UNITED STATES

NUCLEAR WASTE TECHNICAL REVIEW BOARD

WORKSHOP

On Evaluation of Waste Streams Associated with

LWR Fuel Cycle Options

Monday

June 6, 2011

Hilton Arlington Hotel
950 North Stafford Street
Arlington, Virginia, USA 22203

NWTRB BOARD MEMBERS PRESENT

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P R O C E E D I N G S

8:30 a.m.

ABKOWITZ: I want to welcome everybody to the Nuclear Waste Technical Review Board's Workshop on Evaluation of Waste Streams Associated with Light Water Reactor Fuel Cycle Options.

We have a packed house, which is very encouraging. This is an activity that actually was spawned about a year or so ago. The Board had an interest in being able to understand the waste management implications from various fuel cycles. And, from that interest evolved our own initiative to develop tools to be able to forecast what the waste streams would be from various fuel cycle options. And, of course, there's a number of other organizations that have had that interest and have been working in that area for some time.

And, so, the thinking was well, if we're all working on parallel paths, let's try to see if we can come up with a way of evaluating how we're approaching this problem so we can understand what our similarities and differences are and think more proactively about how we might be able to work in the future, as interest in this area continues to grow and evolve. And, that's essentially what led us to where we are today.

I want to spend some time going over the workshop objectives and scope because I think it’s very important to lay the groundwork on the front end in terms of what the expectations are here and what the rules of engagement are. There are hard copies of, I believe, every presentation that will be made today, and, so, I encourage you to have those. They’re out in the foyer. And, I’m going to spend a little time going through this first presentation.

If I could have the next slide, please?

The important objectives are shown here, and I think the one that I really want to underscore is the first bullet. There are several words in here that are important in terms of what they mean to this exercise. First of all, this is a benchmarking workshop. Okay? A workshop in the sense that we’re working constructively together. It’s not a conference where we’re presenting final results and coming up with conclusions and findings, and all that other kind of stuff. This is a working session and the word “benchmark” has important significance because we have picked some scenarios that are not meant to be preferred waste management policies. They are, rather, scenarios that we think a lot less to look into various elaborations of different activities that are under consideration so we can see how each of us are handling it.

And, so, it’s very important that we recognize that nobody is right, nobody is wrong. There may be differences, and we want to explore why those differences occur, and the underlying assumptions that are driving those things. So, I encourage everyone to be, you know, particularly gracious in the way in which their approach is represented and evaluated. But, at the end of the day, this is about trying to learn from each other and work towards a consensus on how we're going to look at these problems going forward.

In that context, we start very fundamental with the information that's available on the inventory today, so we can establish consistency in our input assumptions, how we calculate spent fuel generation and management going forward. We want to see how those calculations manifest themselves and the results, and as I mentioned before, reaching consensus on areas of agreement.

I looked at this little ICON from Google, and I had no idea that it was actually a motion. But, I don't want anyone to think that I've got that type of Power Point down.

If I could have the next slide, please?

I think it's important to recognize that this particular exercise is focused on light-water reactor world. There are a number of you that have extended your work beyond this to fast reactors and other reprocessing technologies, but this is the way that we want to start.

Obviously, if things go well in terms of how the community feels about this activity, there's plenty of room in the future to have additional workshops that will get other phases of what might be in front of us in terms of nuclear power production and waste management.

The way that we structured this particular workshop is in five sequential scenarios. We start very simple with just looking at the data that was available in 2009, December 2009, and just asking how you are working with that information as a baseline.

We then fast forward to 2100, or the period of time from now until 2100, to look at your predictions for, or calculations for how spent fuel is discharged. 2100 is not a magic number, but it has traditionally been the time period that a lot of people have been thinking and discussing, and so we figured that that’s as good a time as any in terms of establishing a consistent way of looking at this problem.

We then introduced repositories into the equation, and looked at what the impact of repository operations would be on the waste management stream.

And, then, independently we bring in the reprocessing and fabrication, but note that we’re just looking at PWRs. Again, this is because it’s just the way that the exercise is being constructed, so that we don’t get too complex in our interactions with a variety of things going on at once.

And, then, we bring together the repository and the reprocessing activity to look at how they work as a tandem.

Next slide, please?

I hate to define things this way, but the way that we have to operate going forward in planning this workshop is we kind of have a caste system. We have participants and we have other attendees, and that's not to mean that everyone in this room is not important. But, there are a group of organizations that have put a lot of time into getting ready for this, and they've done that because they responded some time ago to a desire to look at the scenarios and use their tools to come up with predictions that we could discuss today and tomorrow.

And, so, we have what we call participants, and they are seated at the table directly in front of me. We actually have five participants that will be involved in this activity. We have the NNL and AREVA, MIT, the Nuclear Waste Technical Review Board, and INL, and I don't know whether INL is representing DOE or not, but we'll let Steve make that clarification.

And, then, we have other attendees. And, in the other attendees category, that's all the rest of you. Okay? And, the way that we want to operate is that the participants have a privilege to be able to ask questions and interrupt as we go through the presentations. The observers have an opportunity at the end of each presentation to ask questions and offer comments. And, then, we will have also a public comment period where additional opportunity to speak will be presented.

I don’t want you to think that we don’t care about your opinion. We just have to have a certain amount of structure and order to this, despite the fact that it’s a workshop.

If I could have the next slide, please?

If you look at your agenda, it’s parsed into several activities. I will be starting off momentarily here, giving you a little more background on the scenario definitions and analysis phases. You saw a slide just a minute ago that just showed the five different phases. There’s obviously more detail behind each of those, so we’ll go through the assumptions and the output measures that we’re looking for. And, then, we’ll actually jump into hearing from the presenters.

There are five different tools and methods that will be discussed. Initially, we’re going to ask presenters to just give us the background information, perhaps the motivation for why they designed the tool, some of the capabilities that are inherent within it, and what their plans going forward might be.

And, then, we’ll jump into five different sessions where within each session, we go through a scenario, obviously, starting with the first one and moving forward. In those cases, we will be hearing from each participant, sharing with us the results that they have for that particular scenario. And, then, we'll have a round table discussion following where we've done the best we can to bring these together in a spreadsheet that we'll be putting on the screen, and that will be the basis for being able to see what we have in common and what we don't, and discuss some of the differences, and so forth.

The final session--oh, I should add there's another session, a very brief one, that's in here between the analysis results and where we go from here, a late addition to the program, Terry Tyborowski from DOE EM, is going to make a short presentation to tell us what they've been doing in this particular area.

The final session, which will be chaired by Nigel Mote, is Where Do We Go From Here, and this is going to be a roll up the sleeves, ad hoc conversation to try to get our arms around what we've concluded over the last couple days, and determine what type of path forward, if any, the group as a whole would like to move on.

Can I have the next slide, please?

I think it's important to emphasize that this is a public meeting. And, the reason for emphasizing this is that you are being recorded. So, anything that you say is going to be transcripted, and it will be on the website.

Also, all presentations and documents that are available will be put on the website as well, as are any documents and written comments that the observers may want to share with us at some subsequent point. I mentioned before that your input is welcome and actually encouraged, but at the appropriate times.

