restored before the crew begins to use the extended loss of AC power (ELAP) guidance. In other words, there is some probability that power is restored before 1 hour in that scenario. That is not realistic, and the example should be corrected. Perhaps the staff will need to use other forms of the uncertainty distributions to provide realistic estimates that are consistent with the physical constraints of the scenario. This comment is not intended to be an obsessively detailed critique of probabilistic arithmetic. I think that it is conceptually important for the methodology, because the examples should clearly demonstrate to prospective analysts that the uncertainty quantification is not an abstract mathematical after-thought. The uncertainties should be an integral part of the analysis. They should account for a realistic engineering and operational assessment of personnel performance within the physical and functional constraints of the event scenario. If the uncertainty analysis results provide non-physical conclusions, then something is drastically wrong with those analyses.

4. Finally, if the Committee will indulge me, I would simply like to emphasize the fact that RIL-2020-13 is the product of several key methods and reports that deserve careful attention before conclusions are made about the example FLEX analyses. The relationships among the IDHEAS general methodology (NUREG-2198), the IDHEAS-DATA report, the IDHEAS-ECA application (RIL-2020-02), and finally the use of IDHEAS-ECA to evaluate FLEX actions are shown on Slides 7 and 8 of Dr. Xing's presentation. Those relationships are complex and somewhat convoluted. Thus, until the Committee has an opportunity to carefully examine the IDHEAS-DATA and IDHEAS-ECA reports, specific conclusions or recommendations about RIL-2020-13 may be premature.

The Integrated Human Event Analysis System (IDHEAS) Program Introduction

Sean E. Peters

Advisory Committee on Reactor Safeguards

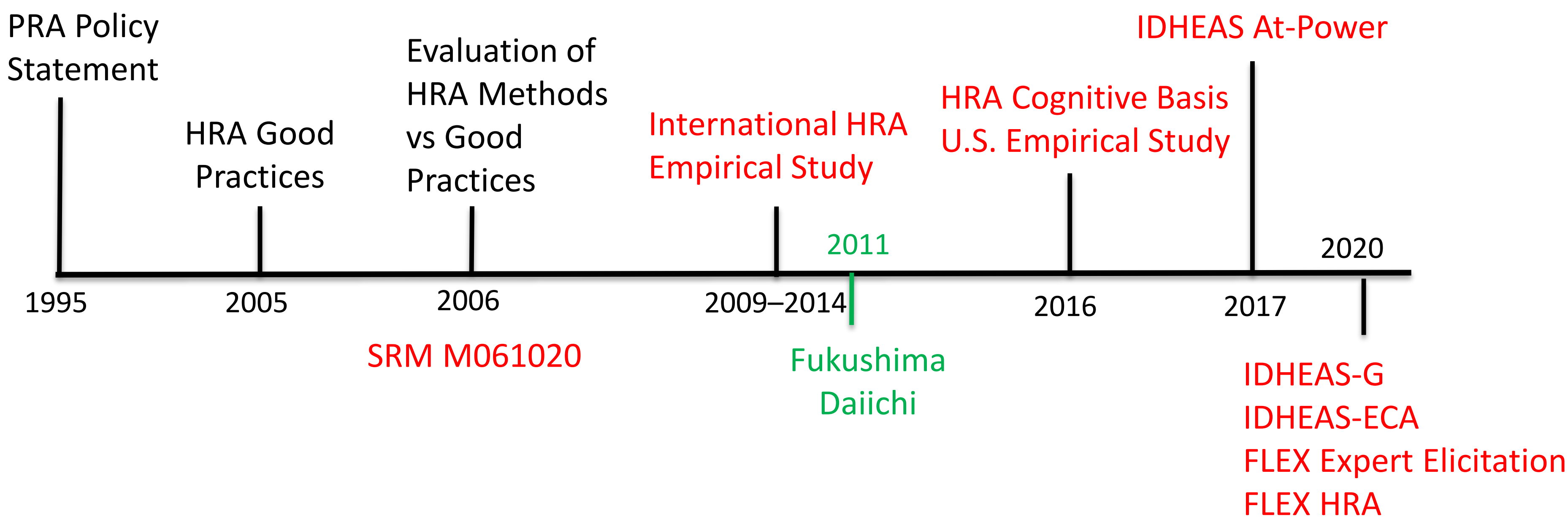
February 4, 2021

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)
- 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-2156 - The U.S. HRA Empirical Study (ML16179A124)

Timeline References (Cont.)

- NUREG-2114 - Cognitive Basis for [HRA] (ML16014A045)
- NUREG-2199, Vol. 1 - [IDHEAS] for [NPP] Internal Events At-Power Application (ML17073A041)
- NUREG-2198 – IDHEAS – General Methodology (ML20329A428)
- RIL 2020–02, Integrated Human Event Analysis System for Event and Condition Assessment (IDHEAS-ECA) (ML20016A481)
- RIL 2020-13 – Vols. 1 and 2 – Applying HRA to FLEX Operations - Expert elicitation and Using IDHEAS-ECA – (ML21033A529, ML20345A318, ML21032A119)

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 Event – March 2011

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 Reactor Project

IDHEAS Reviews

- IDHEAS–G
  - Multiple ACRS Subcommittee reviews
  - 3 external peer reviews, 2 internal peer reviews
  - Used on: Fukushima, US Benchmarking Events, Fuel Cycle Facility Events
- IDHEAS-ECA
  - Used 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)
  - Plans for regular updates

IDHEAS - An Integrated Human Event Analysis System

Jing Xing, Y. James Chang, Jonathan DeJesus Segarra,
U.S. Nuclear Regulatory Commission

Presented by Jing Xing to ACRS Full Committee
Feb-04-2021

Outline

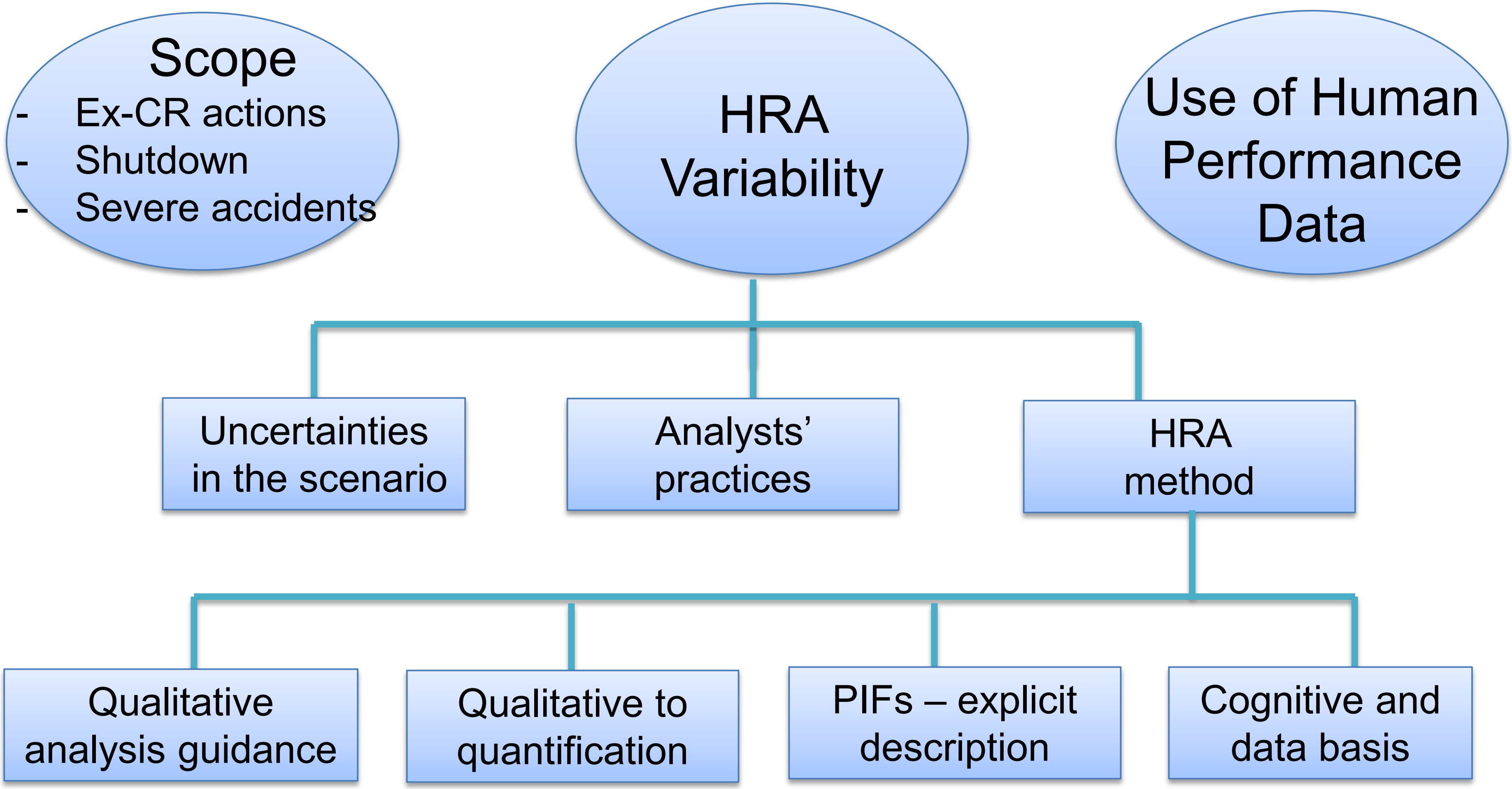
I. Overview of IDHEAS

II. Introduction to IDHEAS-G, IDHEAS-ECA, and IDHEAS-DATA

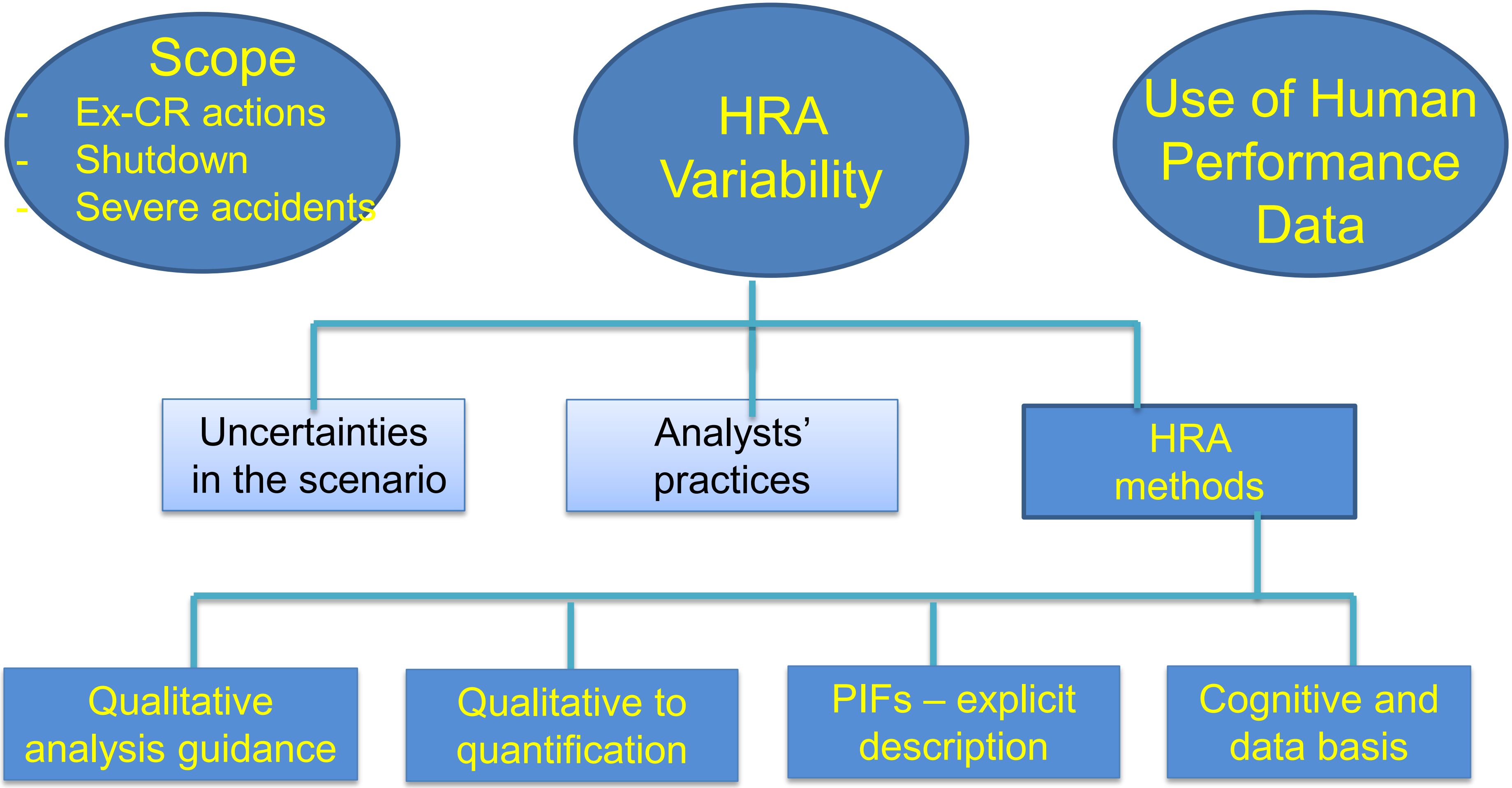
III. Examples of IDHEAS applications

IV. Revision to IDHEAS reports after 9-23-2020 ACRS Subcommittee meeting

Where we were …



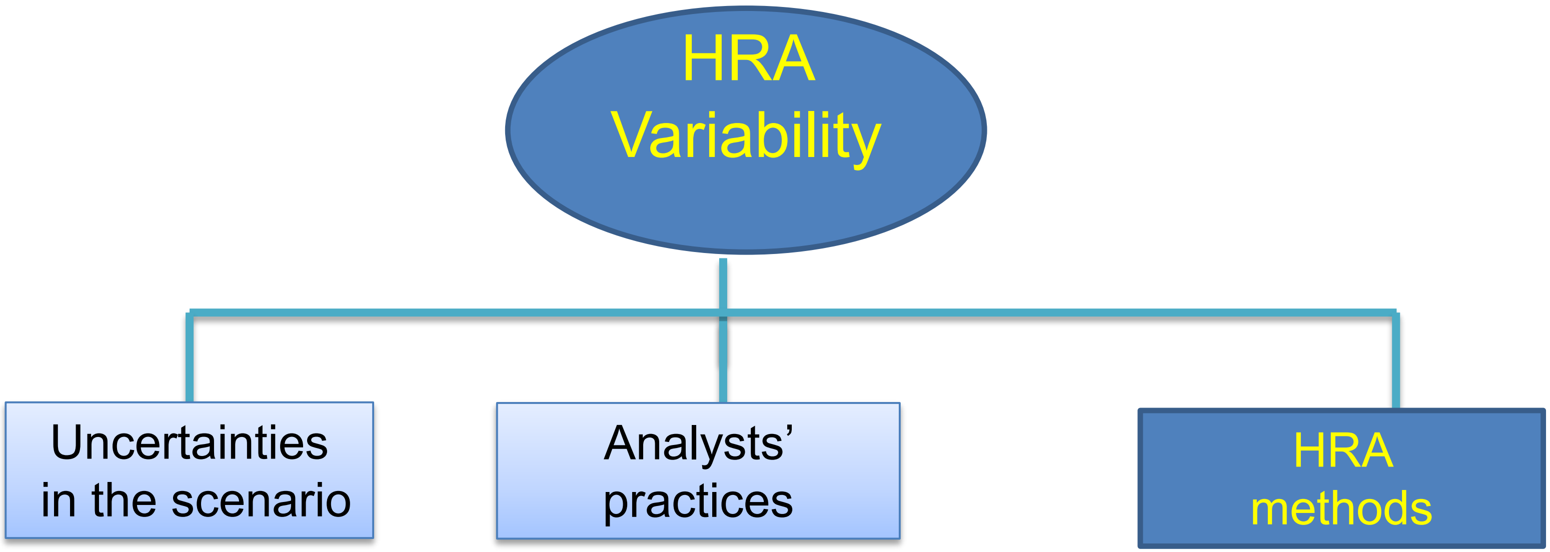
Where we are now



What we have achieved

- Expanded scope – IDHEAS is an HRA method suite for all nuclear HRA applications
- Use of human performance data – Human error data were explicitly used in IDHEAS
  - The method and data structure are based on the same cognitive basis model such that data can be generalized and used by the method.
- HRA variability – IDHEAS improves HRA method variability by enhancing the four areas (identified in HRA benchmarking studies)
  - Systematic qualitative analysis guidance
  - Links between qualitative analysis outcomes and quantification of human error probabilities (HEPs)
  - Explicit attributes for every performance influencing factor (PIF)
  - Cognitive and data basis that links PIF attributes to cognitive failure modes (CFMs)

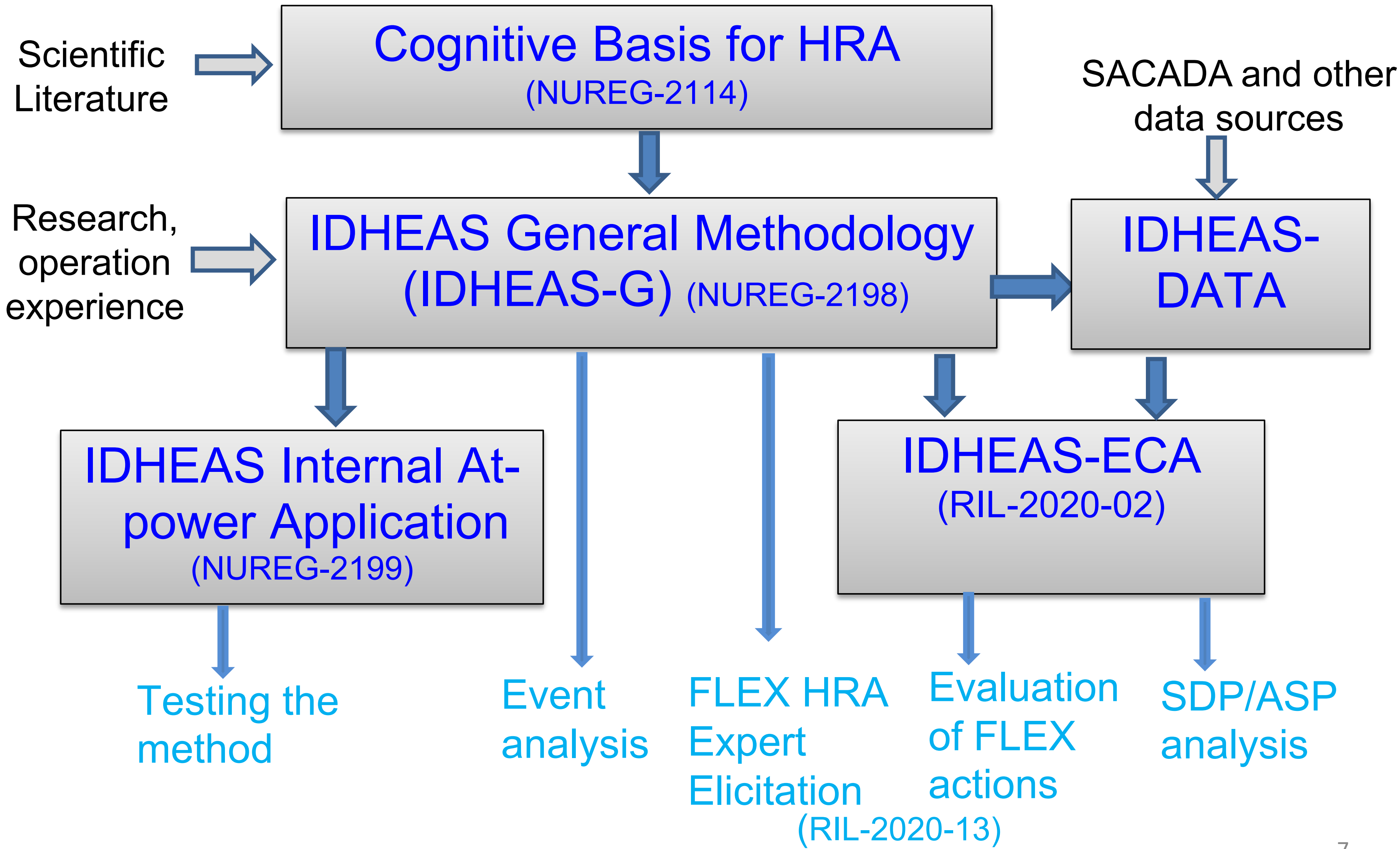
Other sources of HRA variability



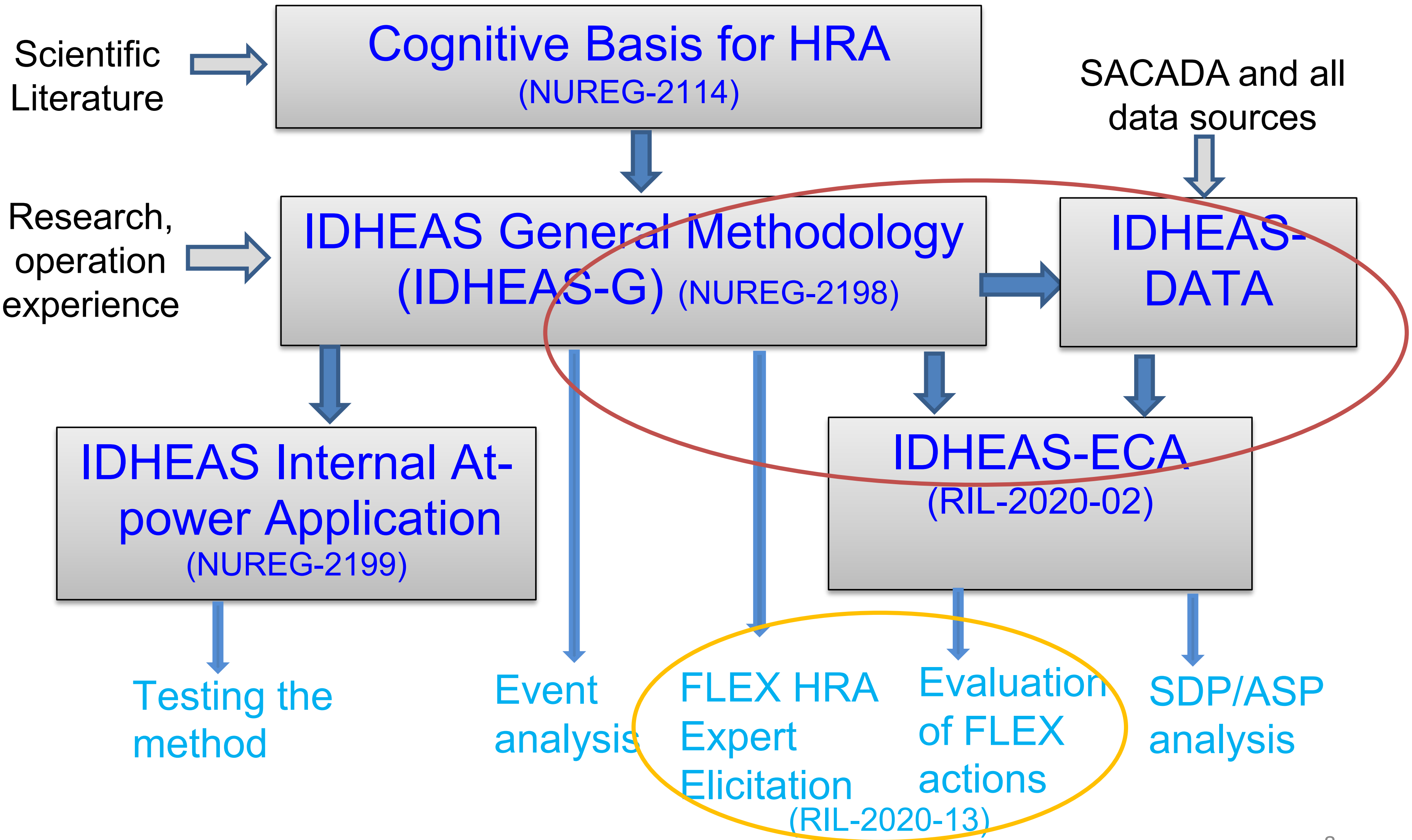
- Uncertainties in the scenario resulting in different analysis assumptions
  - IDHEAS provides guidance on identifying uncertainties in the scenario and tracing the assumptions in the HRA.

- Analysts' practices resulting in different interpretations of the scenario
  - The documentation of IDHEAS structured process provides transparency of analysts' interpretations.

Development of IDHEAS
- An Integrated Human Event Analysis System



Development of IDHEAS
- An Integrated Human Event Analysis System



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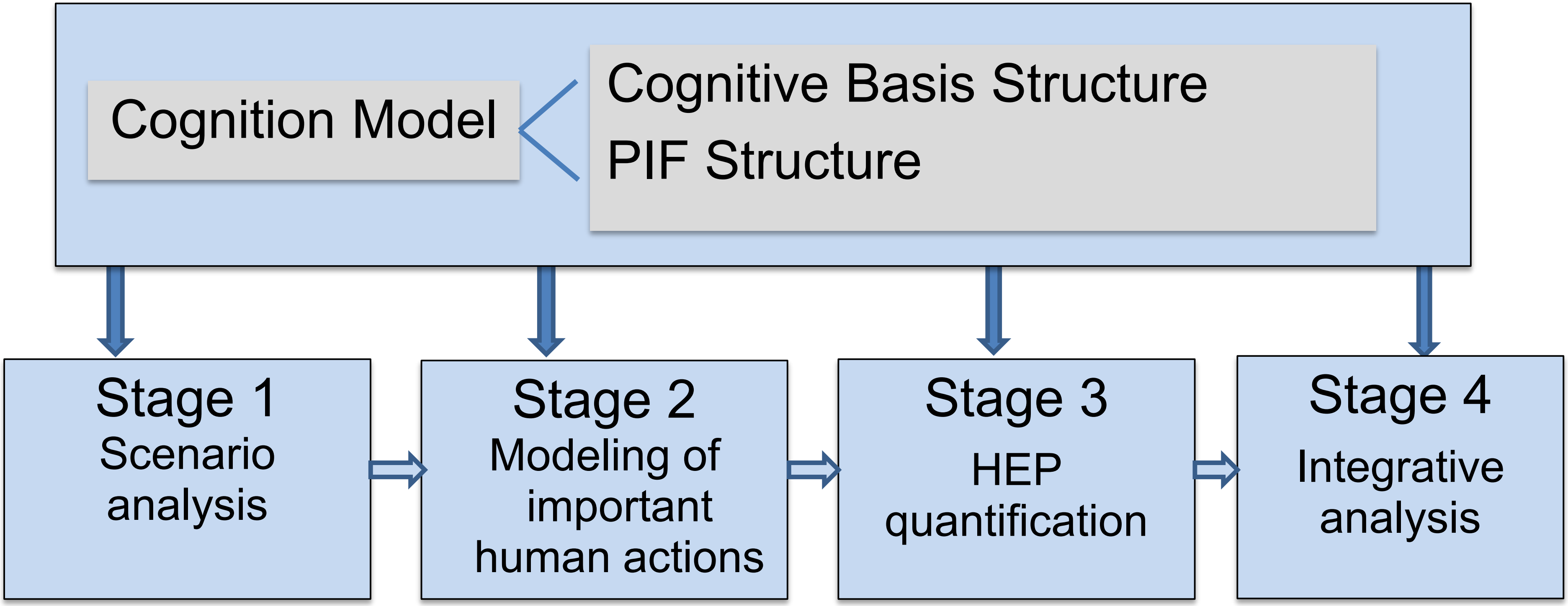
What is IDHEAS-G

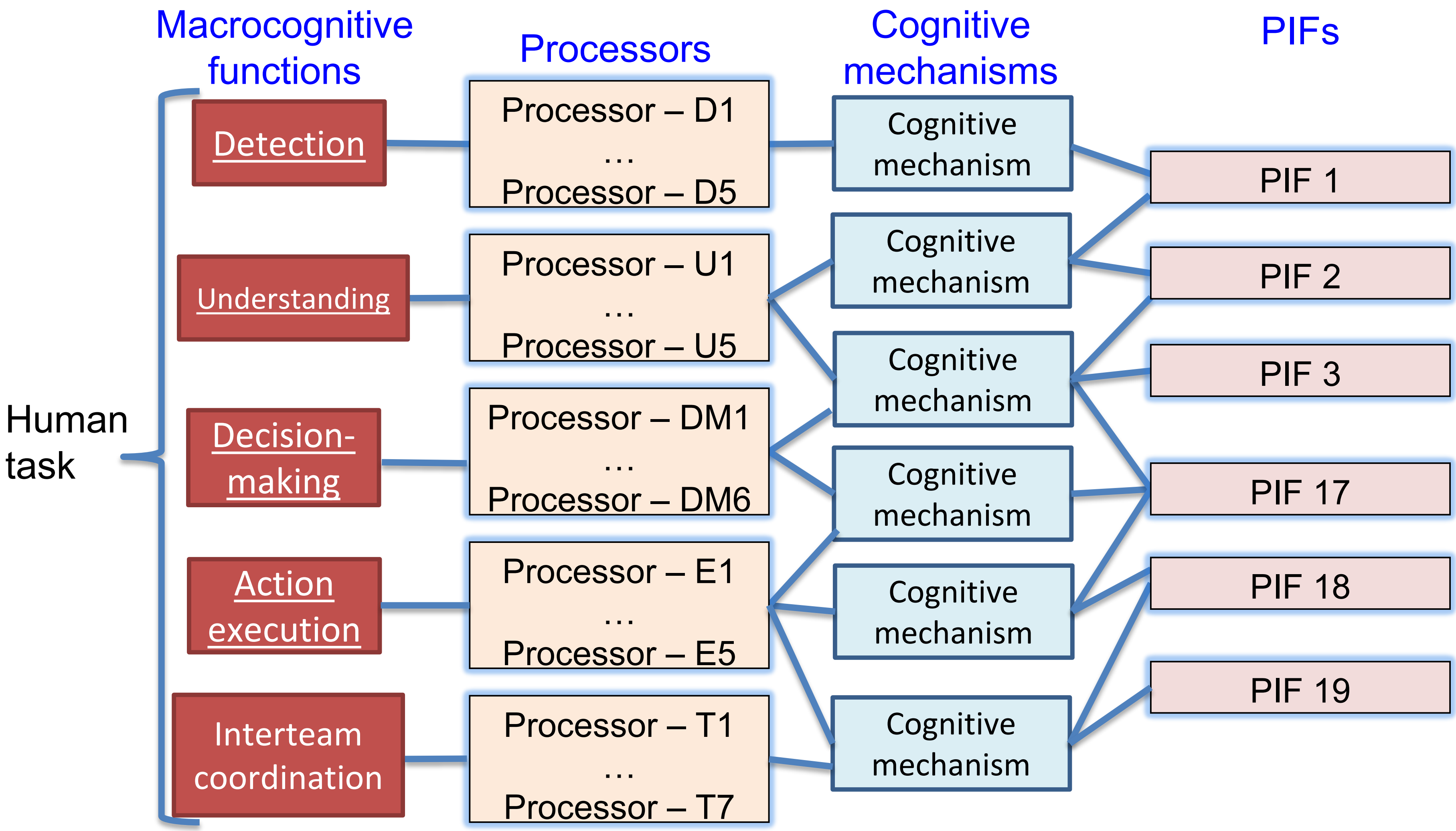
- A methodology for developing application-specific HRA methods
- A platform for generalizing and integrating human error data to support HEP estimation
- A general HRA method for human event analysis and human error root causal analysis

Overview of IDHEAS-G

IDHEAS-G consists of a cognition model as the framework for HRA, its implementation in an HRA process, and detailed guidance for HRA applications.



Cognitive Basis Structure



PIF Structure

Context	Environment and Situation	System	Personnel and organization	Task
PIF	•Accessibility/habitability of workplace and travel paths •Workplace visibility •Workplace Noise Cold/heat/humidity •Resistance to physical movement	•System and I&C transparency to personnel •Human system interface •Equipment and tools	•Staffing •Procedures, guidance, and instructions •Training •Team and organizational factors •Work processes	•Information availability and reliability •Scenario familiarity •Multitasking, interruptions, and distractions •Task complexity •Mental fatigue •Time pressure and stress •Physical demands
PIF attributes	•Poor lighting in workplace •Glare or reflection on physical structure •Smoke or fog-induced low visibility	•Tools are difficult to use •Tools are unfamiliar to personnel •Tools do not work •Tools or parts are unavailable	•Procedure is inadequate •Procedure is difficult to use •Procedure is available, but does not fit the situation	•Sustained high-demand cognitive activities •Long working hours •Sleep deprivation

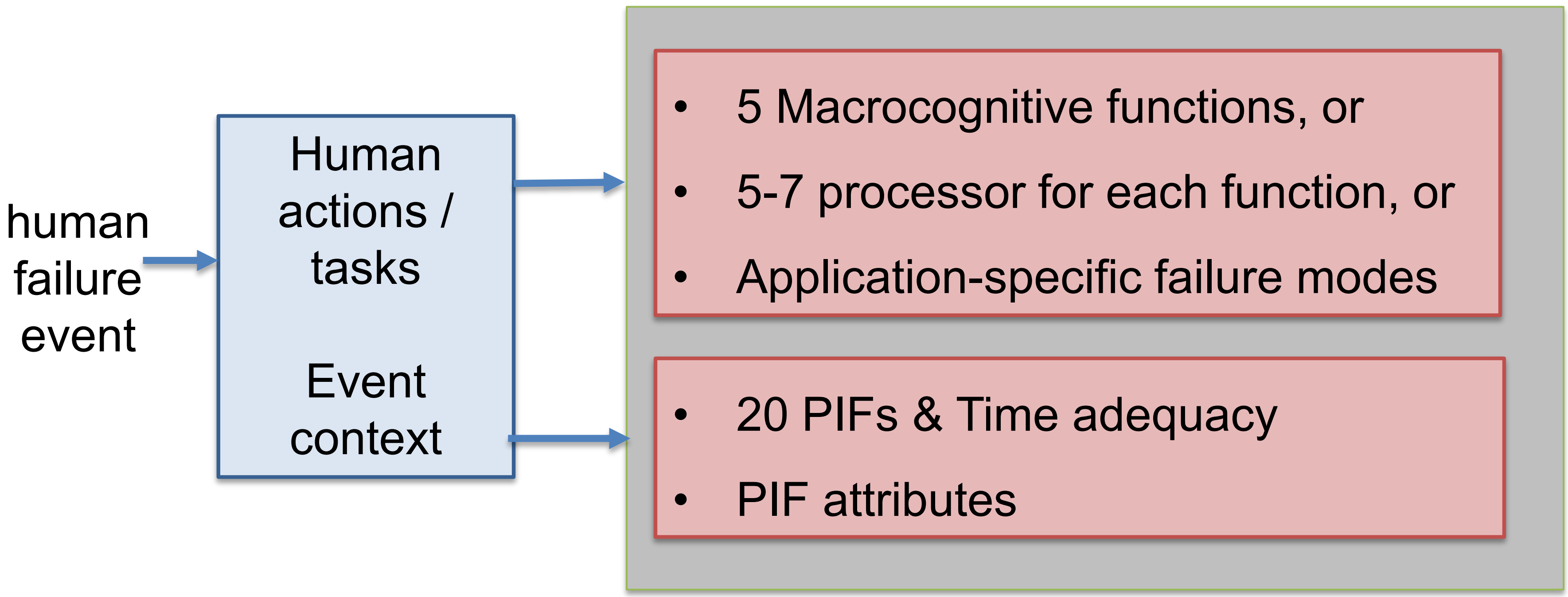
Note: The PIF attributes shown are examples and correspond to the PIFs highlighted in red.

Example PIF - Human-System Interface

- Definition: HSI refers to indications (e.g., displays, indicators, alarms) and controls for detecting information and executing actions on systems.

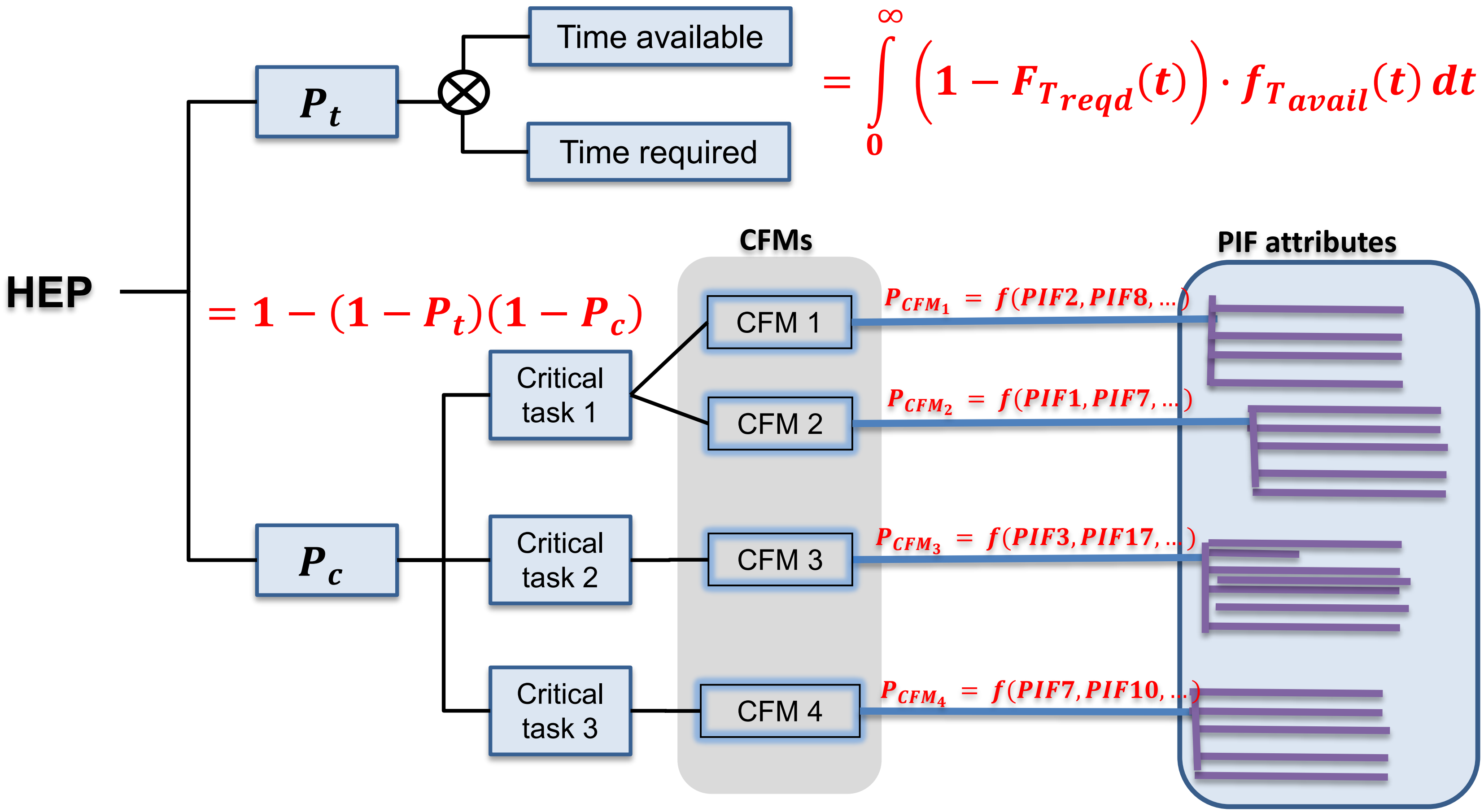
- Attributes:.
  - The source of indication (e.g., indicators, labels) is similar to other sources nearby.
  - The indications have low salience.
  - Indications are confusing or nonintuitive.
  - Controls are difficult to maneuver.
  - Labels on the controls do not agree with document nomenclature.
  - Controls are not reliable, and personnel are unaware of the problem.

How IDHEAS-G models human failure events (Stage-1 and Stage-2)



- Five macrocognitive functions model failure of human actions
- 20 PIFs model the context that affects human performance of an action

IDHEAS-G Stage 3
HEP Quantification—Overview



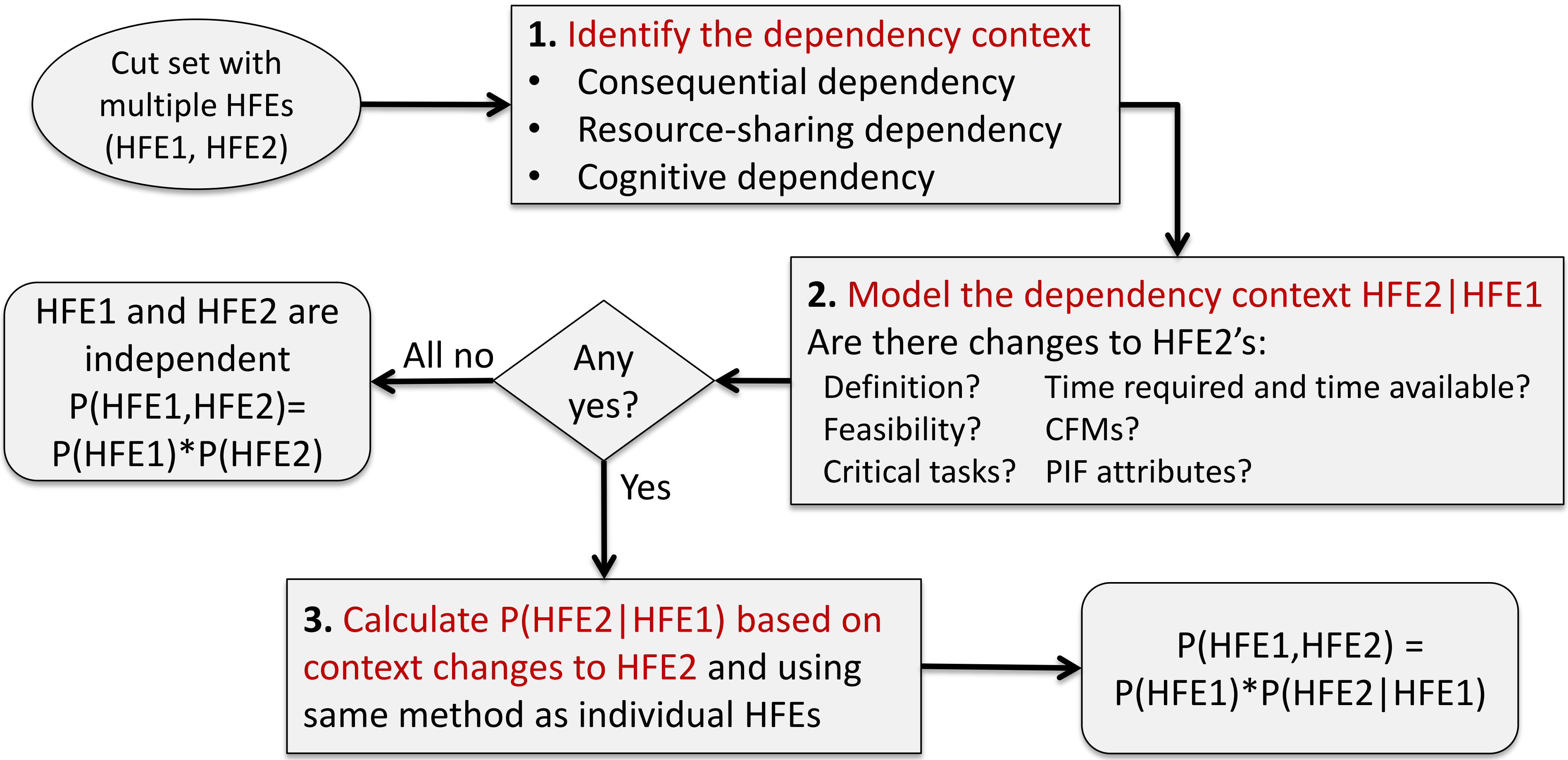
HEP Quantification—P_c

- Probability of CFM, P_{CFM}, can be estimated in one or a combination of the following three ways:
  - Calculation from the number of errors divided by number of occurrences
  - Expert judgment
  - HEP quantification model

- IDHEAS-G provides a data structure of generalizing human error data to support the three ways.

IDHEAS-G Stage 4 – Integrative analysis

IDHEAS Dependency Model



"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.