Just a very quick word about the Board. Most of you are pretty familiar with us, and most of you probably have an opinion of us, and keep that to yourselves. Remember you are being transcripted.

But, we were established in 1987 as a part of the Amendments to the Nuclear Waste Policy Act, and we have a very specific mandate. That’s to be independent and to focus on the technical evaluation of activities that the Department of Energy takes on with regard to two specific waste streams, spent nuclear fuel and high-level waste, and that includes both commercial, research and defense related streams. We also have an obligation to report at least twice a year to Congress and the Secretary of Energy.

We have eleven Board members that are nominated by the Academy of Science, and appointed by the President. Those appointments are for four year terms. I am pleased to say that we have actually six members with us today, and I’m going to call them out by name and just ask them to identify themselves. Andy Kadak, Ron Latanision, David Duquette, Howard Arnold, myself, and who are we missing? Ali Mosleh. Ali is the one local, and, therefore, he's commuting here, and you know what that means.

The next slide, please?

That's all I have as far as introductions are concerned. And, before actually getting started, I'd like to ask the participants that are at the table to each identify themselves and their affiliation, and then I think we can proceed into the next session. Marie?

BRUDIEU: Marie-Anne Brudieu. I work with AREVA.

SHWAGERAUS: Eugene Shwageraus, I'm visiting professor at MIT.

PIET: Steve Piet, Idaho National Laboratory.

GREGG: Robert Gregg from the UK National Nuclear Laboratory.

ROWE: Gene Rowe, Staff, Nuclear Waste Technical Review Board.

MOTE: Nigel Mote. I'm the Executive Director of the Nuclear Waste Technical Review Board.

ABKOWITZ: Before we proceed, are there any participants or Board questions or comments?

KADAK: Could we find out who else might be here?

ABKOWITZ: Well, I'm always given a hard time for running late, but given the circumstances, I think that's a good idea. So, why don’t we go ahead and start to my right here.

LOVE: Greg Love with the MITRE Corporation.

ABKOWITZ: If you would just speak up because it’s a big room.

LOVE: Greg Love with the MITRE Corporation, supporting DOE EM.

HOFFMAN: Ken Hoffman, also MITRE Corporation.

GIDDEN: Matthew Gidden, Hillside Group, University of Wisconsin, Madison.

PASSERINI: Stefano Passerini, MIT

SOWDER: Andrew Sowder, EPRI

WELLS: Andrew Wells, consultant for EPRI and now for NWTRB.

MC CULLUM: Rod McCollum, Nuclear Energy Institute.

MARKLEY: Chris Markley, NRC.

COMPTON: Keith Compton, US NRC.

PENADA: Christine Penada, NRC.

VIENNA: John Vienna, PNNL.

BULLEN: Dan Bullen, Defense Nuclear Facility Safety Board.

FRISHMAN: Steve Frishman, State of Nevada.

BENTZ: Ed Bentz, Bentz and Associates.

WORRALL: Andy Worrall, UK National Nuclear Laboratory.

LEE: Kwan Lee, NRC

AHN: Tae Ahn, NRC

SIPPEL: Tim Sippel, NRC

RIGBY: Doug Rigby, NWTRB Staff.

KIRSTEIN: Bruce Kirstein, NWTRB Staff.

BARNARD: Bill Barnard, general public.

METLAY: Dan Metlay, NWTRB Staff.

PHILLIPS: Chris Phillips, Energy Solutions.

CROFF: Allen Croff, Blue Ribbon Commission.

WILLIAMS: Jeff Williams, Department of Energy.

ZIEGLER: Joe Ziegler, Nye County, Nevada.

ABKOWITZ: Bruce, do you have a name?

KIRSTEIN: Yes, I already gave it.

ABKOWITZ: Oh, I’m sorry. We have an absent minded professor after all. So, in any event, I do want to point out that Dan Bullen is a former Board member, and Bill Barnard is former Executive Director of the Board. So, we have those little bit of an alumni.

If we could move on to the next session? I’m going to go over these scenario definitions and analysis phases. It’s very important, I think, for everyone to understand the assumptions that are embedded in the scenarios that we described. And, it’s going to be pretty difficult to just absorb whatever is on these slides without wanting to have reference to them. So, I would encourage you to, if you haven’t already done so, at the break, make sure that you get a copy of this particular presentation, because as we go through each of the scenarios, you will want to have these assumptions available to you, as well as the output measures that we’re seeking.

If I could have the next slide?

I mentioned before, we’ve got five analysis phases. They are actually numbered, and so as we go through the presentations, you will see people referring to these particular phases. In fact, it may actually have a two point in front of it. I don’t know how people are showing their results, but there’s definitely an order of one, two, three, four, five, or 2.1 through 2.5.

Next slide, please?

The first scenario phase is the characteristics of the U.S. spent fuel inventory as of December 2009. This is the beginning of the benchmarking to make sure that we’re all starting at the same point. As part of the exercise, the Board provided databases to the various participants as the source of that information, and that then launched everyone basically having the same inputs to begin with.

And, what we asked in this first exercise was simply to take that inventory information, and to look at the PWR assemblies and BWR assemblies and how they end up moving forward in terms of matches with various products.

As far as assumptions in terms of the

characteristics of each of those assemblies, we asked the participants to assume that the PWR assemblies have the uranium mass 235 enrichment percentage of burn-up, as you see on here, and similarly the same information that’s characterized for BWR assemblies.

Next slide, please?

The output measures that we’re expecting the various participants to provide in their analyses are listed here. We’re basically interested in masses of various kinds, both totals and certain isotopes. And, keep in mind again the target here is the beginning of 2010. So, it’s really essentially not all that different than the information we had in ’09. This is just information to understand how that inventory information translates in people’s codes to what we see here.

I might also point out before we go much further, that not every participant has performed every analysis. And, so, consequently, we want to leave room for different participants to excuse themselves from different parts of the exercise. And, again, that doesn’t mean that they’re deficient. It just means that the way that they approach the problem doesn’t allow itself to be translated into the manner that we wanted.

I also should mention before we go any further that on the agenda, there is not a specific work of participants listed for presentation purposes, and, so, we did the what we call FIFO in the simulation role, first in, first out. So, consequently, the announced order going forward here will be the NWTRB, NNL, INL, MIT and AREVA.

I also want to point out that we have two screens, and we have all of your slide presentations available to be projected on both screens. So, use that as a tool to whatever extent you like in order to make sure that we have the type of information available for people to see that will help explain what you’re doing.

I would also like to acknowledge Howard Arnold, who has arrived.

ARNOLD: I’ve been here at least ten minutes.

ABKOWITZ: Oh, okay. Okay, next slide, please?

Moving into the second phase, we’re now moving to 2100, but we’re not introducing any reprocessing or repository activity. This is purely looking at how much spent fuel will have been discharged over essentially this century. So, we take the previous assumptions. We further assume that every nuclear power plant, that is in operation starts on the 1st day of the year, and goes for 60 years. We’re assuming constant nuclear power generation, so that you when you have to retire a plant after it’s operated for 60 years, another one pops up in its place starting on January 1st of that coming year.