Summary of IDHEAS-G

- A methodology for developing application-specific HRA methods
- A platform to generalize and integrate human error data from various sources for HEP estimation
- A method to systematically analyze human events, including identification of human failures and root causes
- Applicable to all nuclear applications

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IDHEAS-G as a methodology for developing application-specific HRA methods

- IDHEAS-G has comprehensive sets of CFMs and PIFs, using all of those for HRA is time-consuming
- HEP quantification may be adapted for specific HRA applications

IDHEAS-G vs. application-specific method

IDHEAS-G	Application-specific method
Applicable to all nuclear applications	Specific for the application
Comprehensive but low usability	Concise and easy to use
Referencing the Human Error Data Tables	Calculating HEPs of human actions

From IDHEAS-G to IDHEAS-ECA

Developing application-specific IDHEAS method:

- Define the scope of application, requirements, and available sources for the intended use
- Keep the qualitative analysis the same as that in IDHEAS-G
- Develop application-specific sets of CFMs and PIFs
- Provide HEP estimate using one or the combination of the HEP quantification approaches and generalized human error data

Define IDHEAS-ECA by NRR users:

- Scope: Perform Event and Conditions Assessment (ECA) for all NRC's risk-informed applications; specifically, be applicable for FLEX HRA
- Requirements: Easy to use, not over-burden HRA analysts
- Resources: Human error data, NRC 2018 FLEX-HRA Expert Elicitation

IDHEAS-ECA

DELTA between IDHEAS-G and IDHEAS-ECA – modeling failures and calculating HEPs

IDHEAS-G	IDHEAS-ECA
Qualitative analysis guidance	Same as that of IDHEAS-G
A basic set of CFMs in three levels of details	Five high-level CFMs
20 PIFs and their attributes	• All 20 PIFs preserved • A compressed set of PIF (combining attributes)
Three approaches to HEP estimate	• HEP quantification model; • The base HEPs and PIF weights integrated from IDHEAS-DATA; • Allowing HEP calculation for given failure modes and PIF attributes

HEP Quantification in IDHEAS-ECA—P_c

- HEP quantification model

$$P_{CFM} = \underbrace{P_{CFM\,Base}}_{\text{Base HEPs}} \cdot \left(1 + \underbrace{\sum_{i=1}^{n} (w_i - 1)}_{\text{PIF weight factors from Modification PIFs}}\right) \cdot C \cdot \frac{1}{Re}$$

Base HEPs

PIF weight factors from Modification PIFs

Recovery factor; set to 1 unless data suggest otherwise

PIF interaction factor; set to 1 with linear combination

$$w_i = \frac{ER_{PIF}}{ER_{PIF\,Base}}$$

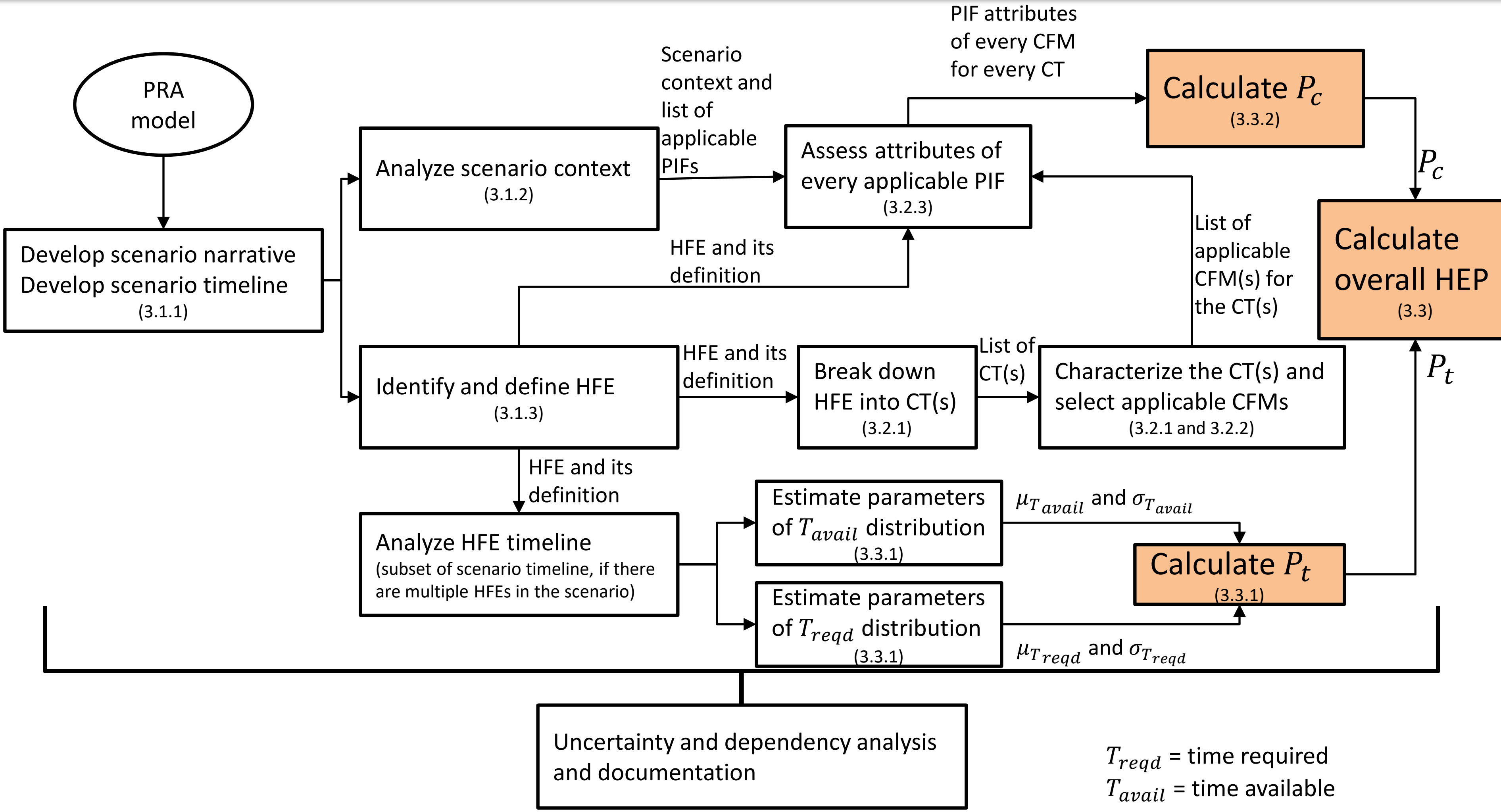
ER_{PIF} ≡ error rate at a given PIF attribute

$ER_{PIF\,Base}$ ≡ error rate when the PIF attribute has no or low impact

IDHEAS-ECA needs:

- Lowest HEPs for the 5 CFMs
- Base HEPs of every CFM for every associated attribute of the 3 base PIFs
- PIF weights of every CFM for every associated attribute of the 17 modification PIFs

IDHEAS-ECA Process—same as IDHEAS-G



T_{reqd} = time required
T_{avail} = time available

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 variability in T_{avail} and T_{reqd}

$\mu_{T\,avail}$ 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}

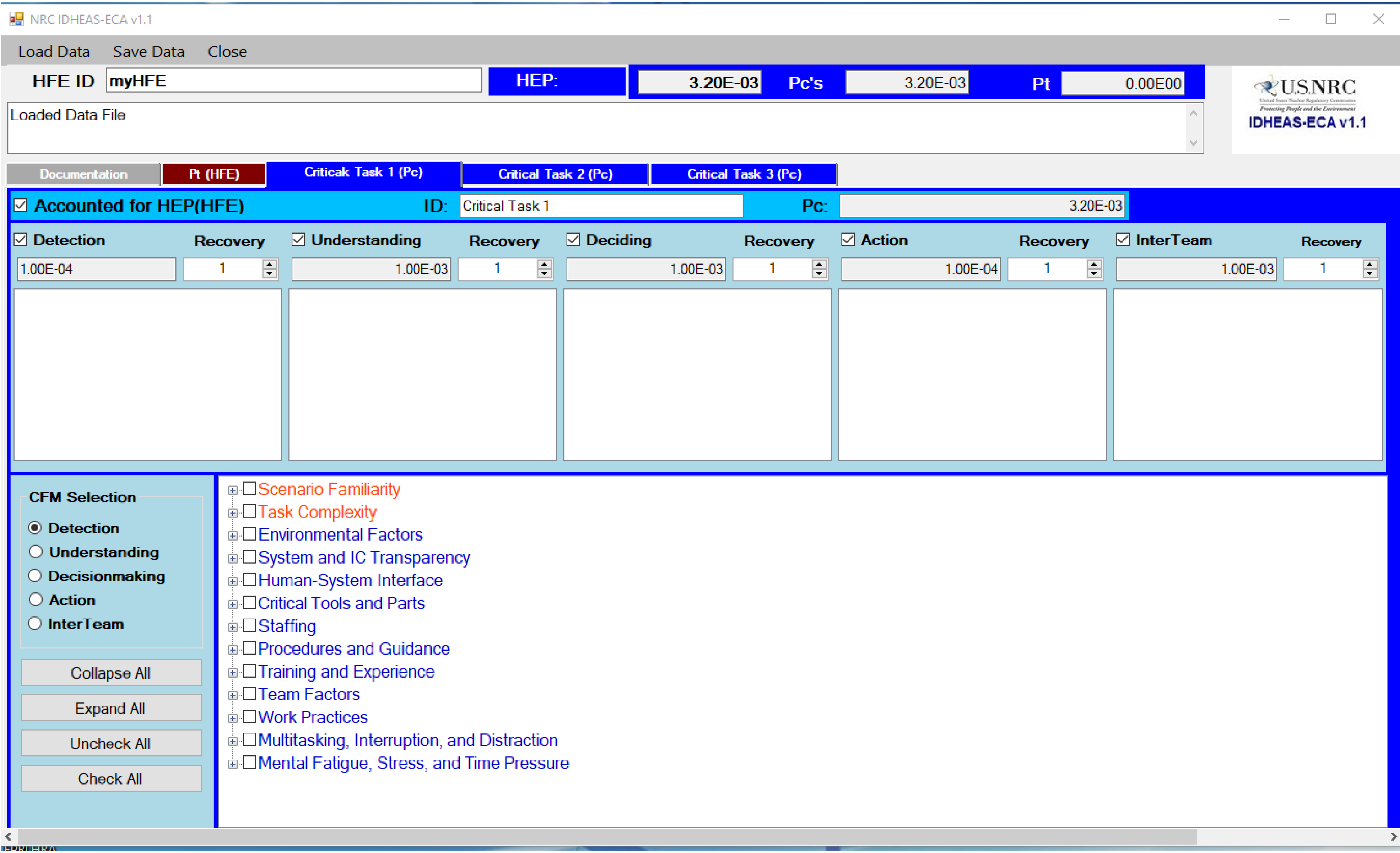
IDHEAS-ECA Products

- IDHEAS-ECA report – including guidance, worksheets, base HEPs and PIF weights, and three HRA examples

- IDHEAS-ECA training materials

- IDHEAS-ECA Software – A computer interface implementing IDHEAS-ECA for HEP calculation
  - Recommended use:
    - Analyze the event and document the results in IDHEAS-ECA worksheets
    - Enter the information from the Worksheets to calculate the HEP

IDHEAS-ECA Software



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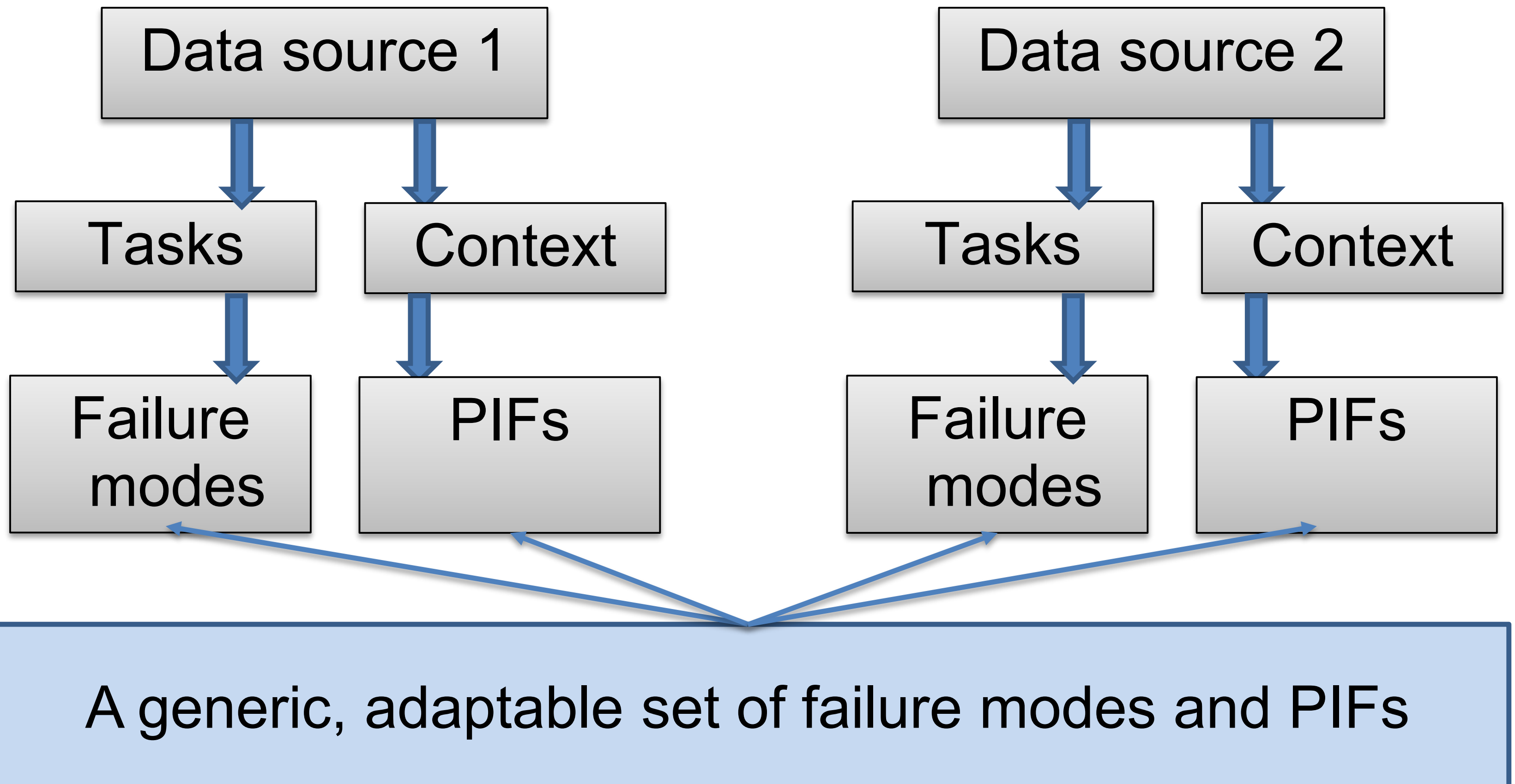
Generalizing human error data to inform HEPs

HEP = *f*(states of performance influencing factors)

- Human error data exist from various domains, in different formats, varying context and levels of detail.



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

Human tasks **->** Cognitive failure modes (CFMs)

Context **->** Performance influencing factors (PIFs)

3. Integration - Integrate the generalized data for HEP calculation

Error rates – *Base HEPs*

Change of error rates - *PIF weights (w_i)*

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, manufacturing)

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. Unspecified 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 rates 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

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-1 Scenario Familiarity IDTABLE-2 Information IDTABLE-3 Task Complexity IDTABLE 4--20 PIF Weights IDTABLE 4-8 Environment PIFs IDTABLE 9-11 System PIFs IDTABLE 11-16 Personnel PIFs IDTABLE 17-20 Task PIFs	IDTABLE-21 Lowest HEPs of CFMs IDTABLE-22 PIF Interaction IDTABLE-23 Distribution of Task Needed IDTABLE-24 Modification to Time Needed IDTABLE-25 Dependency of Human Actions IDTABLE-26 Recovery of Human Actions IDTABLE-27 Main drivers to human events

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Summary of IDHEAS-DATA

By 2020:

- Use of nuclear operation/simulation data (SACADA, HuREX, Halden studies)
- ~300+ literature generalized; another 200+ evaluated and selected for generalization
- The generalized data were independently verified and reviewed.

In the future:

- Human error data needed in teamwork and organizational factors
- Data generalization is an on-going, continuous effort; Data integration should be periodically updated.

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III. IDHEAS applications

- 2018 FLEX HRA Expert Elicitation
- 2019 FLEX HRA Evaluation using IDHEAS-ECA
- Several SDP analysis
- Industry's comparison
- IDHEAS Dependency Group applying IDHEAS-ECA to SDP/ASP events and PRA models

IV. Revision to IDHEAS reports after 9-23-2020 ACRS Subcommittee meeting

Objectives of 2018 FLEX-HRA Expert Elicitation

1. Quantify the HEPs of representative FLEX action
   - for using FLEX equipment during FLEX-designed scenarios and for added defense-in-depth during non-FLEX-designed applications

2. Evaluate the unique performance influencing factors (PIFs) associated with the use of FLEX equipment

3. Quantify the contribution of these PIFs on the HEPs

FLEX-HRA Expert Elicitation Process

- Sponsor: NRC
- Process: Implement the principles and 10-step process in the NRC's White Paper Expert Elicitation Guidance
  - Extensive datasets disseminated on HEPs of surrogate human actions and effects of performance influencing factors
  - Five tele-meetings, one face-to-face workshop
- Expert panel: Three NRC staff and three industry experts who are knowledgeable in PRA/HRA, implementation / audits of FLEX strategies, and maintenance practices at nuclear power plants.

Estimate the HEPs of representative FLEX actions

Estimate HEPs of representative FLEX actions in two scenarios:

i) a non-FLEX-designed scenario (one EDG is down followed by SBO in a design-basis accident), and

ii) a FLEX-designed scenario (SBO caused by a severe external event - strong wind and flooding)

Action 1: Use of portable generators

Action 2: Use of portable pumps

Action 3: Refilling water storage tanks using alternate water sources

Action 4: ELAP declaration

Action 5: Deep DC load shed

Scenario definition and context

Scenario context is characterized with IDHEAS-G performance influencing factors.

Environment and situation	System	Personnel and organization	Tasks
- Accessibility - Visibility - Cold, heat, and humidity	- Information - Tools and parts - Human-system-interfaces (indications & controls)	- Training - Procedure - Teamwork factors	- Scenario familiarity - Multitasking - Task complexity - Mental fatigue and stress - Physical demands

Characterization of scenario context

Example: environment context

Non-FLEX-designed scenario	FLEX-designed scenario
No impact - no weather • Normal day • Water - May be loss of upstream dam bringing debris into contact with plant • Cold	Moderate impact • Visibility - Poor lighting (e.g., darkness, fog, smoke, dust) • Water level – water in some work places or travel paths in water (1-3 feet) • Wind - Strong winds that would focus debris to the intake structure. • Difficult to access some sites or travel paths • Very cold

Result - HEPs for *Declaration of ELAP*

- Non-FLEX-designed scenario - Non-hazard SBO leads to ELAP declaration
- FLEX-designed scenario - Strong wind and flooding result in SBO
- The action is *declaring ELAP by 60mins if power is not back within 4 hours*.

Non-FLEX-designed scenario				FLEX-designed scenario		
1th	50th	99th		1th	50th	99th
0.03	**0.31**	0.57		0.02	**0.19**	0.48

Justifications:

- Information incomplete and uncertain – "I don't have info yet," "I need more info to make decision."
- More preferred alternative exists – Restoring the power instead of going to ELAP
- FLEX-designed scenario has fewer uncertainties, thus easier for the decision

HEP variability due to uncertainties in the scenarios

Example: The action *Load Shed* (open 18 breakers in two locations) in the non-FLEX-designed scenario

Uncertainties in the scenarios:

- Layout and labels of the breakers
- Who does the work
- Travel path to the breakers
- Effect of stress

Experts' judgments of *Load Shed*:

Expert	1th	50th	99th	Justifications
A	0.06	**0.2**	0.4	High stress, variation in ergonomics, unfamiliar
B	0.01	0.1	0.3	
C	0 .01	0.05	0.1	Similar to the actions operators perform routinely, stress should have no impact
D	0.015	0.04	0.1	
E	0.001	**0.01**	0.1	A simple action modeled in SPAR-H, poor lighting, some stress impact

Insights from 2018 FLEX HRA expert elicitation

- The expert judgments captured the technical community's state-of-knowledge about uncertainties, challenges, and opportunities in FLEX human actions.
- The estimated HEPs are valid only for the assumptions and specifications made for the scenarios and actions in this study.
- IDHEAS-G PIF structure was capable of modeling the context of using FLEX equipment in FLEX-designed and non-FLEX-designed scenarios.
- The human error data in the information package were helpful for HEP estimation and should be used in the IDHEAS method.

2019 FLEX HRA Evaluation using IDHEAS-ECA

- Evaluate several representative FLEX actions using IDHEAS-ECA
- Provide feedback for improving IDHEAS-ECA
- Led by NRC (RES and NRR) and the industry (EPRI). EPRI's involvement facilitated participation of industry as FLEX and operations experts, HRA experts, and hosts for two plant site visits.
- The plant visits were the predominant sources of detailed HRA-relevant FLEX information for the HRA analysts to reference.
- Information from a small group of PWR Owners Group and BWR Owners Group representatives, and FLEX experts (both NRC and industry) supplemented the plant-specific information to provide a more generic operational understanding of FLEX strategies and equipment analyzed in the scenarios.

Overview

- Teams of FLEX and human reliability analysis (HRA) experts modeled a sample of FLEX human actions.
- Both teams had plant site visits to better understand FLEX strategies, associated equipment and operator actions;
- The FLEX experts created a set of realistic scenarios and human failure event (HFE) descriptions using FLEX equipment.
- The HRA experts further modified the scenarios then quantified the HFEs using the IDHEAS-ECA quantification tool.
- The HRA experts participated in a 3-day workshop to perform and/or finalize their HRA quantification using IDHEAS-ECA.

Scenarios and HFEs Evaluated

Three scenarios, four FLEX human actions

1. Beyond design basis (BDB) seismic event at a BWR that results in a Station Blackout (SBO)
   - Operators fail to declare extended loss of alternating current (AC) power (ELAP) with variations
   - Operators fail to perform FLEX direct current (DC) load shed
   - Operators fail to deploy FLEX diesel generator
   - Operators fail to perform containment venting

2. Loss of all feedwater with deployment of FLEX pump

3. SBO with pre-staged FLEX plus diesel generator

IDHEAS-ECA HEP Results

Scenario Description: A BDB seismic event occurs that causes an SBO. It is obvious that power cannot be restored quickly.