We are assuming plant capacity factors of 90 percent, and then you see the PWR and BWR fuel assemblies discharged their initial enrichments and their burn-ups, again reflecting what we, you know, sort of put as a marker in terms of burn-ups and enrichment requirements going forward.

If I could have the next slide, please?

The outputs that we’re looking for are essentially masses of various isotopes that are considered to be the ones that most people are particularly interested in, as well as the overall mass of fission products and minor actinides, and the option was provided to either list that information by isotope or as a total. And, then, we’re also interested in the total number of PWR and BWR assemblies that are discharged.

If I could have the next slide?

We’re now, staying with 2100, but we’re now introducing a repository, and that repository starts in operation in 2040, and we look actually at two scenarios. But, you will see two sets of results. One for a repository capacity of 1500 metric tons per year, and the other 3000 metric tons per year. And, again, there is no reprocessing in this particular scenario. We also specified the situation with regard to when spent fuel is eligible to be put in the repository. It must be at least ten years old, and fuel selection starts with the oldest fuel first.

Now, the reason we did this was just to establish a consistent way of interpreting the eligibility of undispensed fuel and how it’s used, so that that doesn’t create a disparity in how people are looking at the problem.

Next slide, please?

The output measures here are pretty straightforward. We’re just looking at masses of PWR and BWR spent fuel. But, you will notice that we are interested in looking at those on a yearly basis from the current period of time to the year 2100.

Next slide?

Okay, things get a little bit hairier when we start introducing reprocessing for the fabrication of PWR MOX and recycled UOX fuel. Again, keep in mind we just, in this exercise, looking at PWR. There are a number of additional assumptions that you see listed here. One is that there’s a sufficient quantity of PWR spent fuel in order to operate at full capacity in a reprocessing facility. And, you can see the conditions under which we are assuming that the fabrication will take place.

All other spent fuel, other than the spent fuel, the PWR spent fuel used for reprocessing, is assumed to be stored. There is an unlimited amount of natural uranium available, and also an unlimited amount of natural uranium enrichment capacity, and new uranium UOX assembly fabrication capacity, again, to make sure that that's not a disparity that's going to throw off one person's calculations from another.

And, then, there's a steady state assumption across a number of different facilities, both on the power production side and also on the fabrication and reprocessing side.

Part 2 of the assumptions gives you much more detail in terms of how the PWR MOX and UOX assemblies are expected to be fabricated. I'm not going to read this or get into great detail, other than this specification is something that we discussed with the various participants. We went through some iterations, and having heard no further constructive comments that we needed to change it, this is how it appeared and how everyone presumably has dealt with that particular process.

In this particular scenario, we actually looked at, I'm sorry, this particular phase, we actually looked at six scenarios. It looks more complicated than it really is. We basically have two different reprocessing capacities, and three different ages of the fuel, and, so, essentially you have six different combinations. And, that's what you see listed here.

The next slide, please?

This is what we’re expecting out of Phase 4. Pretty much some of the same things we’re looking at more at the top, but we are interested in looking at percent reduction in total natural uranium demand. You know, again, this is not an indication of how much reprocessing is going to be able to reduce the natural uranium demand. This is all scenario-driven, so we don’t want to get into, you know, you said 7 percent and I said 14 and someone else said 25. That’s not what this is about. It’s all strictly related to the scenarios that we provided.

We’re interested in the total number or mass, and isotopic composition, of various assemblies that are fabricated, and we’ve got four different categories identified here, which I think is important so that we can drill down and get a better understanding of how each participant is looking at this from the perspective of several different ways in which the assemblies are utilized.

And, then, finally, we’re looking at the mass of the tails that are generated, and we’d like to have that information in two different segments, the new uranium tails and the recycled uranium tails.

Moving finally to Phase 5, we’re now introducing reprocessing with repository disposal, so the two are being brought together. And, again, we have two scenarios that date back to what we looked at before in terms of reprocessing capacity. One at 1500 metric tons a year and the other at 3000.

The rule of engagement here is the fuel has to be at least five years old for reprocessing, and the fuel selection is youngest fuel first. And, then, you see the assumptions that are associated with how PWR fuel is to be fabricated, with the rest of the spent fuel going into the repository. And, the assumption that you see at the bottom is exactly the same as the assumption that was in Phase 4.

Moving to the next slide, the next two assumptions are also similar to what was in Phase 4, which makes sense since we're carrying the reprocessing over to Phase 5. The repository in this case starts at 2040. We're only looking at one particular capacity, which is 1500 metric tons per year. And, an important assumption is that the high-level waste that's coming off of the reprocessing activity is disposed of in the same repository and in the same year the separation takes place. And, the repository has an unlimited disposal capacity.

And, then, of course, the last assumption here with regard to spent fuel, is it's aged before it's eligible for repository disposal.

Last but not least, we have the following output measures, which are essentially a combination of the kinds of things that we were interested in in Phase 3 and Phase 4, basically brought together again.

So, that pretty much runs you through quickly a very detailed set of phases and assumptions and output measures. And, as I mentioned before, I would encourage everyone to have this slide presentation close by so that when we get into the meat of everything, you will be in a position to file back to these things, and recognize why certain participants handled things certain ways in order to maintain a consistency with what we have.

That's enough for me. Oh, Nigel mentioned one other thing that I should reiterate. We consider this workshop informal. He wanted me to actually take my tie off in front of all of you. That would be a little bit theatric, but don't be surprised in a short while if you see me with an open collar. And, those of you that breathe easier that way, I encourage you to do the same.

I'd like to ask any of the Board members if they have anything to add, subtract, integrate.

(No response.)

ABKOWITZ: Okay, how about participants?

(No response.)

ABKOWITZ: Okay, well, I'm always accused of being late, so I'm going to keep this ten minutes in the bank. We're going to break a little bit early. We had only planned for a 15 minute break, so given the number of people here, and the folks I'm sure you want to talk with, we'll just plan on taking a more extended break, and we'll reconvene at 10 o'clock.

(Whereupon, a brief break was taken.)

MOTE: As Mark would not do it, I'm going to show this is informal. But, I'm only going down to the tie.

I would like to make some other announcements, or pass some information on. First of all, would everybody turn off their cell phones, please, so we don't have interruptions. Nobody has had that happen so far, which is good, so, it would be good if you would turn your phones off or on silent.

You will see from the agenda, that we have a lunch break at 12 o'clock. We are being flexible with the time scale here. That doesn't mean to run on, but we'll bend the time, we'll bend the agenda as necessary. Just make the most use of the time to get to the best end point.

There are no arrangements for lunch, so everybody is free to do whatever they want. In this part of the D.C. area, there are many restaurants within easy walking distance. You could probably get any that you want. We will start back at the time that we agree from the end of this session.

Both of them wanted to be at this workshop and wanted to come and present results. The IAEA in particular came to be here unintegrated. This week, they have a technical working group meeting from the section of the IAEA called NEFW, Nuclear Energy Fuel Cycle and Waste Management, I think it is. And, at that technical working group, they will be discussing things similar to what we are here, but not the codes. They're looking at fuel cycle alternatives. And, what they would like to do is have a debrief from this meeting at some point in the future. And then they even asked that from this workshop, we make a presentation, at this point, it's not clear whether that would be a presentation just of the overall results of the workshop, or if they would like the presenters to go and be involved in a meeting where you actually present the results again. But, in the future, they want to be very much more integrated and informed about what we're doing.

AREVA has a presentation, as do the other presenters. There are some minor changes to the presentation slides. What you see on the screen today will be the updated version, and before the end of the workshop, maybe this afternoon, maybe tomorrow morning, there will be updated copies of the printed version on the table outside. So, for today, you may see some differences between the paper copies that you have from the table outside and the presentation that Marie-Anne will make from AREVA.

Can I ask also that everybody here signs the sheet outside, unless they're a participant? Because Scott Ford, who is making the transcription of this meeting, will not have heard all of the names that were spoken before, because not everybody had a microphone. So, it would help if we make sure that everybody is signed in whose details are not known to the Board.

Okay, those are all the introductory statements I wanted to make.

So, this session is going to be a description of the codes, tools and models, as we call it. We're going to kick off with Gene Rowe making a presentation on NUWASTE, that is the Board's model. And, after that, we'll go through in the same sequence as Mark outlined before, a presentation by the other participants.

In many cases, I think in all cases, the participants have one presentation, which includes an overview of the system, and also the phase results in Phase 1, 2, 3, 4 and 5. For this presentation now, what we'd like is just the description of the code itself, the mechanics, the systems, the inputs, the assumptions, the short-comings, the particular features that are of note for this workshop. So, where there are presentations that go beyond that, maybe we can ask the presenters to only present the descriptions of the code, and limit that to this session, and then we will pick up the individual phased results presentations in the later sessions this afternoon and tomorrow morning.

Okay, Gene?

ROWE: Thank you. My name is Gene Rowe. I'm a Staff with the Nuclear Waste Technical Review Board. I'd like to thank Mark Abkowitz, Nigel and Bruce Kirstein who assisted in putting the presentation together and helped with the formatting and development of the NUWASTE code.

I would like to point out something right off the start, and that is the name of our organization. We are Nuclear Waste Technical and Review. And, the reason I point that out is because--because of what our charter is, is what determined how we structured NUWASTE. We are focused not on developing a fuel cycle, or a solution to the energy situation in the United States. We are focused on the nuclear waste. That's the first point.

The second is that we are a technical board, so we are not--we try, and sometimes unsuccessfully, but we try to stay away from the policy issues associated with the nuclear industry, and only look at the technical aspects.

And, again, we are a review board. Our charter, if you look at our charter, our charter is to review DOE's implementation of the Nuclear Waste Policy Act. So, we again try to stay away from specific recommendations. But, rather, we do review of what DOE is recommending.

So, I think that's important because that is really what drove us to the structure that is within NUWASTE.

And, basically, I'll just quickly go through the objectives, the principles, the structure, the waste stream calculations, how we process the assemblies, and some of the calculation methodologies.

Our objective with NUWASTE was first to understand the impacts of the fuel cycle initiatives on the generation and management of waste, both high-level waste and spent nuclear fuel. We tried to make the system as flexible as possible in order to evaluate whatever DOE comes up with this as a recommendation, so we tried to structure it to be as flexible as possible.

Because our main objective is to evaluate a recommendation from DOE, we spent a lot of time in the part of the program that actually does the evaluation. And, I'm not going to get into that during this presentation because we're really focused on how the main program operates. But, we do have a very detailed portion of the program that allows us to evaluate and compare various options within the various parameters of the nuclear waste industry.

The principles. It's really a simple program. It's based on a simple material balance of assemblies and masses, keep track of the goes-ins and the goes-outs, and if they're equal, then we're probably okay.

It's built on fundamental physics concepts and methods. We didn't try to do anything unique or new. We tried to make it as simple as possible so that it would run relatively quickly. And, so, you will see as I go through some of the details, that we make a lot of assumptions in order to try to make it, again, as flexible and operate as quickly as possible.

It covers a full life cycle of the U.S. nuclear power production, as it stands now from production through waste disposition, and looks at various options for waste disposition.

It utilizes data from the open literature and some DOE documents from the Yucca Mountain Project. It's interesting, there's a lot of discussion as to whether to go probabilistic or deterministic. In general, the program uses deterministic methodology throughout. And, the reason for that is, again, we're not trying to get an answer. One of the things we're trying to do is to understand the impacts of various parameters on the results. And, so, if you go into a probabilistic methodology, it could mask some of those results.

So, by enabling the program to change one variable and evaluate what the impact is on the results of changing that one variable, we get a better understanding of what impact that variable has. So, that's why we did proceed with a deterministic methodology.

And, I think as Nigel and Mark indicated, we're focused on the present light water reactor and reprocessing technology.

The structure has two main modules, if you will. It's the waste stream quantities, and as Mark indicated in his opening remarks, we establish the initial conditions, which is based on some DOE data of what is presently in storage, and then some calculations to predict what the assembly discharges will be over any given period of time.

Assembly processing is the main module of the program. Again, it's really got two main parts. It's a material balance, where we make sure the masses and the assemblies, the goes-ins and the goes-outs, are always equal, and then the transitions, the transitions from mass to assemblies when you fabricate an assembly, and then from assemblies to mass when you reprocess, if reprocessing is one of the options.

And, I'd like to spend a little bit more time on this because it's--click on that, would you? Click on that one. What I did is I ran a bunch of ORIGEN, using ORIGEN/SCALE 6 calculations to determine what the isotopic concentrations are for various burn-ups. And, in going through this over the last year or so, I got this feeling it was relatively linear. And, when I plot it out, as you can see, and this is only a couple of the isotopes, these happen to be uranium, a couple of the uranium isotopes, but you can see that the weight percent is very linear as a function of burn-up.

If you go back to the previous spreadsheet, go all the way up to the top. Okay, so if you look at the top numbers, I wonder if I can do this--there we go. These are for the BWR assemblies and these are for the PWR assemblies. These results here, the results come right out of SCALE. Okay? And, as I said, you know, gee, it looks pretty linear. So, I did some high-level math, Y equals MX plus B, and I calculated M and B, okay, and then I used these M and B’s to calculate the isotopic concentration for each isotope as a function of burn-up. Then, I compared these results, my calculated values, to the results out of ORIGEN, and I calculated the errors.

And, actually, if you move either left or right on this spreadsheet, actually, I’m running about 65 isotopes, and you can see that the errors from my calculation, and what the output of NUWASTE is, are very, very small. And, so, this is how I calculate when I do the separation calculation, I don’t go off to ORIGEN and do the separation calculation. I use this relationship that I’ve established in the spreadsheet to do the calculation. And, what that does is it allows me to have a variety of burn-ups, and I can get the isotopic content for just about any burn-up within reason.

So, again, this is a simplistic method, but it gives me reasonable results, and it is very quick, which is important to me.