HFE	Critical Task	HEP Estimate
Fail to Declare ELAP	Case 1: Definitive Wording	1.1E-3 to 2.7E-3
	Case 2: Wording Requires Judgment	1.1E-3 to 3E-2
	Case 3: Wording Requires Judgement and Diagnosis is not Obvious	1.6E-2 to 1E-1
Fail to Perform FLEX DC Load Shed		2E-3 to 6E-3
Fail to Deploy FLEX Diesel Generator	Transport Diesel Generator	1E-3 to 3E-3
	Connect and Start Diesel Generator	1E-3 to 1.2E-2

Case 1: IF AC power cannot be restored within 1 hour, declare ELAP within 1 hour of losing all AC power.
Case 2: IF AC power cannot be restored within 4 hours, declare ELAP within 1 hour of losing all AC power.
Case 3: Same as Case 2 except that it is less obvious that power cannot be restored.

HRA variability – Declare ELAP Case 2

Ana-lyst	CFM	PIF attributes	Justification	HEP
A	DM	**Information Completeness and Reliability -** Information is unreliable or uncertain (**INF2; Level 2)		3E-2
B	DM	**Info Completeness and Reliability -** Information is unreliable or uncertain (**INF2; Level 2)	INF2 level would vary depending on details of what the procedure guidance would say. Level would range from 3 to 5 given the example presented to the team.	3E-2
C	DM	No Impact; No PIF selection	(Operators understand that during evaluation of loss of all AC power, the 1-hour time frame is set in stone and cannot be deviated from due to the importance of getting a FLEX generator deployed and started.)	1E-3
D	D	No impact:	(A decision must be made. The cue is based on the expectation that AC power to any 4.16 kV bus cannot be restored)	1.1E-3
	DM	No impact:		
E	U	No impact:		2E-3
	DM	No impact:		

Insights from 2019 FLEX HRA evaluation using IDHEAS-ECA

- HRA variability –
  - Analyst-to-analyst variability is within an order of magnitude for most human actions
  - Analyst-to-analyst variability remains a concern when using IDHEAS-ECA – due to uncertainties in the scenarios and variation in HRA practices
  - Method traceability supports understanding and reconciling variability
- HRA informs plant risk understanding and mitigation strategies -
  - Procedural cues for using FLEX equipment in non-FLEX scenarios are important for crediting FLEX in PRAs.
  - The integration of FLEX into plant accident response has improved substantially since FLEX was initially implemented.

Preliminary user feedback on IDHEAS-ECA

- from applying IDHEAS-ECA to SDP, ASP, and basic PRA models.

- In general, results from IDHEAS-ECA are aligned with HRA analysts' perceptions
- IDHEAS-ECA explicitly addresses the effects of subtle factors in SDP analyses, such as group-thinking and crediting the supplemental cues that occurred later in scenarios.
- It can be difficult assessing applicable PIF attributes with limited information in basic PRA models.

Final summary
- What IDHEAS has achieved

- Built on cognitive science.
- Generalized and integrated human error data for HEP estimation.
- Reduced HRA variability.
- Improved HRA trackability tracing uncertainties in the scenario; improved HRA transparency discovering analysts' interpretations.
- Produced systematic understanding about human failure events: what can go wrong, what are the causes, and how to militate the causes.
- Increased the applicability of HRA to all nuclear risk-informed applications.

Outline

I. Overview of IDHEAS suite

II. Introduction to IDHEAS-G, IDHEAS-ECA, and IDHEAS-DATA

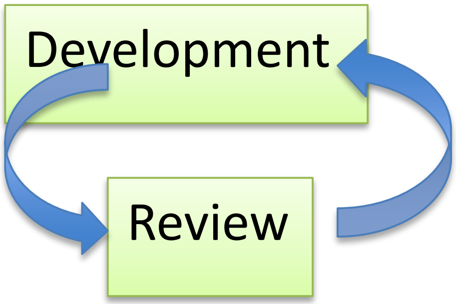
III. Examples of IDHEAS applications

IV. Revision to IDHEAS reports after 9-23-2020 ACRS Subcommittee meeting

IDHEAS-G review and development

IDHEAS-G was developed with inputs from reviewers:

- 10+ ACRS reviews, 3 external reviews, 2 internal reviews
- 7 tear-downs/rewrites of the IDHEAS-G report
- Each rewrite included new developments initiated from review inputs



Examples of review-inspired IDHEAS-G development:

- ACRS recommendation on modeling timing effect → Time uncertainty model as a part of HEP quantification
- Dr. E. Roth comments on teamwork → the fifth macrocognitve function *Interteam Coordination*
- Drs. N Siu and K. Coyne's comments on having a cohesive methodology → the 8-step IDHEAS-G process as a stand-alone method for human event analysis

2020 IDHEAS-G report revision

Comments from

- 9/18/2019 ACRS Subcommittee meeting
- External peer review comments
- NRC management review and project team review

Summary of the revision:

1) All the comments were addressed except for ones that were outside the scope of IDHEAS-G report
2) Additional revisions were made to address some comments on draft reports of IDHEAS-ECA, IDHEAS-DATA, and FLEX HRA evaluation.
3) Major updates to Chapter 6 on data generalization were made to be consistent with IDHEAS-DATA report.
4) The PIF Interaction section in Ch.6 and Appendix D were rewritten using the new materials in the IDHEAS-DATA report.

2020 FLEX HRA report revision

Revision of Volume 1: FLEX HRA Expert Elicitation

1) Most comments were addressed except the ones that were outside the project scope (e.g., assumptions made about the scenarios and context)
2) Several comments were about a major caveat in the expert elicitation process: The experts were uncomfortable estimating the HEP distributions, thus they only estimated the most likely, lower bound, and upper bound of the HEPs. The revision discussed this caveat.

Revision of Volume 2: FLEX HRA evaluation using IDHEAS-ECA

1) All comments provided to the project team that were within project scope and related to the results and conclusions were addressed.
2) A table was used internally to track comments and their resolution. Some comments overlapped or conflicted which is documented in the table.
3) The NRC's resolution of the comments were documented

Revision of IDHEAS-ECA report and IDHEAS-DATA report in 2021

Revision plan to IDHEAS-ECA report

1) Address comments from 2019, 2020, 2021 ACRS meetings as well as internal and external reviewers;
2) Clarify some PIF attribute definitions based on lessons learned from using IDHEAS-ECA in FLEX evaluation, SDP/ASP practices, and Dependency Workgroup;
3) Add a new chapter on guidance of using IDHEAS dependency model.

Revision plan to IDHEAS-DATA report:

1) Address comments from 2019, 2020, 2021 ACRS meetings as well as internal and external reviewers;
2) Incorporate corrections and recommendations from PNNL's independent verification and review of 2020 draft IDHEAS-DATA report.

The Integrated Human Event Analysis System (IDHEAS) Program Path Forward

Sean E. Peters

Advisory Committee on Reactor Safeguards

February 4, 2021

IDHEAS Future Work

- IDHEAS-G - Publication
- IDHEAS-ECA – Refinement/Rollout
  - Dependency
  - Recovery
  - Integrate with SAPHIRE/SPAR Models
  - Publication of revision
- IDHEAS-DATA
  - Completion/Publication
  - Revision

Other HRA Work

- Minimum joint human error probabilities
- **Data!**
- Wish List
  - – Errors of commission
  - – Data for Org Factors
  - – Security (Physical and Cyber)

Path Forward

- Complete/Practical HRA Method
- Improvement to the current state of practice at the NRC
- Human-centered, scientific and data-based
- Program for periodic updates based on user feedback and data
- Can be applied to all NRC applications

- Closure of SRM-M061020?

QUESTIONS/DISCUSSION

Implementation Action Plan (IAP)
Strategy 2

Volume 4 - Licensing and Siting Dose Assessment Codes
Volume 5 - Plans for Radionuclide Characterization, Criticality, Shielding, and Transport in the Nuclear Fuel Cycle

February 4, 2021

Kimberly A. Webber, Ph.D.
Division of Systems Analysis
Office of Nuclear Regulatory Research

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

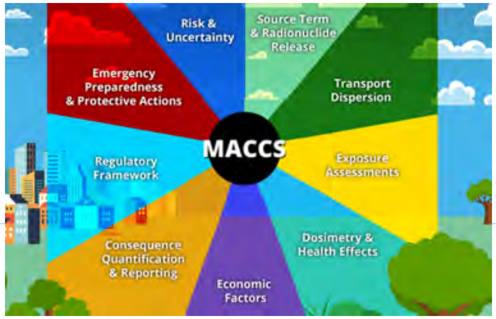
Agenda

- Staff Introduction
- Overview
- Advanced Reactor Code Development Plans
  – Volume 4 - Licensing and Siting Dose Assessment Codes
  – Volume 5 - Plans for Radionuclide Characterization, Criticality, Shielding, and Transport in the Nuclear Fuel Cycle

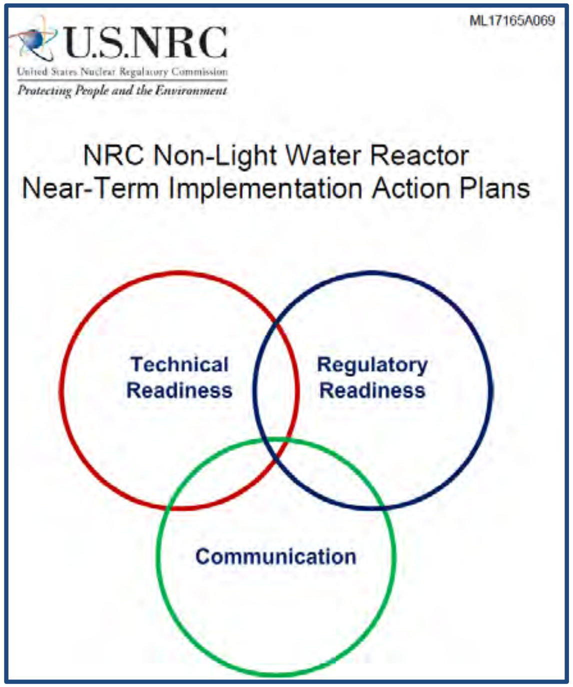
NRC's "Be Ready" Attitude

- Improve mission value while enabling safe operations
  - Deliver cost savings
  - Develop regulatory tools
  - Build staff expertise
  - Leverage collaborations

BlueCRAB



NRC's Integrated Action Plan (IAP) for Advanced Reactors



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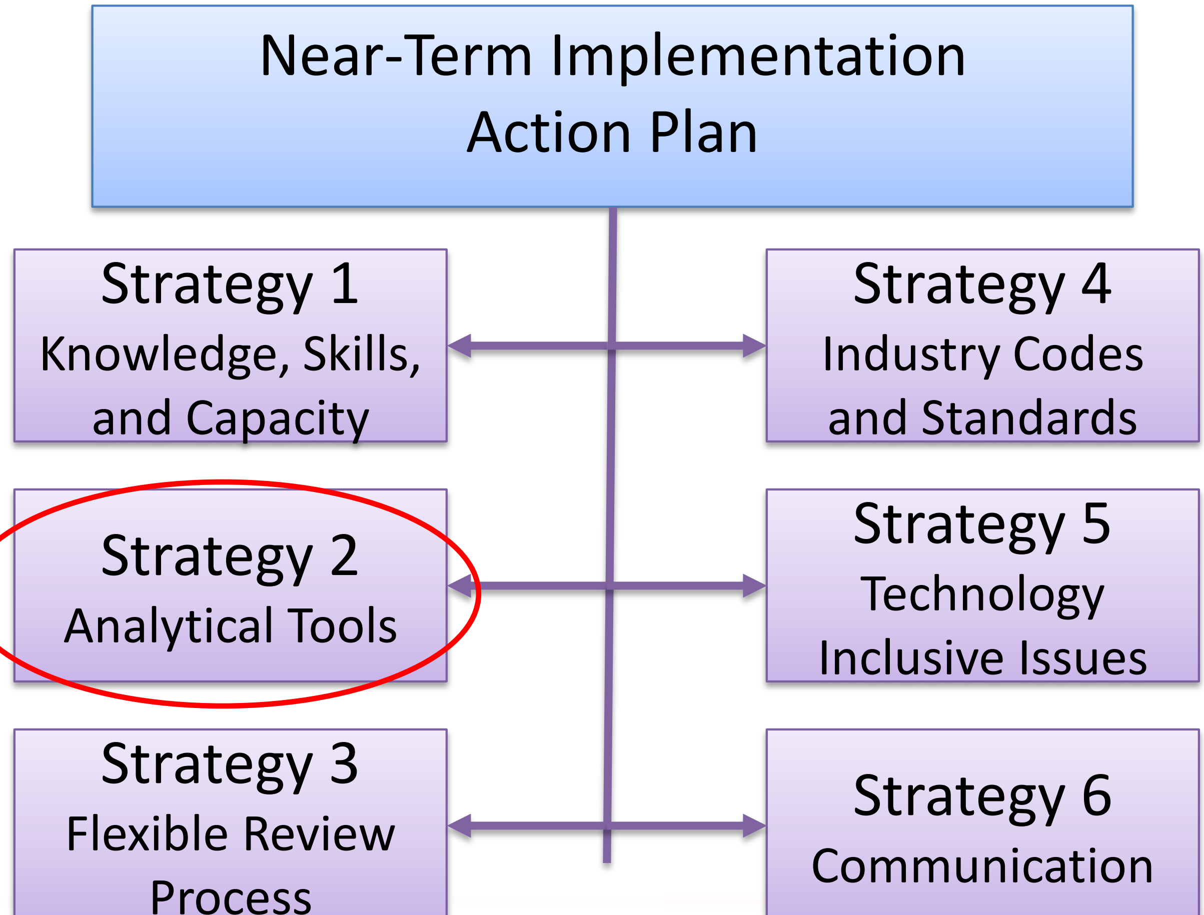

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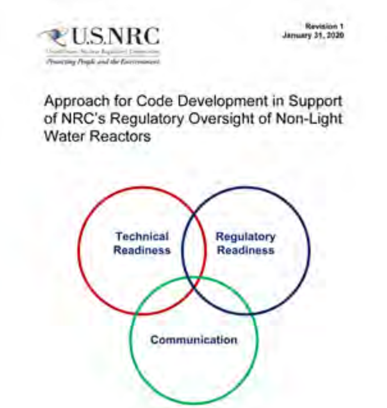
United States Nuclear Regulatory Commission
Protecting People and the Environment

IAP Strategy 2 Volumes to Date

These Volumes outline the specific analytical tools to enable independent analysis of non-LWRs, "gaps" in code capabilities and data, V&V needs and code development tasks.



Introduction
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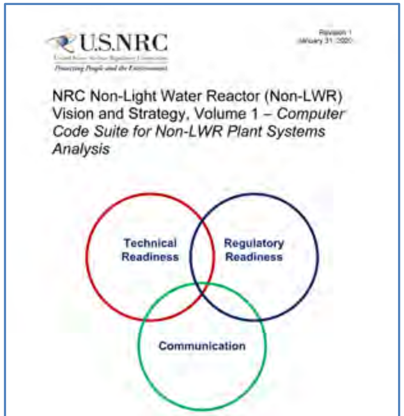

Volume 1
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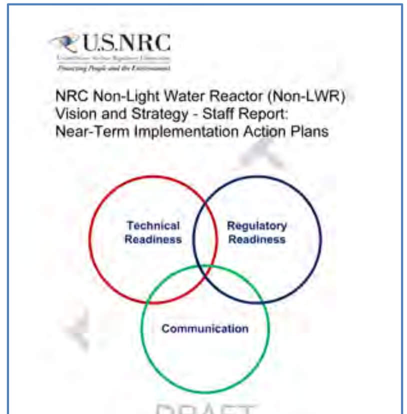

Volume 2
Volume 2 – Detailed Information
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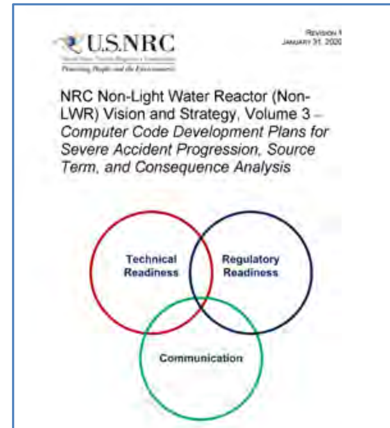
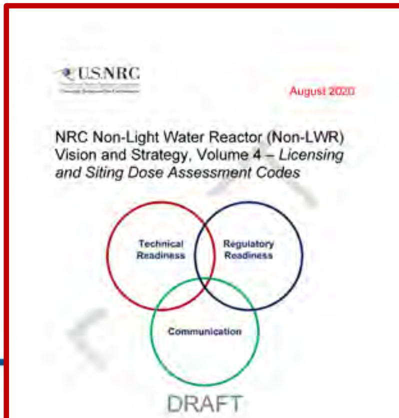


Volume 3
ML20030A178



Volume 4
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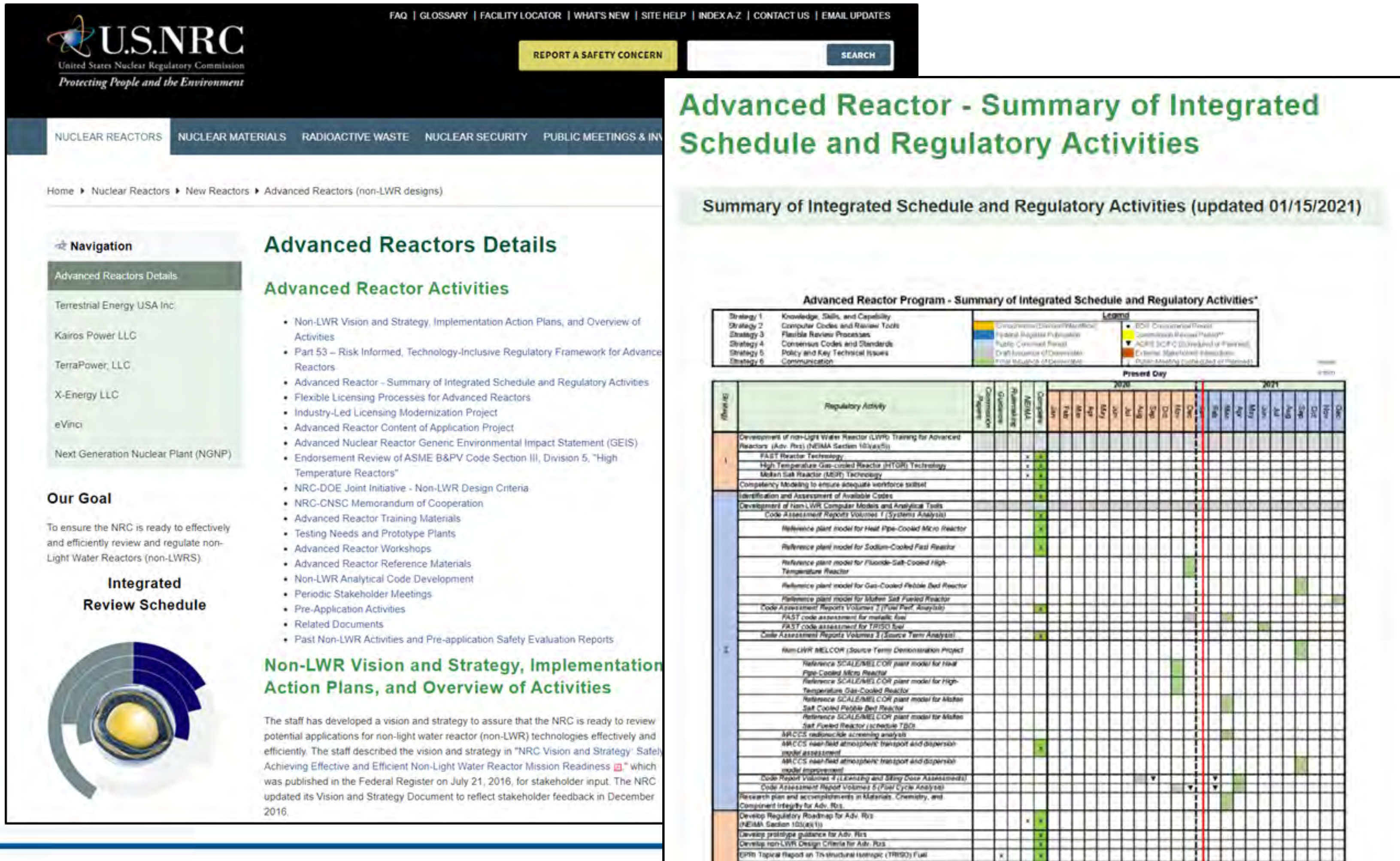
Volume 5
ML20308A744

NRC's Integrated Action Plan (IAP) Status



Volume 4 - Licensing and Siting Dose Assessment Codes

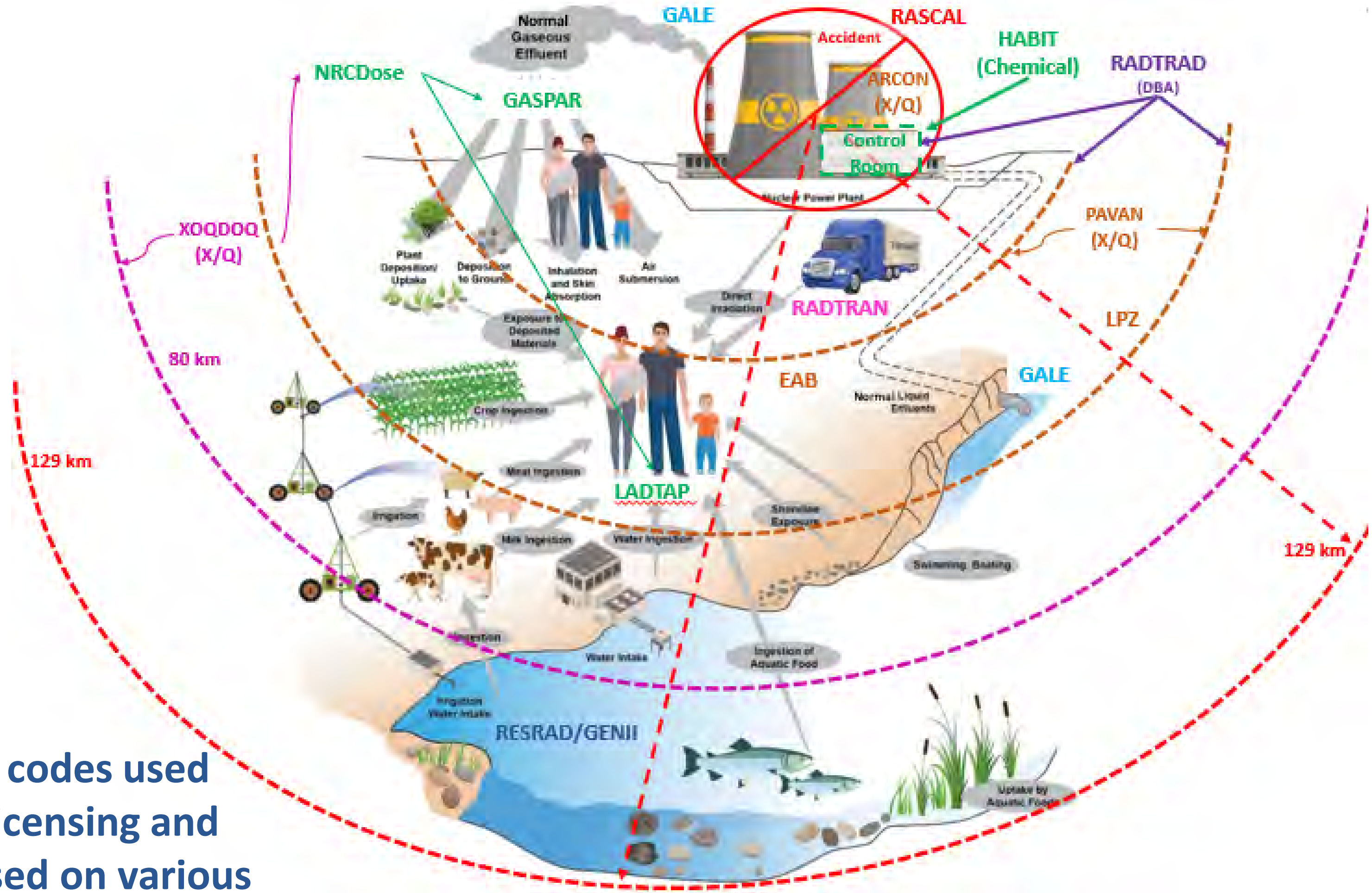
John Tomon, CHP
Chief, Radiation Protection Branch
Office of Nuclear Regulatory Research

2/04/2021

Volume 4: Licensing and Siting Dose Assessment Codes

- Technical Issues
  - Potential for a spectrum of Non-LWR and fuel designs
  - Over 10 licensing and siting dose assessment codes
  - Inconsistent code development practices, by various contractors, over decades
  - Overlap in code capabilities and need to use resources pragmatically
- Approach (Tasks)
  - Consolidate/Modernize Dose Assessment Codes
  - Improve characterization of Source Terms
  - Improve Atmospheric Transport & Dispersion Models
  - Update Dose Coefficient values
  - Update Environmental Pathway Model

Licensing and Siting Dose Assessment Codes



Over 10+ codes used for NPP licensing and siting based on various regulations.

Image adapted from BNWL-1754, Models and Computer Codes for Evaluating Environmental Radiation Doses.

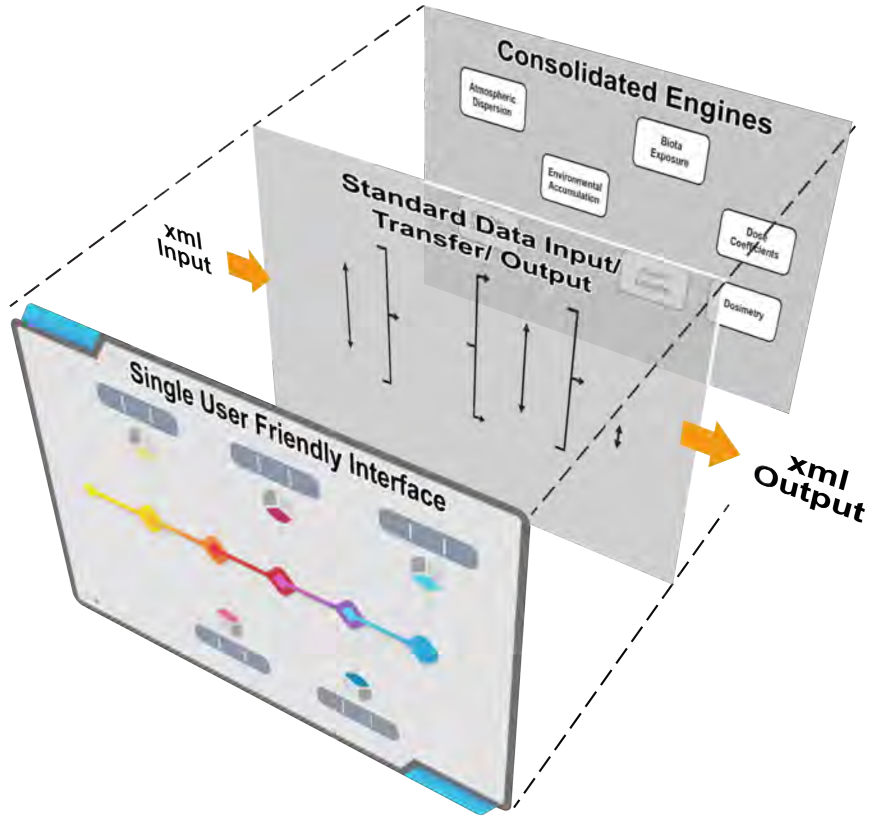
Code Consolidation and Modernization (Task 1)

- Given the large number of Non-LWR technologies being conceived and developed, it will be resource intensive to modify each of the siting, licensing, and emergency response codes for each design type.
- Therefore, the staff is proposing to consolidate and integrate them into several codes (i.e., two or three) that are modular, flexible, efficient, and user-friendly.

Code Consolidation Approach

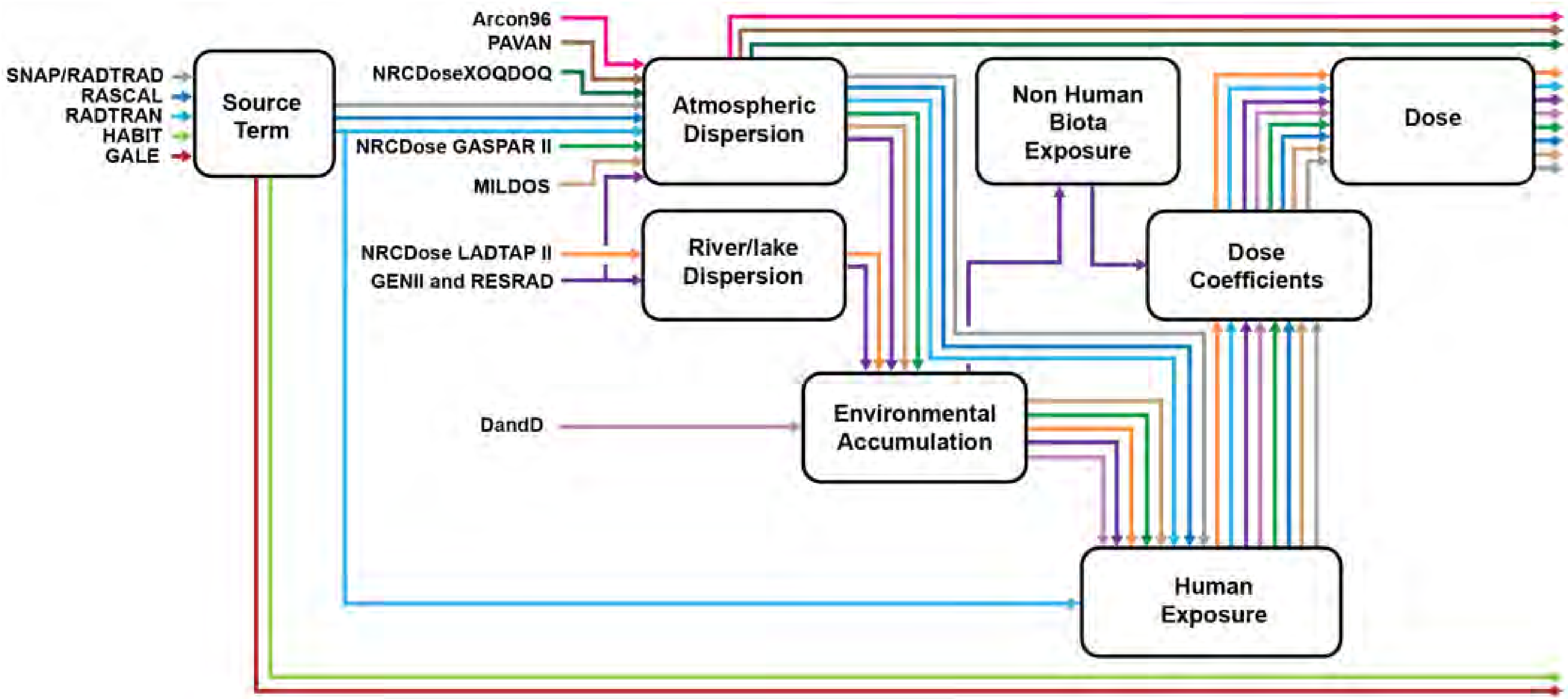
The three pillars to the dose assessment code consolidation process:

- **Create consolidated engines**
- **Develop a standardized data transfer schema**
- **Build a single user interface**



PNNL-29717, Health Physics Codes Consolidation and Modernization

Conceptual Model for the Consolidated Code



PNNL-29717, Health Physics Codes Consolidation and Modernization

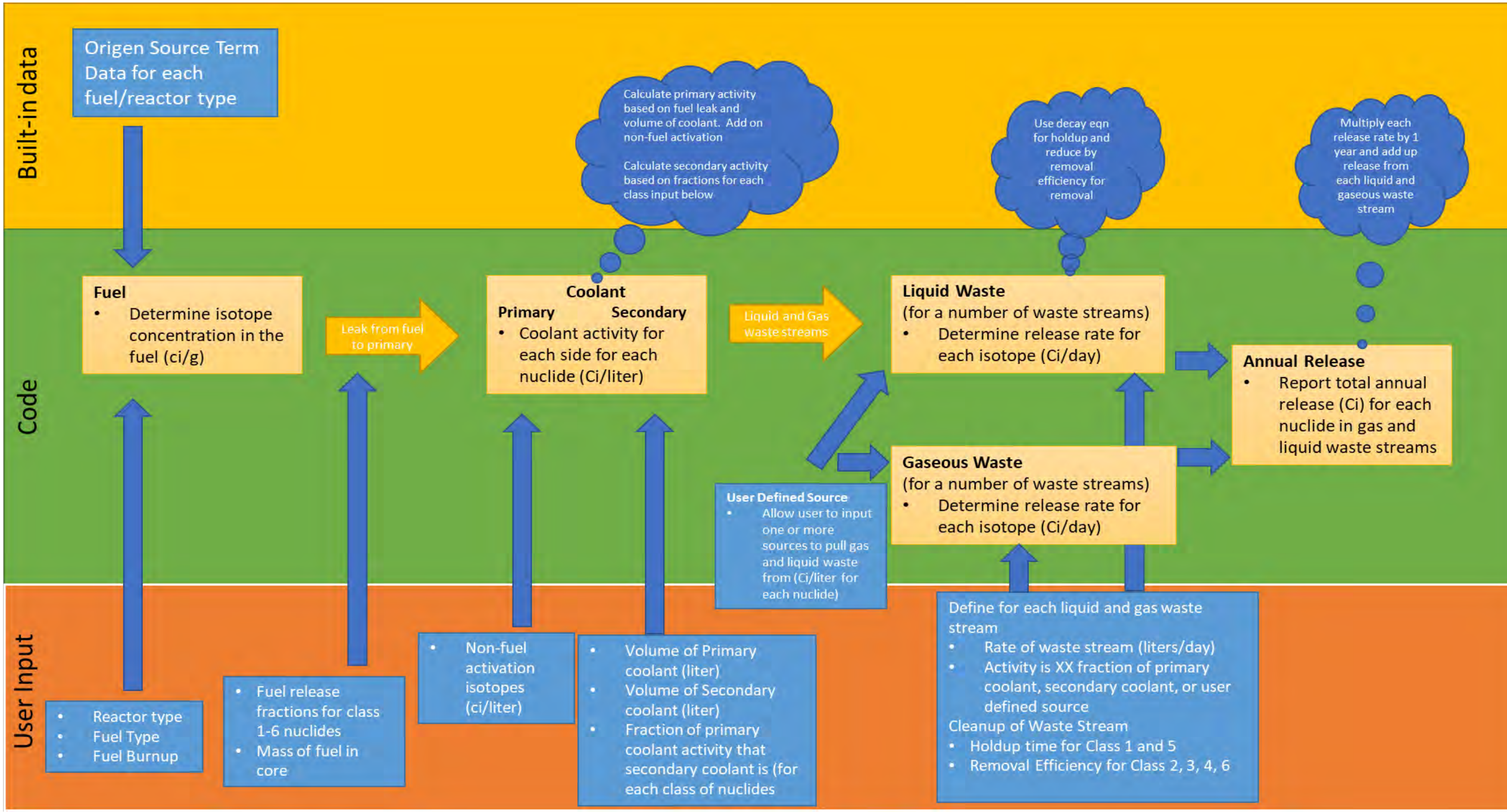
Source Term (Task 2)

- Identify source terms inputs (i.e., radionuclide fuel inventories, reactor coolant inventories, plant design and operational data) for each of the Non-LWR designs.
  - Normal (Routine) source terms
  - Severe Accident source terms
  - Design-Basis Accident source terms
  - Transportation source terms

Source Term (Task 2)

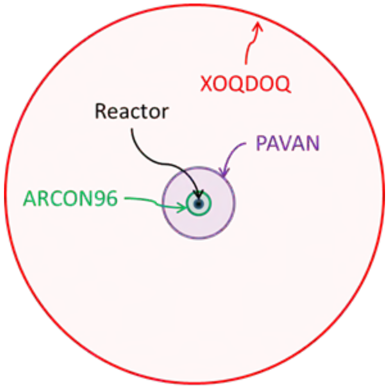
- Source Term Considerations:
  - Source term/release rate framework database will:
    - Leverage activities from Volumes 3 and 5
    - Estimate inventory in core/release from core
    - Identify dominate release pathways
    - Characterize mechanism to reduce release (e.g. filters)
    - Estimate release rates,
    - Use operational data where applicable

Normal Operation Source Term



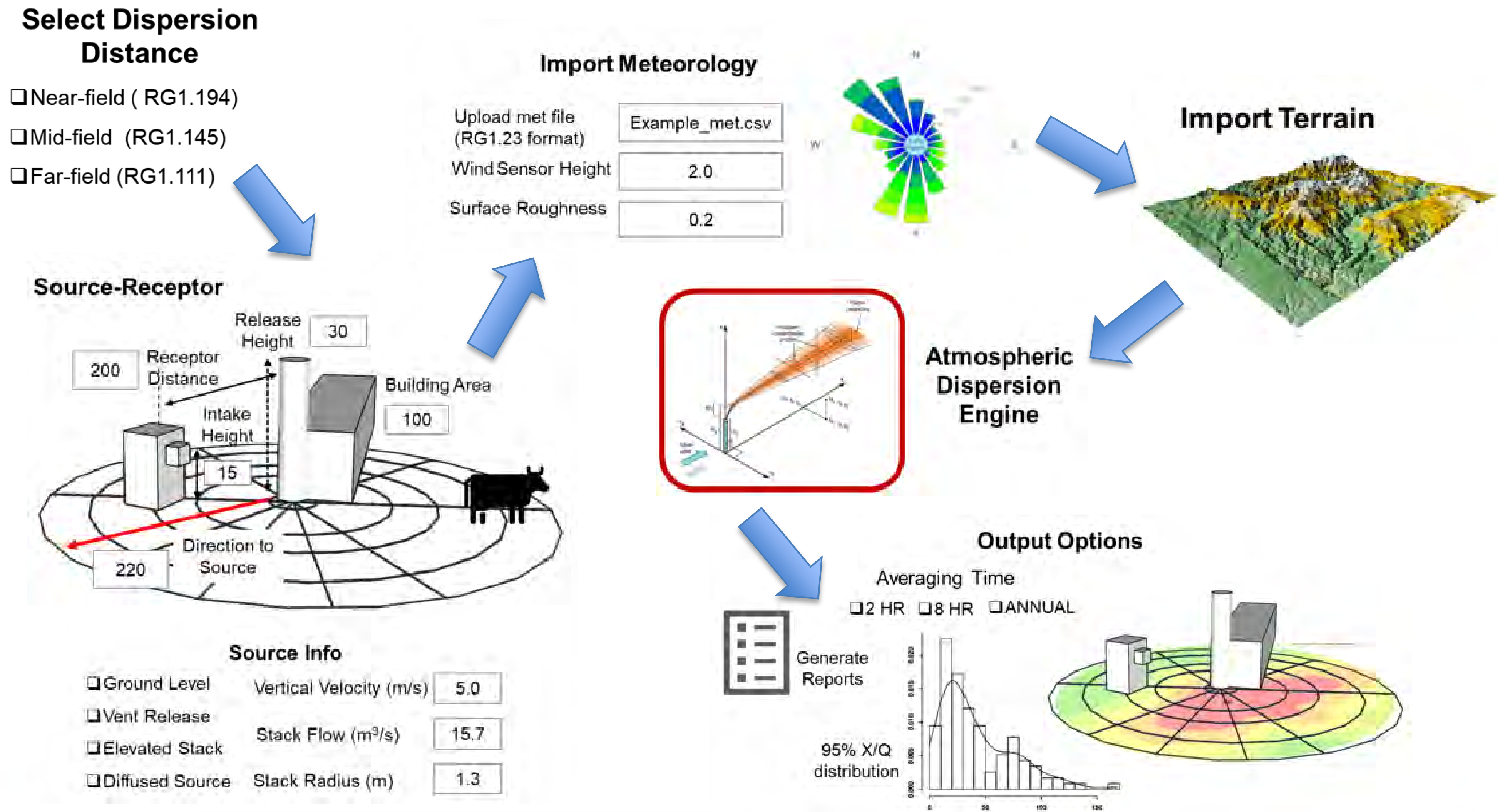
ATD Module (Task 3)

- ATD consolidation in Phases:
  - Phase 1: Consolidate ARCON, PAVAN & XOQDOQ.
  - Phase 2: Evaluate the applicability of the near-field and ATD models for Non-LWR technologies.
- These phases would leverage the experience of the NRC-meteorology staff and any near-field modelling efforts from Volume 3.



Dispersion Distances

Atmospheric Engine Prototype



Dose Coefficient Module (Task 4)

- This task involves:
  - Developing dosimetry modules/engines that have the flexibility to use different dose models and dose coefficient values
  - Examining dose coefficient models with respect to aerosol particle size in addition to exploring the impact of tritium and carbon-14 biokinetics since these radionuclides may be in higher quantities in non-LWRs.

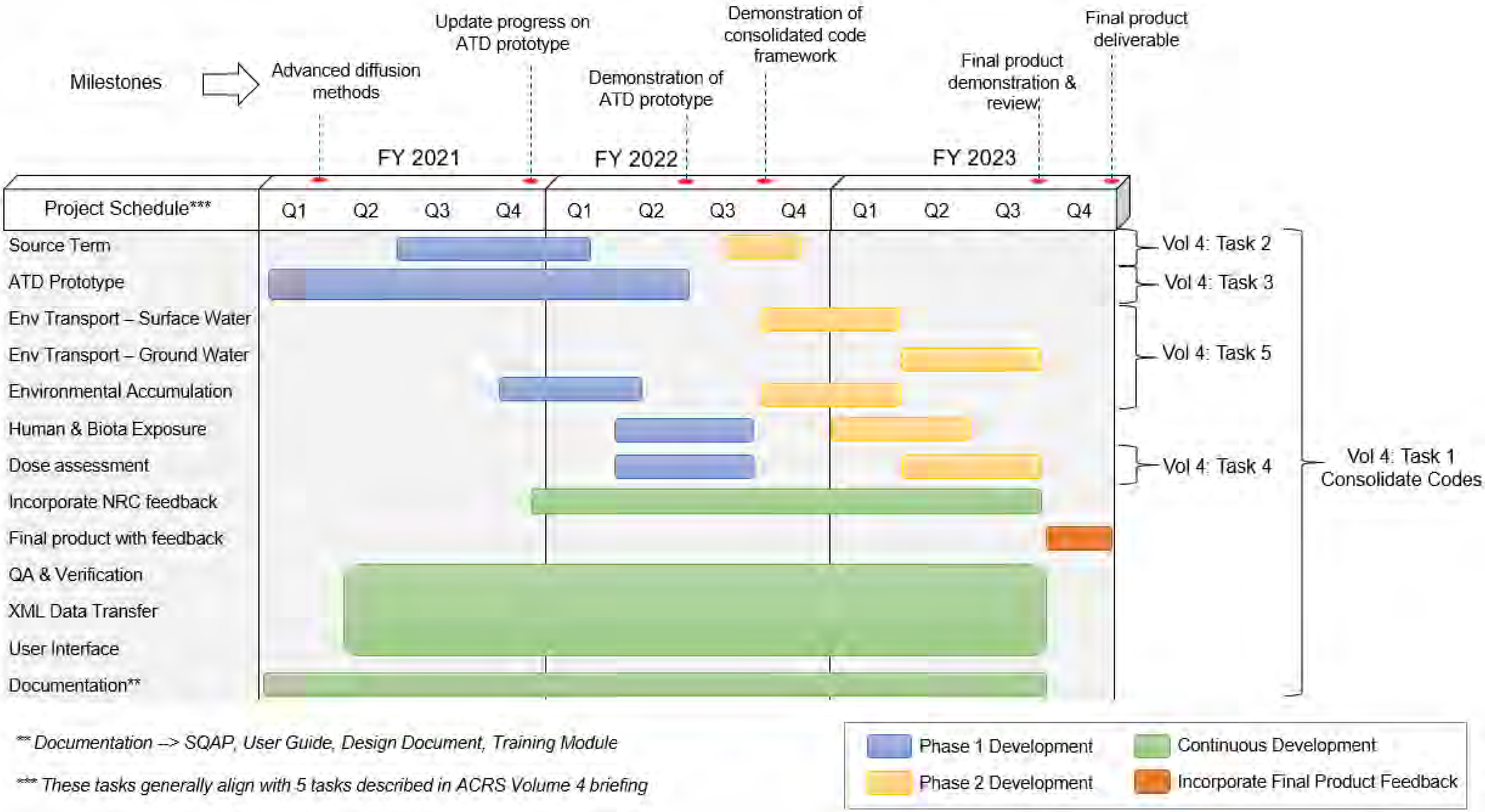
Dose Coefficient Considerations

- Vision for module:
  - Flexible Engines for different dose coefficient values
  - Dose Coefficient Package Code (DCFPAK)
  - Aerosol particle size relative to dose coefficients
  - H-3 and C-14 relationship to dose coefficients
- Current State
  - Some codes can choose different data sets.
  - Leveraging DCFPAK datasets with US EPA.
  - Possibly acquiring international dosimetry codes.
  - Training RPB staff on specific designs where internal dosimetry could be significant such as MSRs.