This is the basic structure of NUWASTE. Basically, you can start down here with the mining of the uranium ore and the enrichment and the fabrication of assemblies, and my terminology, I have to apologize, U0, U represents Uranium, Zero is it has not been exposed. So, it's a fresh uranium assembly. The nuclear power plant, it stays in the nuclear power plant for a certain amount of time, and then goes off into commercial spent nuclear fuel inventory.

And, since it's been exposed one time, it is now considered a uranium first number one assembly. Those assemblies, for those types of assemblies, two things can occur. The priority is if we have reprocessing available, is to send that to a reprocessing facility, and there's a defined minimum/maximum age and selection sequence, so that we can really define what the reprocessing process will be.

Then we do chemical separation, and basically, what we do is we divide the products into three main categories. We have the recycled uranium, the recycled plutonium, and then the fission products and minor actinides.

The recycled uranium can be re-enriched, and you can go and you can fabricate a new assembly from that, and that can go into the nuclear power plant, comes back into inventory as a second cycle--second generation uranium assembly. We only reprocess natural uranium assemblies in this module, and there's some reasons for that, which I'm sure AREVA will correct me on, but basically, the philosophy that we have is there is a very large inventory of assemblies out there, and you would need a very large, and some of the results will show that, you need a very large reprocessing capability before you run out of those assemblies.

The other fact is some of the physics of continuing to reprocess don't work quite as well as if you were reprocessing a first generation assembly.

So, we only reprocess, and you can see from this little diagram, the only thing that goes to the reprocessing, are the fresh uranium isotopes that are discharged. Everything else goes to the repository.

For the MOX, the plutonium comes out in the MOX. You obviously need some kind of uranium to mix with the MOX, and we have six choices for that uranium. I'm not recommending any of these, and I'm not saying that they're all practical, or whatever, but we wanted to evaluate what the impact of using various sources of uranium were. And, so, basically, you can use fresh uranium as the filler for the MOX assemblies. You can use enriched fresh uranium, or you can use the tails from the fresh uranium.

Obviously, what's done most of the time these days is the uranium tails from fresh uranium is what goes into the MOX fabrication. We can also use the same types of uranium from the reprocessed uranium. For all of the exercises we're doing today, we're obviously using the uranium tails from reprocessing fresh uranium.

For the waste stream calculation, basically, we establish some initial conditions of that, and this is the information that the Board sent out to all the participants, as to what is presently in inventory and what are the initial conditions.

And, plant parameters, such as megawatt thermal electric, core size, fuel pool size. BOL is beginning of life of the plant, end of life of the plant, and what the life extension status is for the plant.

And, then, the assembly storage status as of December 2009, the MTU and the number of assemblies, both wet and dry.

Okay, go to the next slide. Thank you.

The discharge calculation is a simple calculation. First, it looks at what the plant life is based on any life extension, whether the plant has already received the life extension, whether an application has been submitted for life extension, or whether no life extension has been submitted.

Again, what we're trying to do is model what the U.S. nuclear program is. And, so, we're trying to represent the U.S. fleet as accurately as possible. So, these types of parameters are important in that calculation. And, we can establish what kind of a life extension duration we can use. It’s a user input, generally use 20 years, what normally is used.

And, we know also we have three scenarios that we can run based on the generation. The present plants only, based on one of these life extension assumptions. Present plus planned, right now, and it changes every year, there’s something like 25 plants that have submitted license applications to the Nuclear Regulatory Commission, and, so, we have included those plants as a separate scenario.

And, then, we have included a third scenario, which is a scenario that we use for all of the calculations that are going to be shown today, and that is we have sufficient plants to maintain the present nuclear generation capacity, which is about 100.3 gigawatts.

I’m not going to go through this too much. This is just a flow chart of the waste stream calculation, the actual code that is used. And, again, it just goes down through and it looks at what year is the calculation in, and in that year, what is the condition of the plant. If it hasn’t started up, obviously, you don’t generate any new assemblies. And, if it’s within its operating life, then there’s a simple calculation that generates how many assemblies it made, and those will go into storage. If it's the year after the end of life, one year after the end of life, then it discharges the whole core, so that we can maintain the proper inventory.

It also looks at the size of the fuel pool to determine whether the waste goes into dry storage or wet storage. And, what we've done is maintained the pool at full capacity minus a core, which is basically what the NRC's tech specs require. And, we start unloading the core five years before end of life, and it's complete--we start unloading the pool five years before the end of life, and the pool is completely empty five years after end of life.

And, you will see that's important because you will see some of the curves that I'll show later, that where you would expect to see a very nice smooth curve of the number of assemblies that it discharged, and it's not, it kind of wiggles a little bit. And it wiggles a little bit because we are looking at the actual discharged assemblies, not just an estimation--not a calculation, but the actual discharge.

Okay, the main part of the program is the assembly processing, and it contains two nested loops. The primary loop cycles through the PWR assemblies and then through the BWR assemblies. The sequence is we try to reprocess the fresh uranium, UOX assemblies first, if we have a reprocessing capacity and we have assemblies to reprocess, and then we try to dispose of the assemblies. And, it goes by year, by year basis. Okay?

And, we look first at trying to fabricate MOX assemblies, and what we try to do is use all of the plutonium that was discharged, or that was reprocessed, or separated the year before. So, there's a one year delay in there from when the assemblies are fabricated and when the masses are separated. Then we try to do fresh--next we do separated uranium. We try to do as many of the reprocessed uranium assemblies, and then we do the fresh uranium assemblies. We fabricate enough of the fresh uranium assemblies to make up for whatever the demand is for that particular year.

I'm sorry, this is disposal. I'm sorry. We dispose of MOX fresh and then separated uranium. And then the fabrication sequence is MOX--this is still wrong--separated and then fresh. I'm sorry, those are backwards.

Then the secondary loop will cycle through the years. It starts at 2010, and it ends at the user defined variable, which in this case is usually 2100.

This shows a process which I'm not really going to go through too much, I basically did. It selects PWRs, and it goes through all the process for the PWRs, then it goes back up and repeats it for BWRs, updates some data, and then it indexes the year, one year, goes back to the top, starts with the PWR assemblies, and goes back down. So, it's just two nested loops.

Calculation methodology. The fabrication, full core assemblies are fabricated one year before the beginning of the life, and we assume that the plant starts operation on January 1st. We do one year time steps. Assume the same number of assemblies are discharged each year. Again, we're not trying to calculate, we're not doing core criticality calculations. This is an extremely simple calculation, which if you average it over the lifetime of the plant, I think gives reasonable results, and that's all we're looking for.

And, the assembly fabrication is just the thermal power times the capacity factor divided by the burn-up and the MTU per assembly, and that gives the number of assemblies per year. And, as I said earlier, we do a full core discharge the year after plant shutdown.

The enrichment calculation, again, it's pretty straightforward. This calculation comes out of the Reference Management of Reprocessed Uranium, and it just shows that the final concentration of the very isotopes is a function of the enrichment of the 235.

The feed and tails mass is a simple mass balance, solve the two equations and six unknowns, and you get these two equations. And, basically, you know what the enrichment is, what the feed mass concentration is, and what the tails concentration is, and you can calculate either the tails mass or the enriched mass or the feed mass, or the enriched mass, depending on which one of those variables you know. It's a simple mass balance, that's all.