Environmental Pathways (Task 5)

- Further developing the aquatic pathways (river/lake/ocean dispersion), environmental accumulation, and human/non-human biota consequence modules for codes.
- Lower priority because they are less dependent on Non-LWR designs and fuel types.
- Explore the feasibility of radionuclide particle size behavior in the environment for some non-LWR designs.

Volume 4 Implementation Plan



*** Documentation --> SQAP, User Guide, Design Document, Training Module*

**** These tasks generally align with 5 tasks described in ACRS Volume 4 briefing*

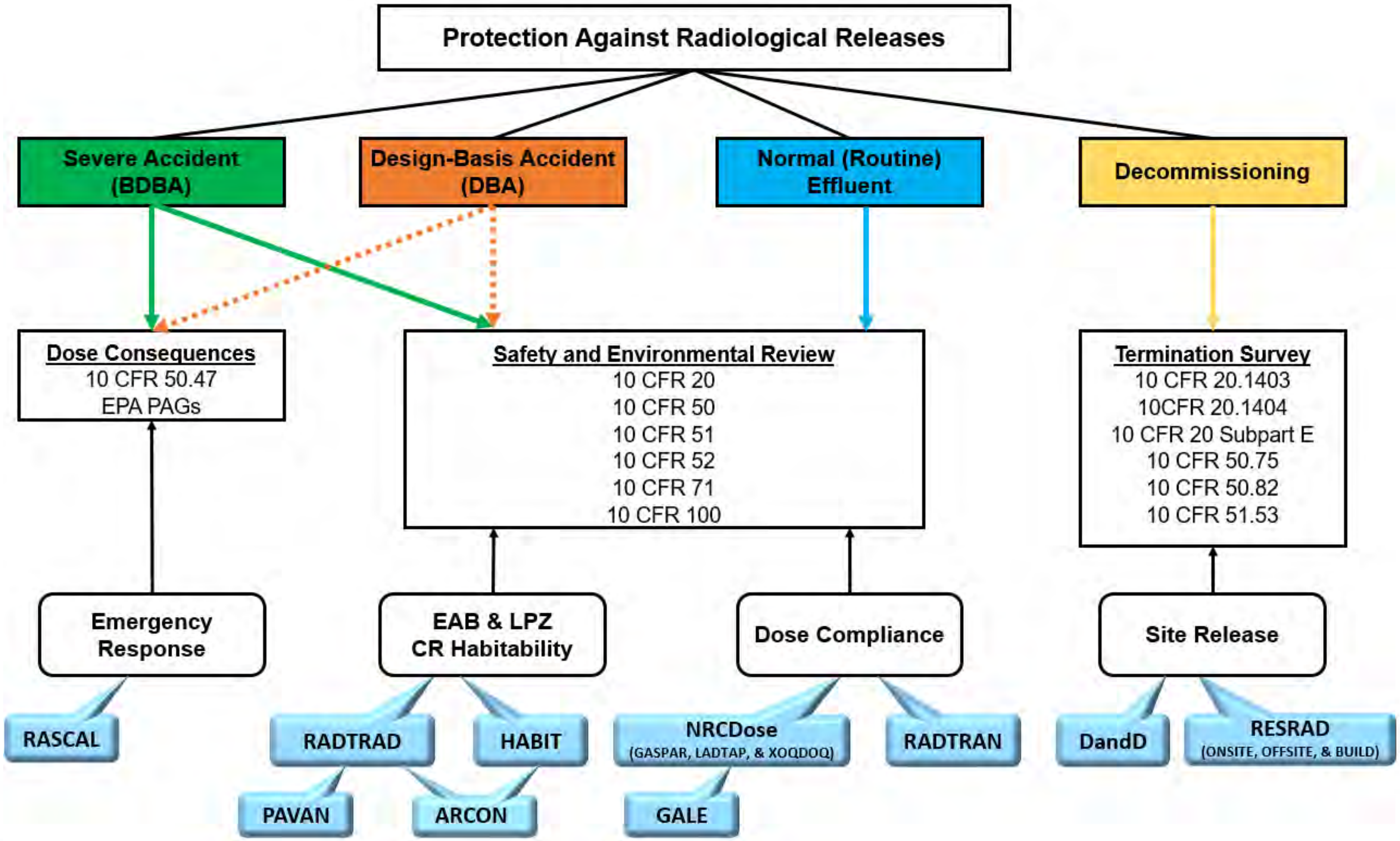
Thank You

Back Up Slides

Non-LWR Technologies

	Non-LWR Plant Description	Examples	Fuel Types
1	HTGR; prismatic core, thermal spectrum	Framatome	TRISO (rods or plates)
2	PBMR; pebble bed core, thermal spectrum	X-energy, Starcore	TRISO (pebbles)
3	GCFR; prismatic core, fast spectrum	GA	SIC clad UC (plates)
4	SFR; sodium cooled, fast spectrum	PRISM, ARC, TerraPower	Metallic (U-10Zr)
5	LMR; lead cooled, fast spectrum	Westinghouse, Columbia Basin, Hydromine	(Possibly nitride fuel.)
6	HPR; heat pipe cooled, fast spectrum	Oklo, Westinghouse	Metallic (U-10Zr)
7	MSR; prismatic core, thermal spectrum	AHTR	TRISO (plates)
8	MSPR; pebble bed, thermal spectrum	Kairos	TRISO (pebbles)
9	MFSR; fluoride fuel salt, thermal/epithermal spectrum	Terrestrial Thorcon, FliBe	Fuel salt
10	MCSR; chloride fuel salt, fast spectrum	TerraPower, Elysium	Fuel salt

Regulatory Needs for Dose Assessment Codes



Safety & Environmental Review Codes

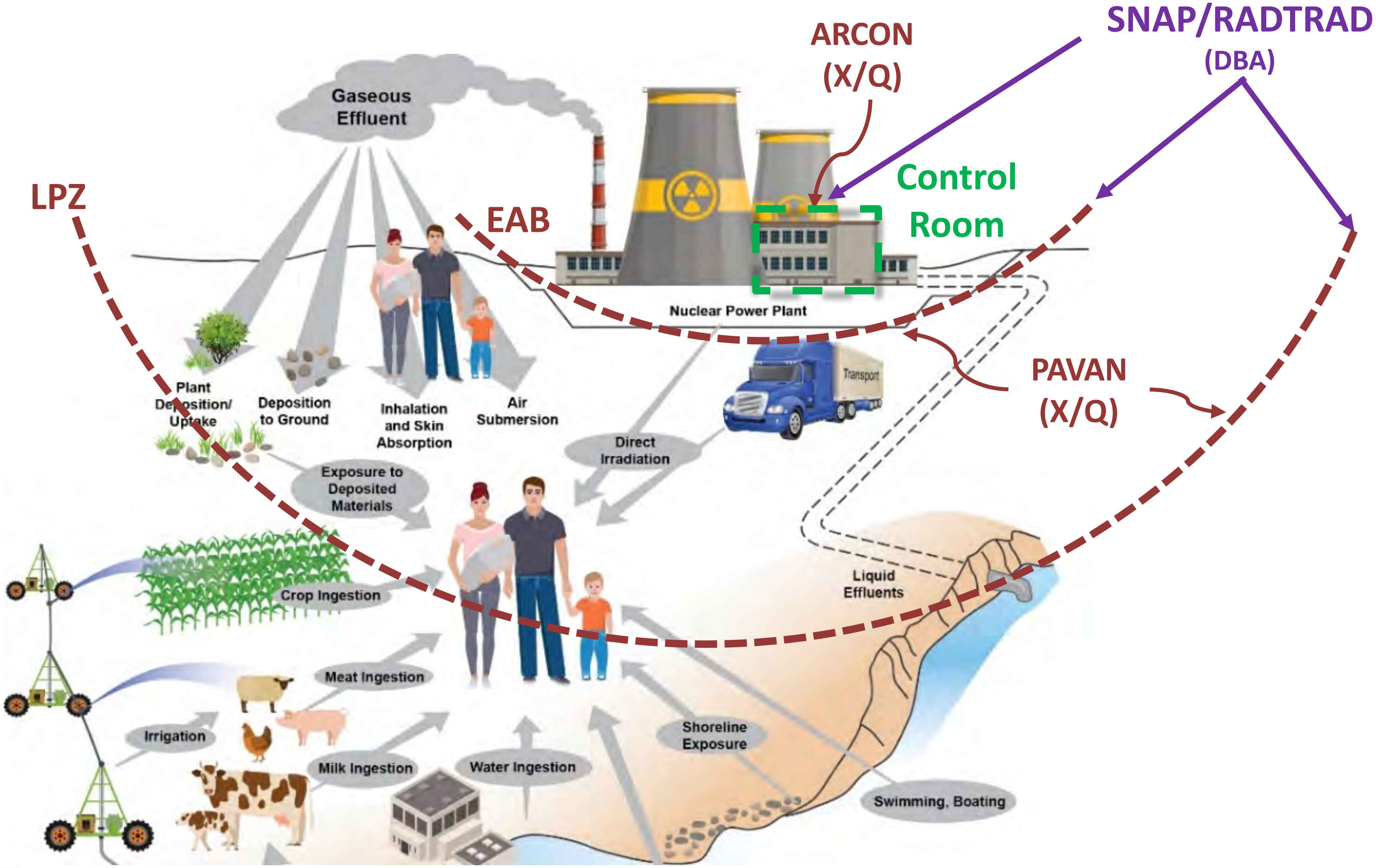


Image adapted from BNWL-1754, Models and Computer Codes for Evaluating Environmental Radiation Doses.

Safety & Environmental Review Codes

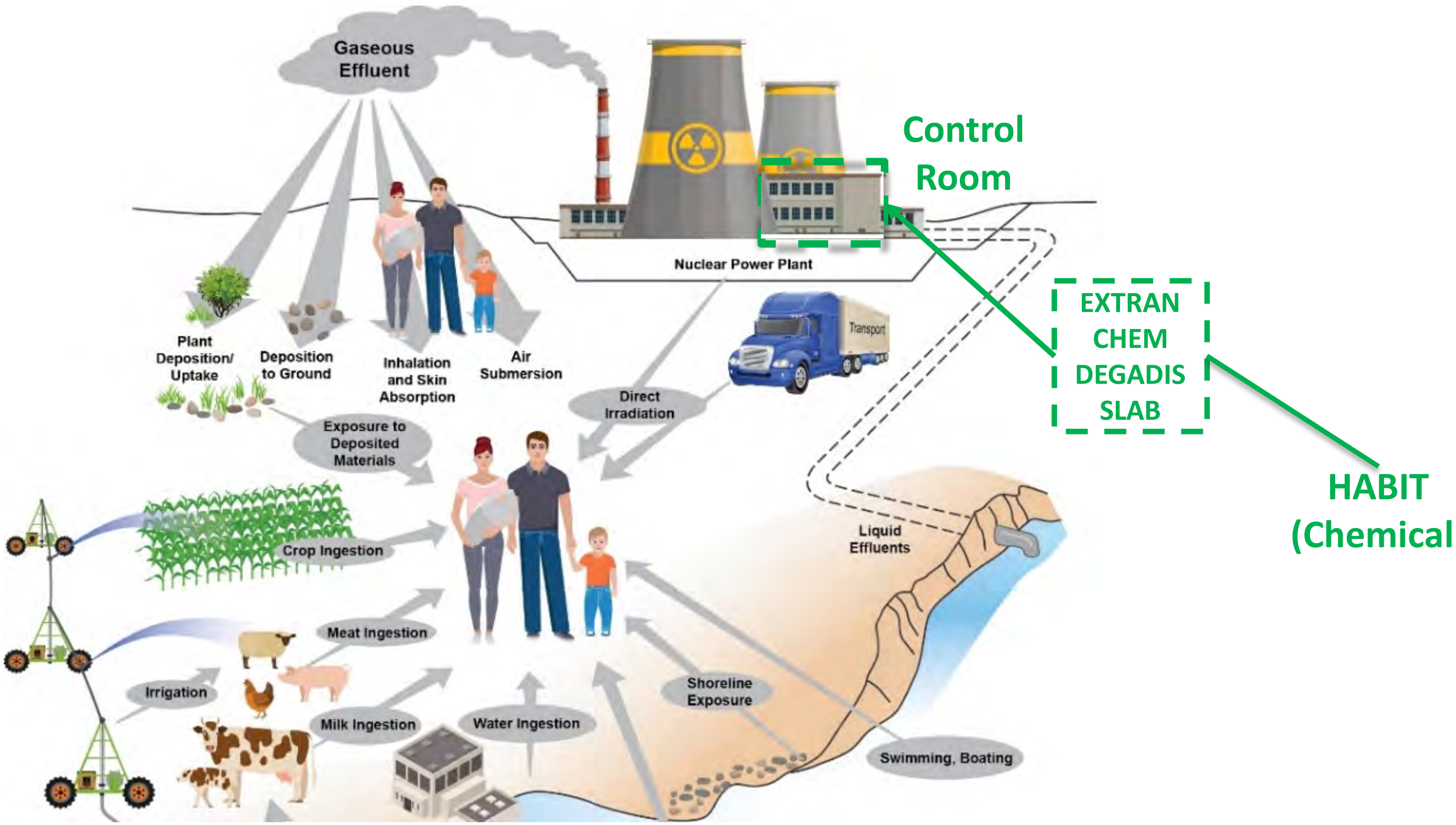


Image adapted from BNWL-1754, Models and Computer Codes for Evaluating Environmental Radiation Doses.

Safety & Environmental Review Codes

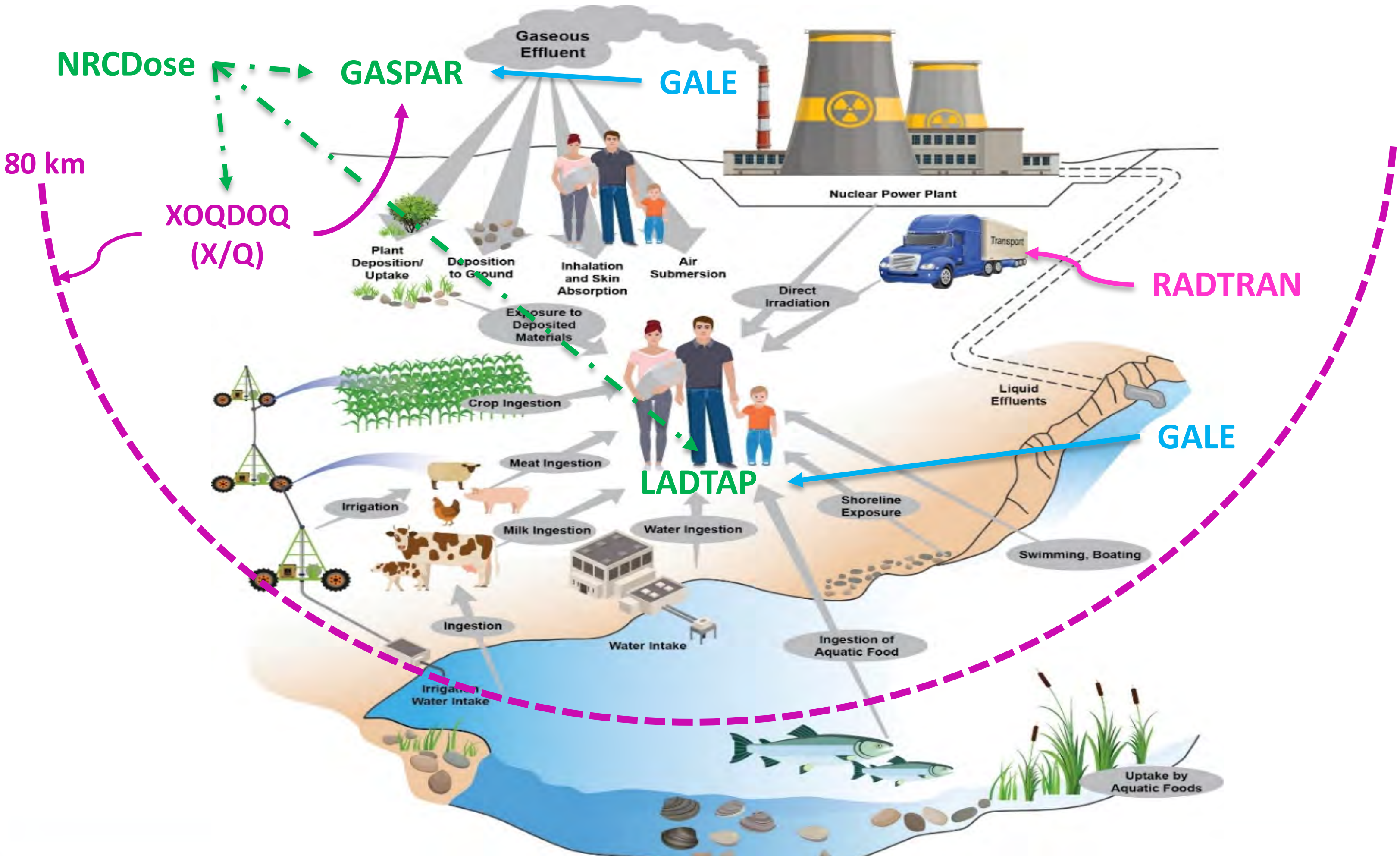


Image adapted from BNWL-1754, Models and Computer Codes for Evaluating Environmental Radiation Doses.

Dose Consequences Code

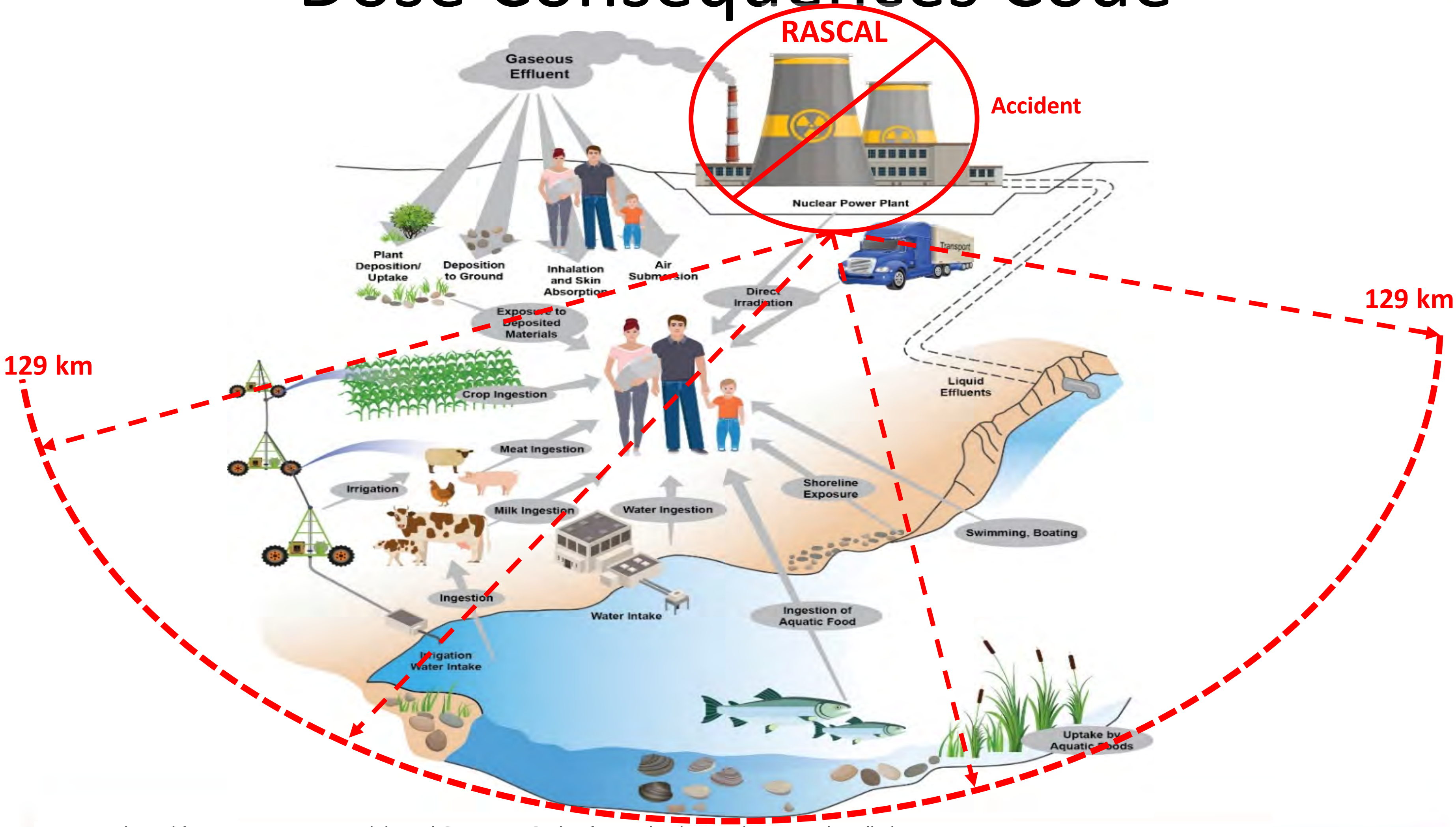
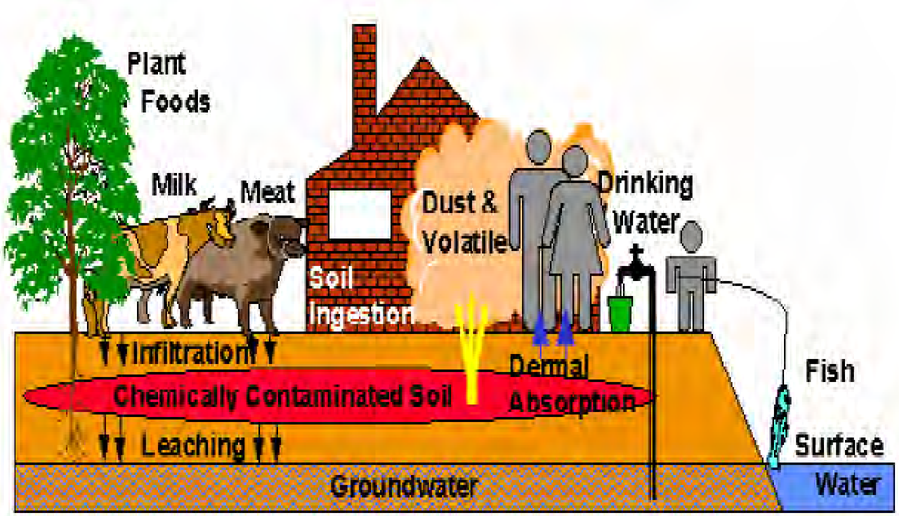


Image adapted from BNWL-1754, Models and Computer Codes for Evaluating Environmental Radiation Doses.