Okay, the fabrication methodology is, as you know, the separated uranium has a build-up of U236 in it, which is a neutron absorber, so you have to increase the U235 concentration in order to compensate for the 236. Again, we try to make this as simple as possible. There's a curve that we got out of this reference that shows the factor K, which is the compensation factor, if you will, as a function of the U236 concentration in the new assembly.

So, we did a fit to this curve, and came up with this calculation to determine what the new assembly 235 concentration is. This is kind of a difficult equation to solve algebraically because of the exponents. So, what happens in NUWASTE is it just iterates the U235 until the equation converges.

And, this reference, and also I have a reference from Oak Ridge that indicated that at a certain point, the K factor approaches about .2 isotopically. So, for greater than .1 percent, then we just do a very simple calculation based on the .2 percent K.

The MOX fabrication, I want to thank my buddies from NNL, who provided a great deal of help, in coming up with again, a relatively simple methodology for calculating what percentage of plutonium goes into the MOX assembly, based on the quality of the plutonium. And, this shows for a particular plutonium vector, okay, the blue line indicates the data that comes out of the--I'm sorry, I can't remember the program that this comes out of. Is it--

GREGG: It was probably an CASMO simulation.

ROWE: Yeah, whatever. So, for a particular plutonium vector, okay, you get what the weight percent of plutonium is as a function of the equivalent U235 assembly. Okay? And, it's a pretty straight line. I love straight lines. And, again, I can use my good old Y equals MX plus B to come up with an equation to give me what the plutonium weight percent is for an equivalent U235 assembly. This is only for a specific plutonium vector. Okay?

So, if you go to the next slide, is that you can approximate for a different plutonium quality, you can estimate what the plutonium content would be by just a ratio of your reference quality to the actual quality of the plutonium, where the quality is defined as the sum of all the plutonium nuclides, times the effective fissile coefficient. So, again, it's a relatively straightforward calculation, and we'll see how the results compare to the other calculations.

I have to point out this calculation is assuming a .2 percent U235 in the uranium, which is a normal value for the tails concentration. So, I do a simple correction, which I look at the reactivity of the plutonium, and I just ratio that to the actual concentration of U235 in the uranium. So, that if we use .3, then it changes the plutonium concentration, obviously.

One of the other things we do in the program, is we look at the amount of low-level waste. This curve came from a DOE document that predicted various low-level waste streams from reprocessing, as well as from a repository. And, again, it’s a very simple calculation, do a Mathcad fit to get an equation to represent that line, and then the actual waste generated as a function of facility capacity is calculated. And, we do this for the various waste streams.

The direction, we’re still working at various scenarios and data sets to evaluate. We want to gain feedback from this workshop to make sure that we have some consistency with the rest of the world. We are looking at including facility costs into the calculation, as well. That’s an important variable, obviously. And, consider extending some of the NUWASTE capabilities, centralized storage, transportation, alternate reprocessing, reactor technologies, and disposition of DOE HLW and SNF.

I think that’s it. Any questions?

MOTE: Thank you.

WORRALL: Andy Worrall from the NNL.

I couldn’t see all the details of your spreadsheet with the isotopics, and so on. I guess the details aren’t so important, it's just to flag something. I think what you were saying is with all of your isotopics, you have a linear relationship, or you saw a linear relationship. I'm really surprised at that. For U235, that is not a problem, it's just depleting. But, if you look at some of the plutoniums, for example, the mechanism by which you generate, for example, Pu239, they also equate and then compete and wants to destroy it.

ROWE: Go to this slide. You notice that--what you're saying is right. Those lines are not quite as straight as the other ones.

WORRALL: It's just that I think in total plutonium, it's probably right. I'm just concerned with the isotopics, and the reason being is that then you start looking at mechanisms like curium, and so on, that then come from the plutonium, and the curiums, the one that gives you the heat, is the one that gives you the neutron doses, so when you actually look at an inventory analysis, whether it be CASMO simulator, as Robby mentioned, or whether it's ORIGEN, you begin to see kind of curves that then turn over and level. So, I'm just concerned. For the moment, you might be okay because you might be on that linear part of the curve. But, the higher burn-ups, and I don't mean super high, I'm talking about, you know, 40, 50 gigawatt days plutonium, you're going to see that curve change with the isotopics.

ROWE: Do you want to make that full screen? Yeah, you can. Next one, zoom to selection. Okay, you can see that the ORIGEN calculation, we’re up to 65 megawatt days per ton, and those curves aren’t really that linear. I understand what you’re saying and I agree with what you’re saying. Okay? And, if I was going to design a core, I wouldn’t do this calculation. But, I’m not designing a core. Let me see, we are the nuclear waste, we are looking at waste, okay, and this calculation is relatively simple. It gives me a lot of flexibility, and it gives me reasonable results. But, I agree with you.

WORRALL: It’s just the reason that’s linear on there is the weight percent is the total plutonium, when you’re actually looking at the plutonium vector, each of the isotopes within the plutonium, that curve is a lot more dramatic. I think you’re absolutely right. I think it’s, for the purposes of this, it’s fine.

ROWE: Yes.

WORRALL: But, I would just like to make a comment that be careful, because if this was the case, we wouldn’t need to use any inventory codes. The NRC wouldn’t require reactor physics calculations. We’d just use Excel and we’re all done. So, just be careful. A message can be interpreted in certain ways by certain people.

ROWE: That’s why I started this presentation as we are a waste organization.

WORRALL: It’s just a little flag, you know, buyers beware.

ROWE: I got you. Anything else? Yes, sir.

SHWAGERAUS: Eugene Shwageraus, MIT.

Just along the same lines, another comment on the non-linearity. The burn-up effect is just one thing to look at. Another thing is decay after discharge, you know, the age of the fuel is another factor that might come into play when you look at non-linear behavior.

ROWE: That calculation, what that is is the isotopic concentration at discharge.

SHWAGERAUS: Yeah, which is not interesting.

ROWE: No, but then I decay any isotopes that have a reasonably short half-life, then I decay off, you know, like the 241, the plutonium 241, et cetera. So, I decay in the krypton, I decay those off separately. But, I start off at the concentration at discharge from the reactor. But, you’re right.

SHWAGERAUS: Yeah, just another thing to be aware of, the age of the fuel.

ROWE: It makes a big diff.

SHWAGERAUS: Yeah, things become more--

ROWE: Well, that’s why we did the three scenarios, five year olds, 25 year old, and 50 year old, to show that difference. Anything else?

(No response.)

ROWE: Thank you.

MOTE: Thank you, Gene. It seems that we all are already finding interesting things to discuss about this before we even get into the results. And, as you will see, there are Excel spreadsheets printed out that are available now, and they will be the subject of discussion tomorrow--actually, I guess, starting from the discussions after lunch. And, one of them is that the MIT results do, I think, show the difference between aging and not aging the fuel.

SHWAGERAUS: Oh, absolutely.

MOTE: That was the Board’s model. And, next we have the National Nuclear Lab, and although we have Robby Gregg sitting at the table there, I believe Andy Worrall is actually going to do the discussion of the ORION code.

WORRALL: Okay, thanks. My name is Andy Worrall from the UK National Lab. I just wanted to do the introductory comments, and the codes, and so on.

Just a couple of words by way of introduction. Many of you may have not even heard of who the heck is the UK National Nuclear Laboratory, and I’m not standing here to make a pitch, the reason I’m standing here to mention this now is it gives us some kind of credibility and some justification for actually being here and participating in this, but also hopefully adding values.

The UK National Nuclear Laboratory, has actually been established in the last couple of years, and the comments of the wonderful decision--and, I say that very ironically, nobody can pick that up from the tone of my voice--the wonderful decision by the UK government to actually break up and sell off the UK nuclear industry, just at the time that the resurgence of nuclear around the world is happening. And, so, the organization that we came from was the British Nuclear Fuels, Limited, BNFL. And, if people hadn't realized it, there is no such thing anymore. The BNFL no longer exists.

And, the UK government, in 2005, decided to break up and sell BNFL. So, they established what is called the Nuclear Decommissioning Authority, and they took responsibility for not only the liabilities, for example, the Sellafield site, but also for the assets, things like the plutonium, the hundred plus tons of separated plutonium the UK owns is also now the NDA's responsibility.

So, BNFL was broken up. Westinghouse was sold to Toshiba. The likes of the back end of the fuel cycle was sold to Energy Solutions, here represented today, VT Group, et cetera, et cetera, and that left behind BNFL's research division, and they looked and said what the heck do we do with these people, so do we break them up and sell them, too, do we sell them off as one entity? And, they actually made a really wise decision. They actually decided to keep the organization together and form the UK National Nuclear Laboratory.

So, we are the former research division of BNFL, so we're now a government owned national lab. Okay? So, we're a government owned, contractor operated, so we're a GOCO, so very much like the U.S. national labs, and we actually often chair, in fact, another fact is that we're actually also managed by Battelle, amongst others. So, we're actually a consortium of CIRCO, which is an organization in the UK that manages things like prisons and national physical laboratory, and so on, on behalf of the government, Battelle and the University of Manchester. So, that's our contractor operated part.

The final thing I would just like to point out is a very important point. If you take nothing else from these introductory remarks, we are not funded by our government. We get all of our funding from customer work. Okay? And, that makes us unique as a national laboratory in the world, I'm sure. We get not one single cent from our government.

If you follow the pounds far enough back up the chain, they often do come from government. So, for example, we do work for the Nuclear Decommissioning Authority. We do work for the Ministry of Defense. So, we do work for cleaning of Sellafield, and if you follow the pounds back then, that leads back to government. But, we get not one single cent for underpinning R&D. Okay? So, we're here funded by a customer, not the NWTRB, but by our Nuclear Decommissioning Authority has funded us to be here. So, I just wanted to make that point.

Okay, so that's who we are. That's where we come from. So, the reason why it's mentioned already is our involvement in fuel cycle assessment, fuel cycle modeling is only one part of fuel cycle assessment, I just want to underline that point also. Fuel cycle modeling is part of an assessment that we do, and as part of BNFL, we've been involved in fuel cycle assessment, fuel cycle modeling for 30 plus years, and our direct technology at the time, as you may have heard, of Sue Eon (phonetic), Sue Eon had a very good vision years ago, 20 years ago probably, that said if I push and prod the fuel cycle somewhere, I want to know where it affects me elsewhere.

So, for example, if you change specifications of the fuel at the front end, what does it do on the back end, where is it going to bite. And, that was Sue Eon's vision. And, ORION that we're going to talk about here today is something that came out from that, from her vision. Okay? So, it's not, don't get confused with VISION, that's another fuel cycle modeling tool. That was her vision and this is part of it.

Okay, so that’s our background, our credibility. So, thanks for that. Next slide, please? Can you just bring all the bullet points up? That’s fine. Next one? Maybe next one? Okay, go back one. Okay.

So, the key thing here is this is slightly different in a sense. I think what we’ll hear from this point forward is what’s normally classically the fuel cycle modeling. So, the thing is with the fuel cycle modeling tool we’re talking about here now, this is very much what I think is more akin to the traditional fuel cycle modeling tools. So, we’re looking at classic production and movement of radionuclides in the fuel cycle. We’re looking at a whole type of different models. The most complex part, of course, is the transformation in reactor, and we’ll come on to how we do that shortly.

But, I think another important point is when we’ve been developing our fuel cycle analysis over the years, there are many different metrics, many different questions people will ask of you of the fuel cycle. It could be masses, it could be heat, it could be radiotoxicity, they are all the classics. We’ve taken that further over the years where we actually look at economics, of course, but also we’ve done a lot of work over the last few years, probably the last two or three years, in particular, in terms of the publication of work on non-proliferation, on how do you look at non-proliferation, the metrics thereof? We've actually narrowed that into our fuel cycle, too.

So, what it means is you can actually track how your fuel cycle is affecting, positively or negatively, the proliferation resistance, it's not resistant, it's just levels of resistance. Okay, so, we've done those kind of things. It's the tools we've developed are deliberately, incredibly flexible. They look at anything from thermal to fast reactors, to closed to open fuel cycles, thorium, ADS, we've pretty much fully analyzed most of them in different senses. And, of course, the time scales can be huge.

So, ORION is something that's been developed over the last probably ten years or more now. And, what you see there is just a screen catcher. My colleague, Robby Gregg, has done all the hard work. I'm just here, the front man, so Robby did all the hard work, and he will talk more through the details of how these models were put together.

But, what you see here on this is basically the user workbench that the users click and drag onto the desktop the respective fuel cycle components, and then they link them together, and you will see that they apply later into the NWTRB analysis.

So, typically, we're tracking things on a year by year basis, of course. We track up to two and a half thousand nuclides. We can actually take the likes of ORIGEN or FISPIN, is the UK equivalent to ORIGEN, we can take the datasets directly and run those codes directly from the fuel cycle model, using high performance cluster, these things can be cooled down and monitored, modeled. Of course, this would increase the run time no end.

Things often decay. The really important part, of course, is transmutation. In reactor, that's where the real engine and the changes are going to come, that's where the real hardware is. So, there's a couple different approaches here. You can use pre-calculated inventories that kind of sit in the database, a bit more like Gene was saying in terms of the interpolation side of things. But, also, we can actually pull off using specific cross sections from, typically we use CASMO for all our thermal reactors. For anybody who is a reactor physicist, CASMO simulate, used by more than 50 percent of the world's light water reactors, so incredibly highly validated, probably the most highly validated code system in the world, I would suggest, for light water reactors.

And, then, the second one, in terms of fast reactors, is the ECCO code suite from the CEA, very much again highly validated, used by U.S. national labs, and others, indeed. So, these are the kind of like approaches, very much the hardware groupings, a couple of different approaches that can be used here. And, you will see how we’ve done that when Robby talks later.

So, just a couple of slides by way of further background. And, we’ve published papers on ORION, and you will hear more details when we make the presentations themselves in terms of the assumptions and the approach we use, probably see more value in those parts. But, just a couple of points here.