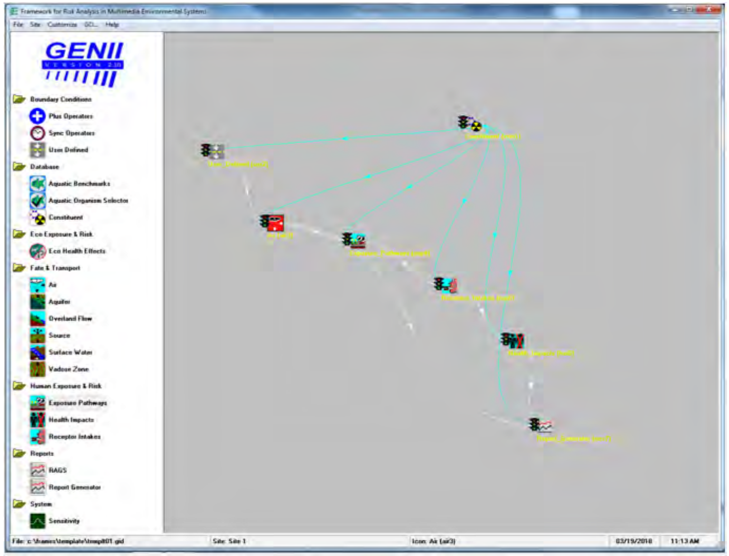
Decommissioning Codes

- **DandD (Decontamination and Decommissioning)**: compliance with the dose criteria of 10 CFR Part 20, Subpart E. Perform simple estimates of the annual dose from residual radioactivity in soils and on building surfaces.
- **RESRAD (Residual Radioactivity):** Family of codes used to analyze human and biota radiation exposures from environmental contamination of residual radioactive materials.



Research and Other Purposes

- **GENII (Generation II computer code)**: a set of programs for estimating radionuclide concentrations in the environment and dose to humans from acute or chronic exposures from radiological releases to the environment or initial contamination conditions.
- **Dose Coefficient File Package (DCFPAK):** that includes nuclear decay data and dose and risk coefficients for exposure to radionuclides.



- **SCALE** and **MELCOR** are used in development of core radionuclide inventory and severe reactor accident source terms as described in Volume 3. Plan to leverage work done for Volume 3 in the licensing and siting dose assessment codes.

Other Considerations/Challenges

- Timing of Non-LWR submittals vs code readiness
- Consolidation vs no consolidation
- Wide range of program office participation and input
- Managing expectations

Code Readiness

- Next Steps for Volume 4: (Near- & Mid-Term)

Activity	Date
Brief SC and Full ACRS	Sept 2020/Feb 2021
Build Consolidate Code Framework	FY 2021
Obtain Source Terms from Most Probably Designs	Ongoing
Pilot of Atmospheric Models	FY 2021
Include Non-LWR HP Operational Experience (Domestic and International)	FY 21 and beyond
Dose and Environmental Engines	FY 23 and beyond

“NRC non-Light Water Reactor Vision and Strategy, Volume 5: Radionuclide Characterization, Criticality, Shielding, and Transport in the Nuclear Fuel Cycle”

Presented by
Don Algama (RES) and Drew Barto (NMSS)

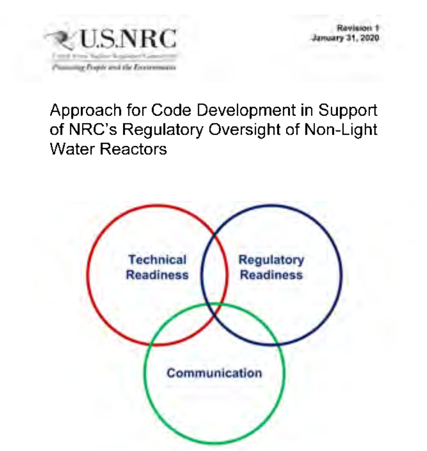
United States Nuclear Regulatory Commission
Office of Nuclear Regulatory Research (RES)
Nuclear Materials Safety and Safeguards (NMSS)

02/04/2021

Acknowledgements

- This work was completed thanks to many contributors from NMSS, NRR and RES.
- Dr. David Luxat (Sandia) and Dr. William Wieselquist (ORNL) were instrumental in the plan development.

IAP Strategy 2 Volumes to Date



Introduction
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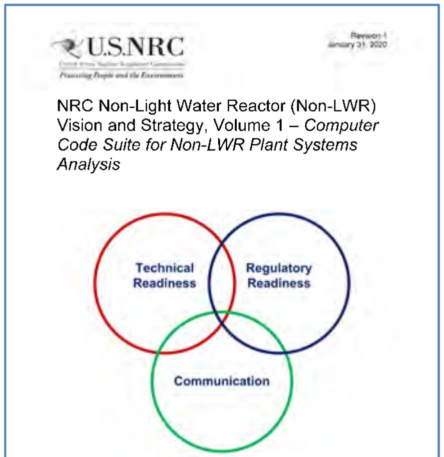
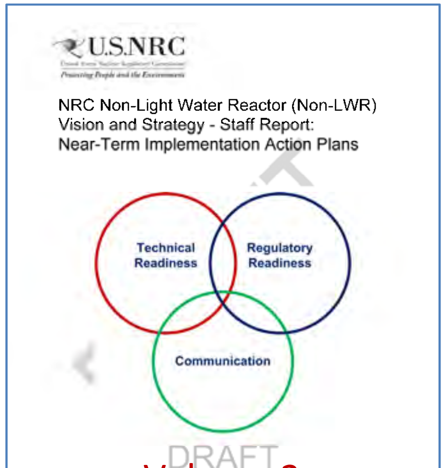
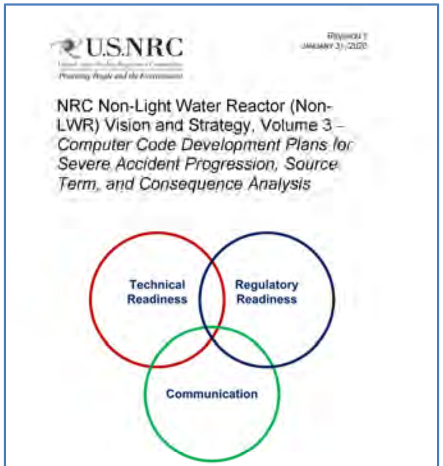


Volume 1
ML20030A176



Volume 2
Volume 2 – Detailed Information
ML20030A177

Volume 5
ML20308A744



Volume 3
ML20030A178

Volume 4
ML20028F255

Objectives

- Elements of the fuel cycle plan
  - Evaluate and demonstrate computer code readiness
  - Evaluation and use of existing NRC computational tools for accident analysis (Volume 3) and consequence assessment (Volumes 3/4)
  - Incremental development approach based on existing LWR fuel cycle as reference
  - Staff experience with anticipated non-LWR fuel cycle and use of computer codes
  - Development of non-LWR fuel cycle reports and publicly available input decks

Analysis Approach

Develop accident scenarios by reviewing available information including documents such as:

- NUREG/CR-6410 "Nuclear Fuel Cycle Facility Accident Accident Analysis Handbook"
- NUREG-1520 "Standard Review Plan for Fuel Cycle Facilities License Applications"
- NUREG-2215 "Standard Review Plan for Spent Fuel Dry Storage Systems and Facilities – Final Report"
- NUREG-2216, "Standard Review Plan for Spent Fuel Transportation"
- DOE-HDBK-1224-2018: "Hazard and Accident Analysis Handbook"

Severe Accident & Consequence Analysis (LWR/non-LWR example)

analysis end-points

ENDF/B
Physics data
Thermal scattering law, resonance data, energy distributions, fission yields, decay constants, etc.

JEFF Activation
Isomeric cross sections, activation reactions

Sources4C
neutron emission data (alpha,n)

Kinetics Data
nuclide-specific beta-effective, precursor data

NIST
natural abundance, atomic mass

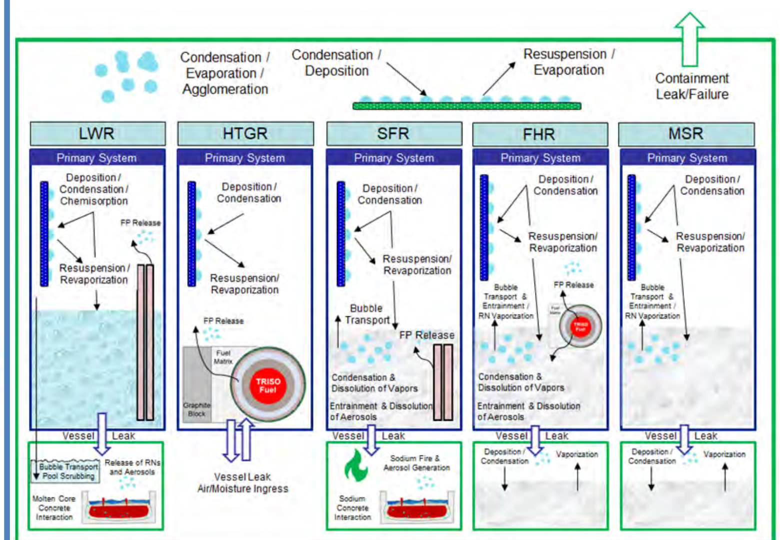
scale
Nuclear Systems Modeling & Simulation

AMPX
Validated cross section libraries in multigroup (O(100g)) or continuous-energy (O(100,000g); depletion and decay data

ORIGEN
General depletion, decay, source term

TRITON/SHIFT
General reactor fuel neutron transport + depletion

ORIGAMI
Reactor-specific radioactive isotopics/source term characterization



MELCOR
Severe accident progression and mechanistic source terms

consequence analysis

"NRC Non-Light Water Reactor Vision and Strategy, Volume 3 – Computer Code Development Plans for Severe Accident Progression , Source Term, and Consequence Analysis," Revision 1, January 2020, ML20030A178

Scope of Analysis

- Assess existing codes to cover neutronics and radionuclide and non-radionuclide hazards throughout non-LWR fuel cycles
- Consequence and radiation protection methods are covered under Volumes 3/4
- Mining, milling, long term storage and disposal are not considered in this activity
- Leverage Volume 3 non-LWR designs
  - Fluoride-Salt-Cooled (Solid-Fuel) High Temperature Reactor (FHR)
  - Heat Pipe Reactor (HPR)
  - Sodium Fast Reactor (SFR)
  - High Temperature Gas Reactor (HTGR)
  - Molten Salt Reactor (MSR)

Follow these analysis steps used in Volume 3 and previous fuel cycle work for LWRs

1. Define scenario
2. Identify safety related item(s) of interest
3. Ask the right safety questions / Phenomena of interest / Understand the dominant features
4. Survey experiments available that provide fundamental information
5. Develop physics models to capture dominant feature and allow prediction
6. Translate physics models into computer code
7. Perform verification testing (unit testing; and integrated testing as code complexity increases)
8. Perform validation with experiments. Capture the integrated codes performance (with uncertainty analysis)
9. Document findings

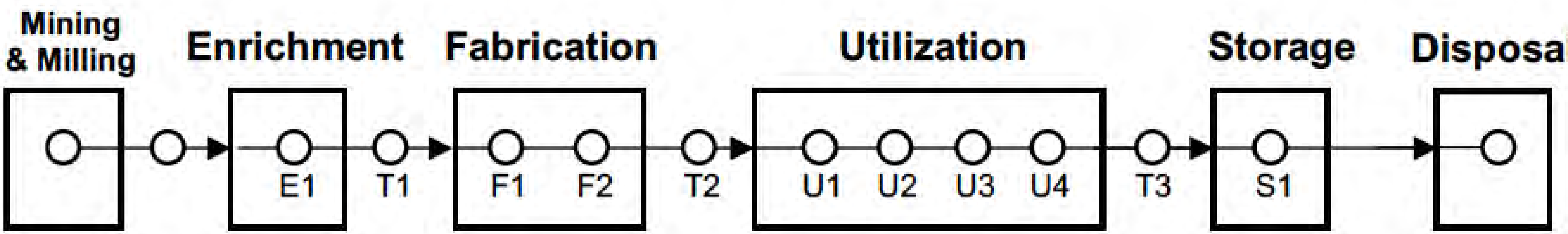
Deliverables

- 10 reports are defined as a result of this plan
  - Each report defines a set of accident scenarios during a portion of the fuel cycle
  - Perform assessment, analysis, and generate demonstration input files
- 5 non-LWRs currently considered, and openly available reference designs are defined in Volume 3:
  1. FHR Fuel Cycle Analysis (Berkeley Mk. 1)
  2. HPR Fuel Cycle Analysis (INL Design A-MET)
  3. SFR Fuel Cycle Analysis (MET-1000/VTR)
  4. HTGR Fuel Cycle Analysis (PBMR-400)
  5. MSR Fuel Cycle Analysis (MSRE)
- 5 front end (FE) reports centralize FE analysis among these non-LWRs
  6. Enrichment and UF6 Handling up to 20 wt.%
  7. TRISO Fuel Kernel Fabrication
  8. Uranium Metallic Fuel Fabrication
  9. Fast Reactor Fuel Assembly Fabrication
  10. Pebble TRISO Fuel Fabrication

This organization of deliverables allows prioritizing specific designs and reducing overlap. For example:

- HTGR analysis requires the following reports 6→7→10→4.
- For FHR, it would require 6→7→10→1. 6,7, and 10 are already available!

Reference - LWR Cycle

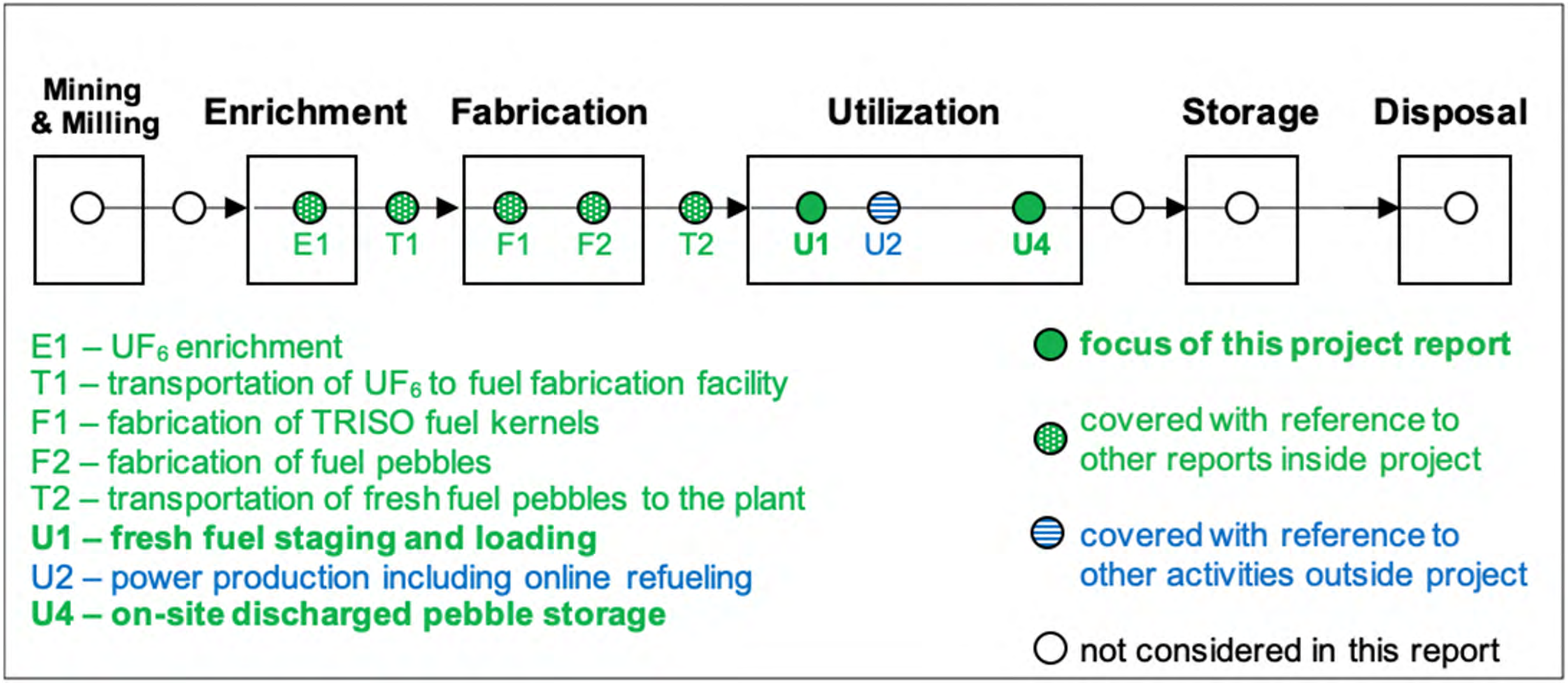


E1 – UF_6 enrichment
T1 – transportation of UF_6 to fuel fabrication facility
F1 – fabrication of UO_2 fuel pellets
F2 – fabrication of LWR fuel assemblies
T2 – transportation of fresh fuel assemblies to the plant
U1 – fresh fuel staging and loading
U2 – power production
U3 – spent fuel pool/shuffle operations
U4 – on-site dry cask storage
T3 – transportation of spent fuel to off-site storage
S1 – off-site storage

Each analysis report tackles one or more of the equivalent fuel cycle stages for each non-LWR.

NOTE: Transportation off-site and off-site storage (T3 and S1) are currently not considered in this fuel cycle assessment plan due to uncertainty with this part of the back end.

HTGR Fuel Cycle Report



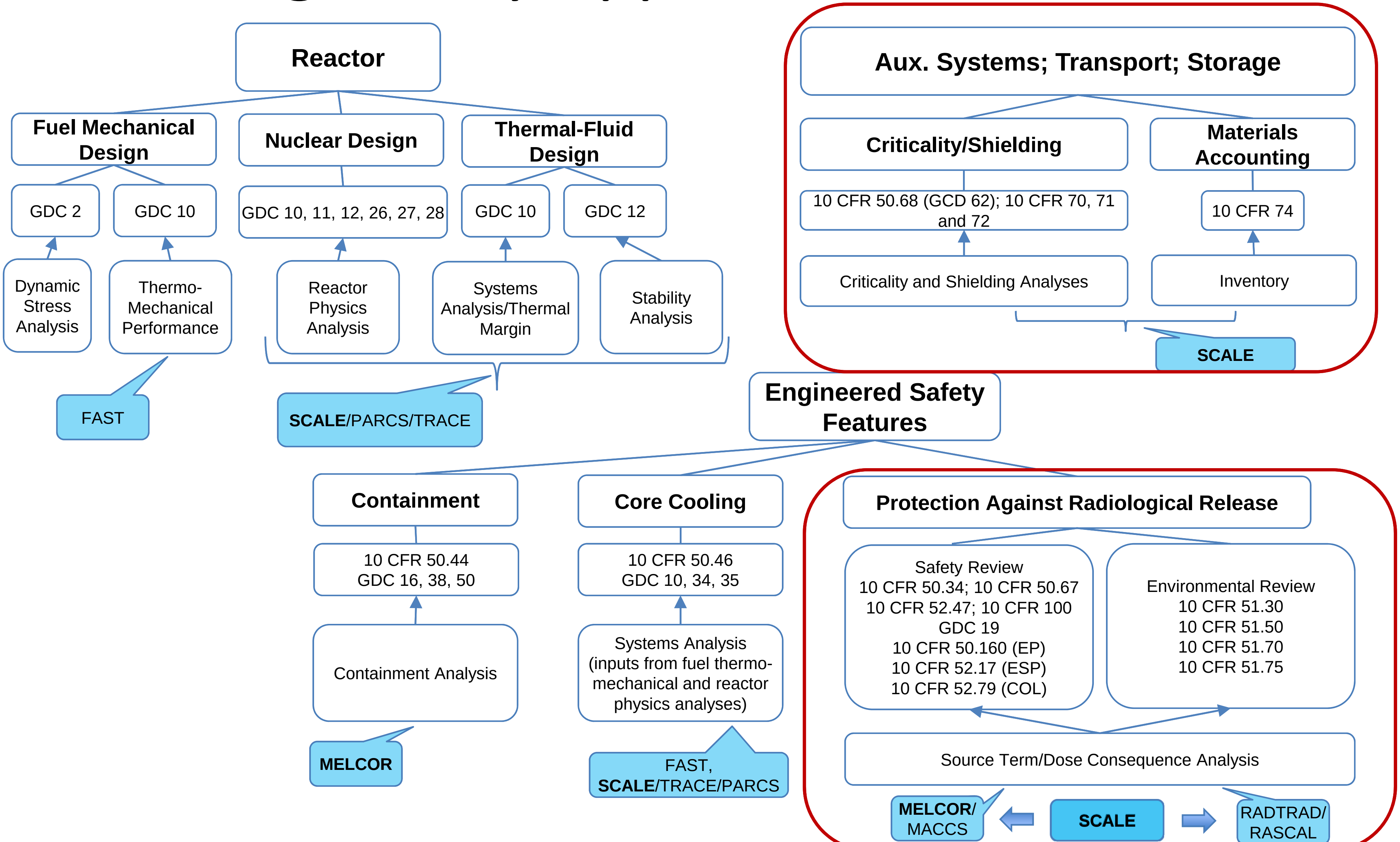
The HTGR fuel cycle report develops and analyzes new accident scenarios related to stages U1 and U4 and links them to front-end stages (E1, T1, F1, F2, T2) analyzed in this project and in-reactor accident scenarios U2 from volume 3. Front end analysis is basically the same as for FHR.

Concluding Remarks

- Relying on a reasonable and flexible approach
- Sufficient capabilities to support non-LWR fuel cycle analyses
- Decades of model development and validation can be applied to non-LWR analyses as in Volume 3 and other programs
- Plan will be updated as more experience is gained and as new information becomes available

Back Up

Regulatory Application of Codes



Transportation and Storage Licensing (LWR)

analysis end-points

ENDF/B
Physics data
Thermal scattering law, resonance data, energy distributions, fission yields, decay constants, etc.

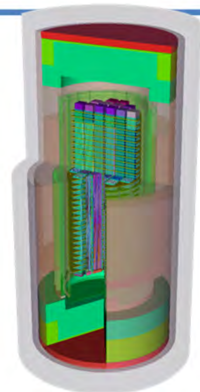
JEFF Activation
Isomeric cross sections, activation reactions

Sources4C
neutron emission data (alpha,n)

ICRP
dose conversion factors, radiotoxicity

NIST
natural abundance, atomic mass

scale
Nuclear Systems Modeling & Simulation



AMPX
Validated cross section libraries in multigroup (O(100g)) or continuous-energy (O(100,000g); depletion and decay data

ORIGEN
General depletion, decay, source term

TRITON/SHIFT
General reactor fuel neutron transport + depletion

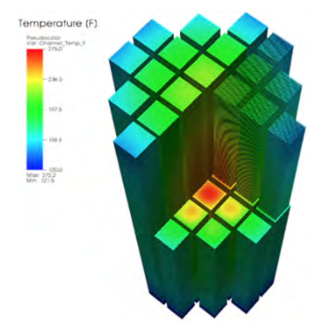
SHIFT/MAVRIC
3D shielding and dose rate analysis

CSAS
3D criticality safety analysis

ORIGAMI
Reactor-specific radioactive isotopics/source term characterization

Thermal Analysis

Structural and containment (cask) analyses

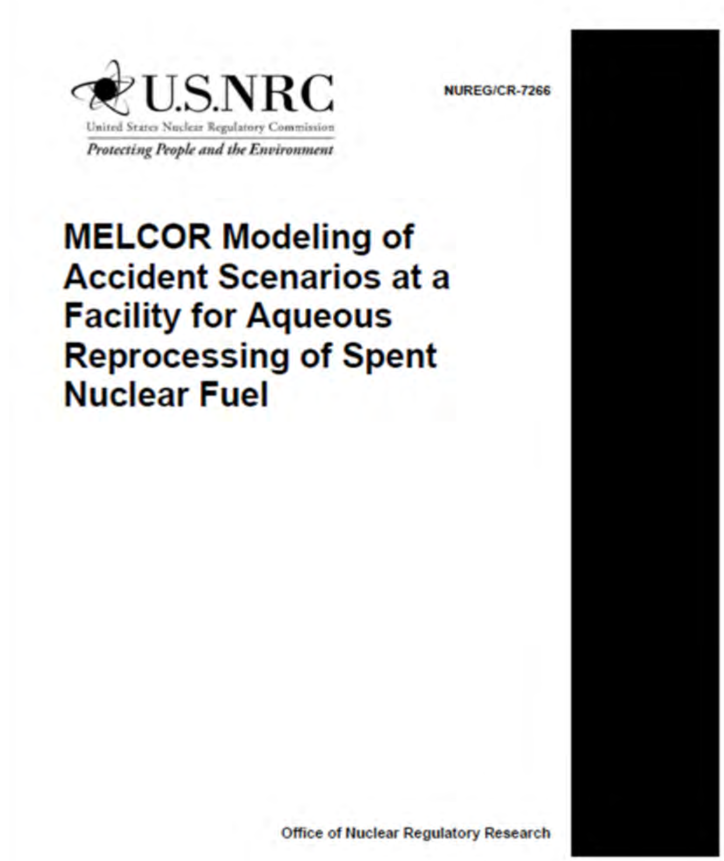


Examples of Existing Fuel Cycle Analysis

- Level 3 PRA Project
  - SCALE/MELCOR are used to support PRA development of accident sequences and source terms including non-reactor scenarios for the spent fuel pool
- NUREG-2161
  - SCALE/MELCOR was used to study the performance of a SFP under severe accident conditions
- NUREG/CR-7108/7109
  - Here SCALE was used to estimate isotopic depletion and criticality code, and cross section data bias related to burnup credit in spent fuel storage and transportation systems

Examples of Existing Fuel Cycle Analysis

- Barnwell – Non-Reactor Safety Assessment
- SCALE/MELCOR utilized as part of best-estimate analysis methodology in NUREG/CR-7266
- Spent fuel inventories developed in SCALE package
- Aerosol transport modeling
  - Integral analyses estimate radiological transport and release
  - Aerosol modeling enables estimation of transport of hazardous material within facility and to environment
- Accident scenarios considered relevant to broad range of facility accidents
  - Explosion scenario
  - Fire scenario
  - Combined explosion and fire scenario


U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

NUREG/CR-7266

MELCOR Modeling of Accident Scenarios at a Facility for Aqueous Reprocessing of Spent Nuclear Fuel

Office of Nuclear Regulatory Research

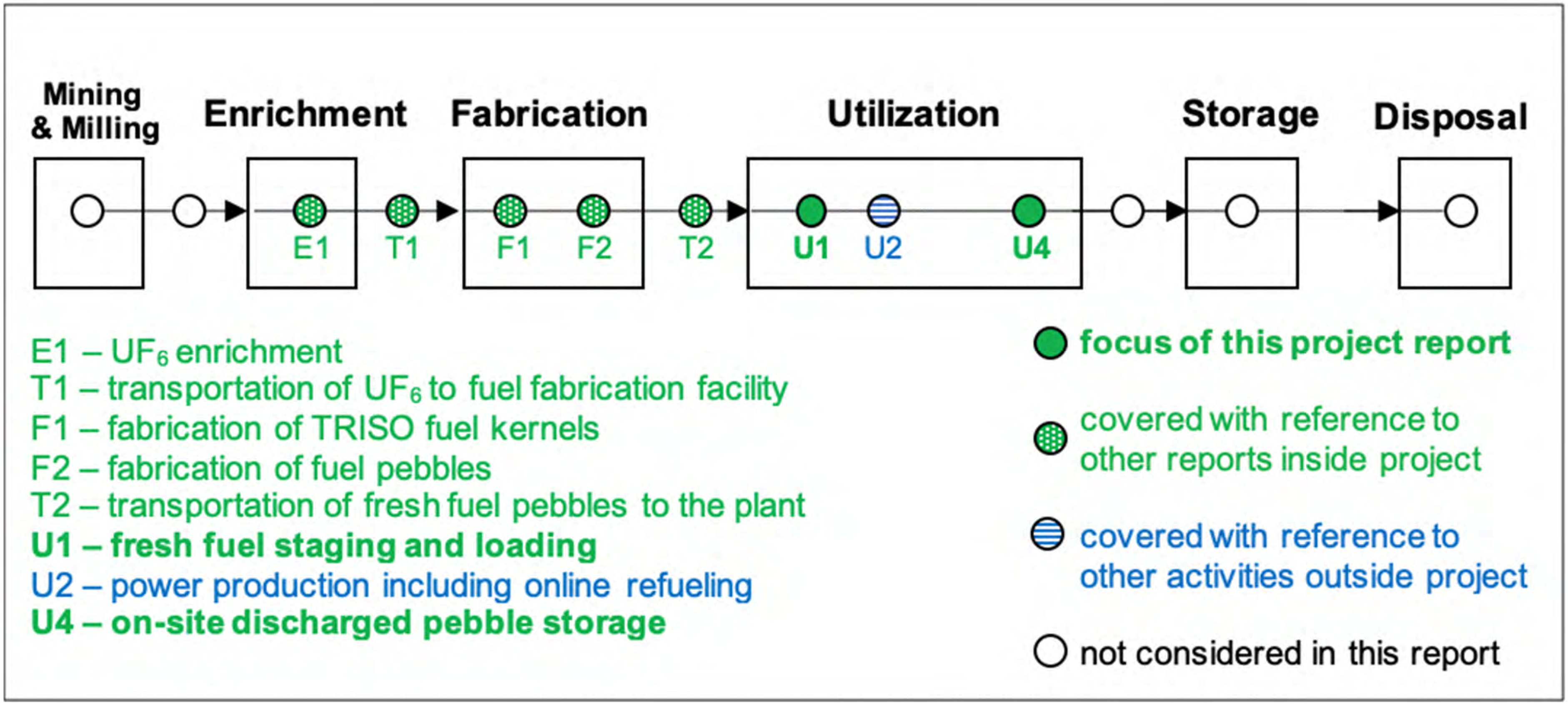
non-LWR Characteristics

Table 1-1. Comparison Between LWR and Non-LWR

Reactor Type	Enrichment (wt.%)	Fuel Form	Typical Discharge Burnup	Fuel Residence Time	On-Site Fuel Processing	Fuel Storage / Transport
LWR (Ref.)	<5	U Oxide	Peak Rod Average: <62 GWd/MTU Max Assembly Average: <55 GWd/MTU	Assemblies burned for approximately 3 to 4 cycles	No	Storage: Fresh and spent fuel storage on-site or off-site Transport: FE: UF_6 solid transport in 30B cylinders, fresh fuel assembly and fuel component (UO_2 powder/pellet) transportation packages BE: Used fuel transport and dry storage containers
LWR: HALEU /HBU (Ref.)	5 – 10	U Oxide	Peak Rod Average: ~75 Wd/MTU Max Assembly Average: ~60-70 GWd/MTU	Assemblies burned for approximately 3 to 4 cycles	No	
HPR	5 – 20	U Oxide U Metal	2-10 GWd/MTU	Up to 7yrs	No	To be evaluated*
SFR	5 – 20	U Metal	Up to 300 GWd/MTU	To be evaluated*	No	To be evaluated*
HTGR	5 – 20	TRISO (UCO or UO2) in pebble bed or prismatic array	100-200 GWd/MTU	To be evaluated*	No	To be evaluated*
FHR	5 – 20	TRISO (UCO or UO2) in pebble bed	100-200 GWd/MTU	To be evaluated*	No	To be evaluated*
MSR	5 – 20	^{235}U dissolved in molten salt	To be evaluated	2-3yrs	Yes	To be evaluated*

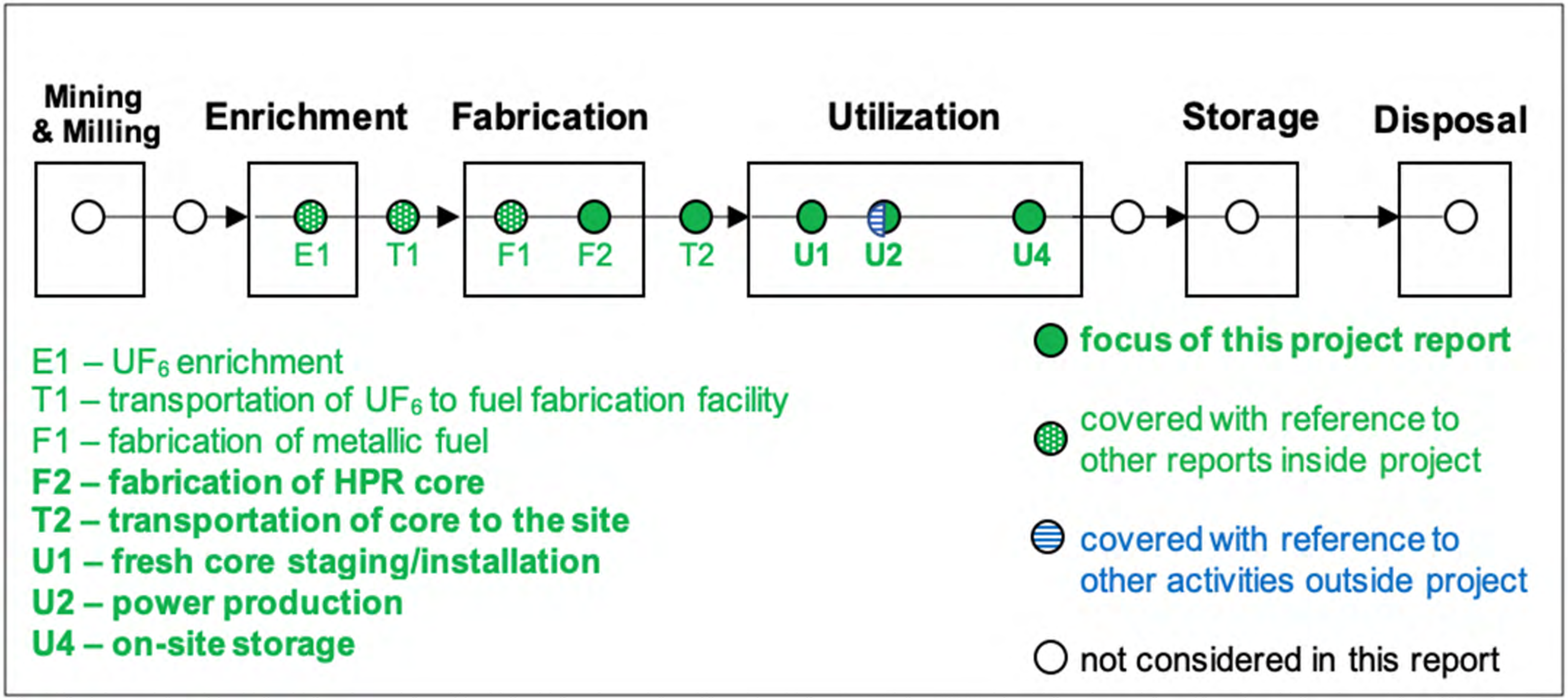
*Will be evaluated based on information available at the time work is undertaken, e.g. based on current DOE and industry input.

FHR Fuel Cycle Report



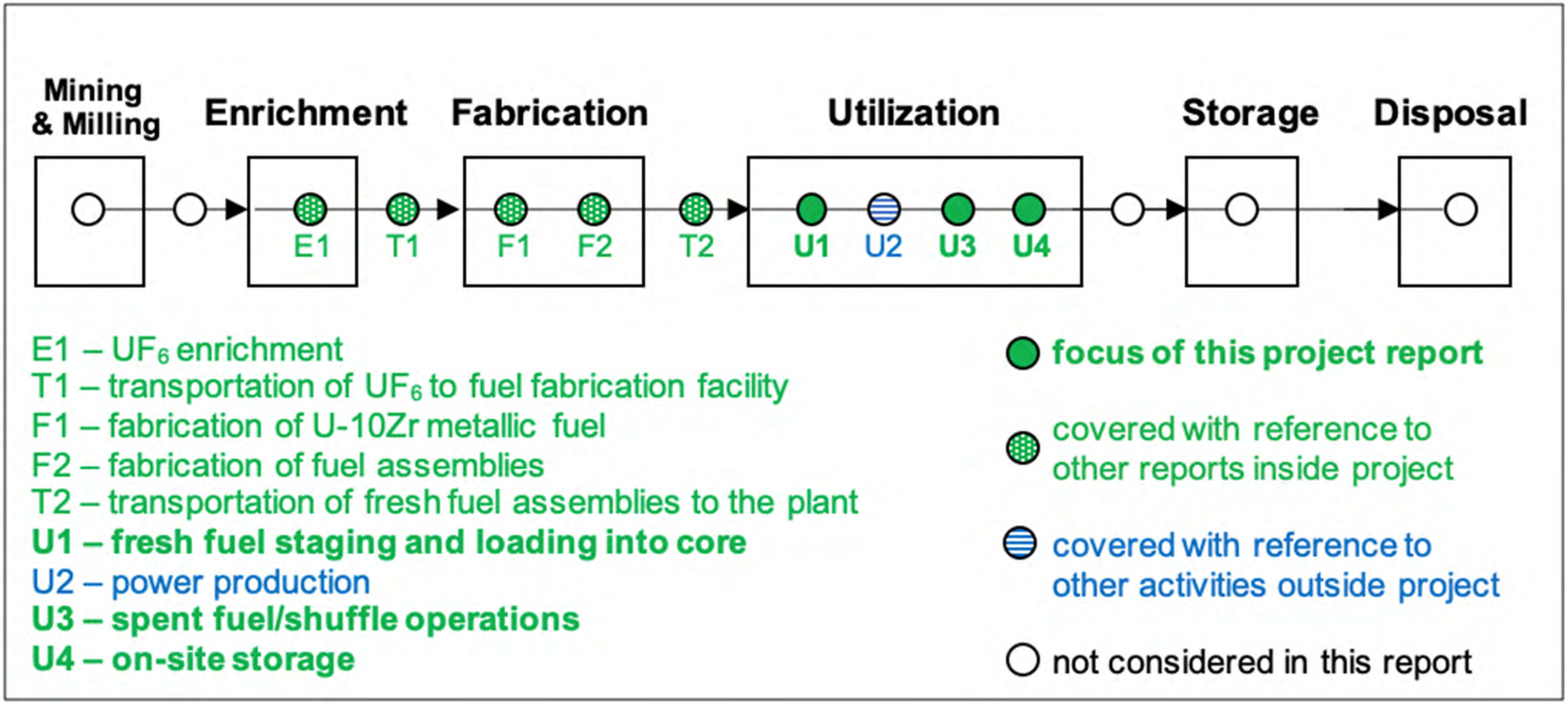
The FHR fuel cycle report develops and analyzes new accident scenarios related to stages U1 and U4 and links them to earlier front-end stages (E1, T1, F1, F2, T2) analyzed in this project and in-reactor scenarios U2 from volume 3.

HPR Fuel Cycle Report



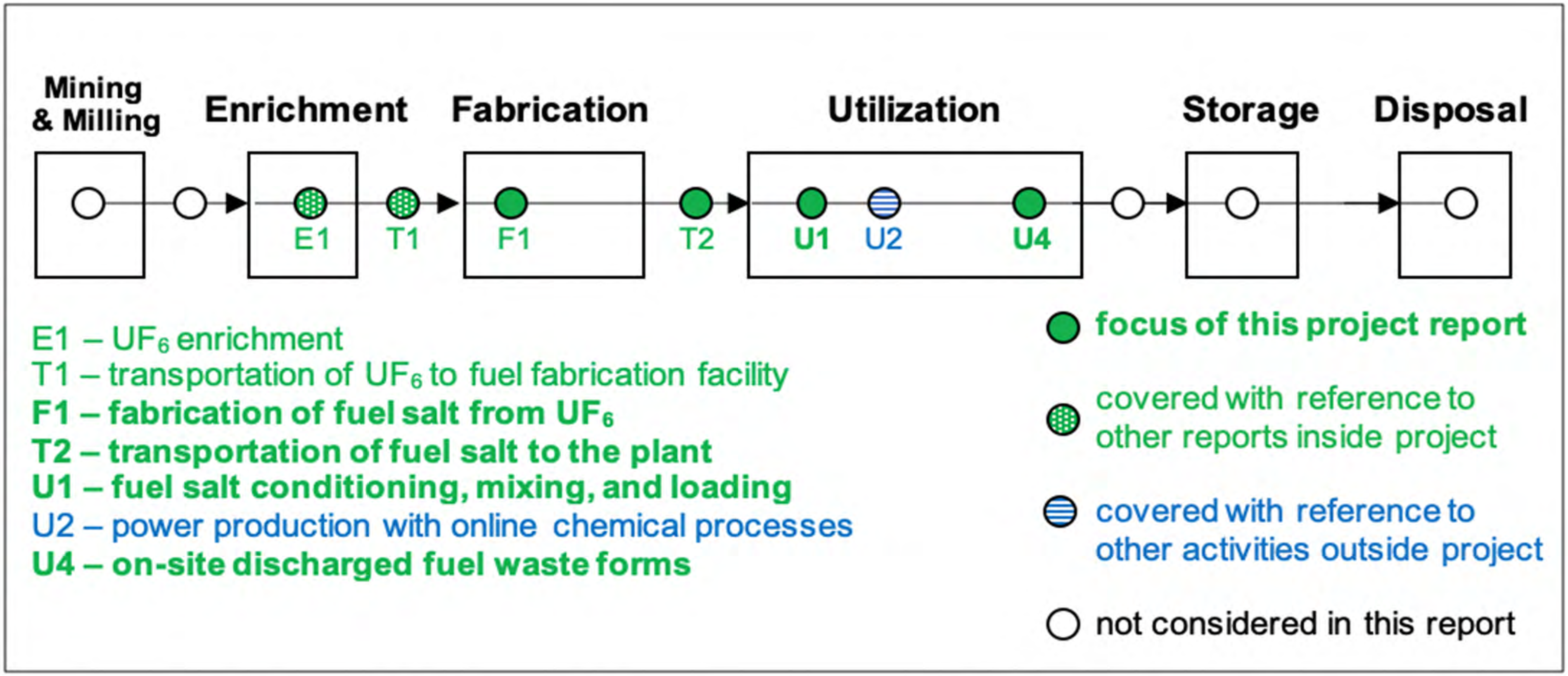
The HPR fuel cycle report develops and analyzes new accident scenarios related to stages F2, T2, U1 and U4 but also requires re-analysis of U2 for a metallic fuel system (current source term demo calcs using oxidic fuel). NOTE: The F2 and T2 front end stages are included in this report because fabrication and transportation of an HPR core will be specific to that design and thus nothing is gained from putting those stages in their own analysis reports.

SFR Fuel Cycle Report



The SFR fuel cycle report develops and analyzes new accident scenarios related to stages U1, U3, and U4 and links them to previously studied E1, T1, F1, F2, and T2. NOTE: The F2 and T2 front end stages are not developed as separate reports, since fabrication and transportation of an HPR core will be specific to the reactor design. Nothing is gained from putting those stages in their own analysis reports.

MSR Fuel Cycle Report



The MSR fuel cycle report has the least overlap with any other design and develops and analyzes new accident scenarios for F1, T2, U1, and U4 in the main MSR analysis and links them only to front end E1 and T1 for UF6 enrichment and transportation.

Leveraged Programs

- HALEU
  - UF_6 transport packages
  - Fresh fuel transport packages
- Volume 3 (codes and plant models)
  - Capabilities to characterize utilization stage
  - Hazardous material transport for non-water systems
- DOE Programs
  - DOE-NE spent fuel and waste science and technology program
  - Support hazard identification and characterization