We’ve applied these tools on quite a few different areas. One of the big activities at the moment in the UK is what the hell do we do with these hundred tons of plutonium that we’ve separated. So, we’re looking at a lot of strategies, technical and fuel cycle assessment strategies, whether that will be continued storage, immobilized, or indeed reactor reuse. So, we have looked at a lot of strategies for those things. And, we’ve come to conclusions that although we’ve got a hundred tons, that actually isn’t enough to give us a sustainable fast reactor cycle, depending on the growth of fast reactors you need. So, we need some more plutonium, exactly the same situation in France, for example. They’re about the same number of tons short. We can maybe do a trade. Looking at sustainability, again, that kind of growth, and environmental impact, and impacts on repositories, of course.

We’ve actually done a lot of work--and, again, this is quite interesting, the dynamics are here. Although, we, the UK that is, didn’t participate in GNEP directly, the Global Nuclear Energy Partnerships, we actually did work with Energy Solutions as a partner with Energy Solutions, to support the U.S. DOE and the programs there. So, it’s interesting, the UK’s national lab isn’t doing work for its own government. It’s actually doing work for the U.S. Government and the U.S. company. So, that’s politics for you. So, we’ve done a lot of work with Energy Solutions on the GNEP scenarios, and again, published papers, but also made substantial contributions there.

We’ve also, in the European context, looked at a whole range of different areas. GoFASTR is a gas cooled fast reactor program looking at the role of the gas cooled fast reactors, as an alternative, sodium fast reactors. PUMA is a plutonium minor actinide utilization and incineration in high temperature reactors, in HTRs, things like Pebble bed of the HTR, and so on. We’ve done a lot of work on those. And, these two, the proposal stage within the European community. SUCCESS is a European fuel cycle initiative, looking at European fuel cycle parks. The benefits, for example, of sharing the stocks of material, or indeed repositories, and so on. And, THORIZON is a thorium, as the name suggests, is a thorium activity. So, these are the kind of things we’ve been involved in in the European context.

And, then, finally, things like looking at the values of reprocessed uranium, support the UK energy review for the economics, and so on.

The reason I included this is that hopefully, we'll bring to this party, to these analyses, but also the analysis going forward, there's a lot of experience we can probably bring to the table here, similarly the way that ARVEA does, we have been tapped into a lot of these programs, so we hope to be able to challenge and push the bounds in those things.

The other things, as well, and Gene kind of alluded to some of these already, in addition to ORION, you will be hearing about, in terms of the presentations here, we've actually got quite a few other tools that we have used. Originally, we developed supporting BNFL. And, again, to quickly go through, just conscious of the time, this is just a list of the other tools that we use. ORION is the one we'll be hearing about today, but things like, for example, if you take something like the reprocessed uranium calculation that Gene was referring to, we've done things like we have reactor coefficients built into a tool that we have called RUCALC, and it will actually determine if you tell it, for example, I need the equivalent of 4 ½ weight percent U235, it goes away and does a linear reactivity calculation. Puts the coefficient in and tells you what your final fuel will be, and does a nice topic mass balance calculation in that.

ENRIC is a similar kind of thing, but given certain economic numbers, it will calculate the overall cost of fuel. So, these kind of things begin to get coupled in and rolled into the overall ORION model. Another one here, I think this may be one, the PFC, I think this is the plutonium fissile coefficient, where again based on a lot of analysis we have done and also underpinning reactor physics, you can give it a plutonium vector and also tell it I want this to be equivalent of, you know, 4 ½ percent U235, and it will go away and calculate therefore what your MOX composition will be. And that, I think, may be the coefficient that we provided to Gene.

And, the final one here is FCE, which is an interesting one. Again, this is used in the linear reactivity model, where again, you can tell it what kind of fuel cycle you're operating, you know, an 18 month scheme. We have this kind of an 18 month load factor, and so on and so forth. And, using the linear activity model, it calculates the enrichment that you will need, and it also has burn-up poison penalties built into it. This is all based on linear activity models, but also a lot of experience. We've actually, this has been benchmarked and demonstrated to be accurate to within something like .05 weight percent U235, so it's very accurate and this is a very good scoping tool.

Again, just something to underline here, that although ORION is the tool you will be hearing about, as I just showed you, there’s a lot of underpinning numbers and calculations and experience gone in from, whether it be from reprocessed uranium, MOX, or whatever else it may be, but also as part of that, we’re also backed up pretty extensively by the reactor physics community. Both Robby and I are reactor physicists by trade, as it were, and origin. Again, that’s a wrong word, origin isn’t a nuclear data code. How we started off our careers. So, we rely an awful lot on things like generating the appropriate cross-sections from a real reactor physics analysis, whether it be thermal or fast, and so on. So, again, just to reiterate, this is very much underpinned by all that experience, too.

Okay, so the rest of it is just the results. So, you will hear more from the actual explicit analysis, and some of the kind of assumptions and simplifications we have to make, as Robby goes through the results later.

But, I’m happy to take any questions or clarifications.

MOTE: Thanks, Andy. As a personal note, I will say that I was recalling my early days in the industry when Andy was talking then, and back in my BNFL days, I’m sure nobody noticed the accent, but I am in fact a Brit by birth. And, my early days, Sellafield, we were in contact with Zorita in

Spain and I guess in Santa Maria de Garona also in Spain, and they were one early BWR, one early PWR, and every time we dissolved fuel, we would phone the results back to the utilities, and they used them to calibrate their reactor codes, because we knew what was in the fuel better than they did. And, now, I see that coming through in the codes NNL has.

Okay, that was the second presentation. The third one is Steve Piet from INL. So, Steve, tell us all about your model.

PIET: I'll try to talk a little bit about VISION. A year ago, I had the opportunity to address the Board on the VISION model, so I won't give another 45 minute talk. So, don't worry too much about that. I'll hit a few high points.

VISION is the tool for the advanced fuel cycle program, to look at all the different options. Like the previous speaker, let me give you a little bit of the history.

We started this when the program was the Advanced Fuel Cycle Initiative. Then, the program turned into GNEP, and now it's called Fuel Cycle Technologies. And, since it's a new week, we might have a new name.

That history is important. Any tool is for some particular set of purposes. So, when we started, we had a certain option space and a certain type of calculations people wanted us to do. Well, when we turned into GNEP, they wanted more and more detail. Now that we're back to looking at all of option space, option space has grown, so we end up with a very flexible tool, but one that is not always the easiest thing to use.

We have now a tool that can basically be used for any uranium or transuranic fuel cycle. We'll probably add thorium options in the future, any reactor you want. We do not deal with fuel assemblies because some of our options don't have fuel assemblies. The pebble bed, multi-salt reactors, and so forth, we don't even do fuel assemblies.

We do not model individual reactors. We look at types of reactors in any given scenario. Any separation technology, if you want to guess what its performance is, we put it in the model.

And, then, something we've worked a lot on in the last several years is that the specifications for nuclear energy growth, reactor mix, fuel type, fuel fabrication, repositories, routing, which I will talk a little bit more about in a minute, all these can be changed year by year in a simulation. And, it's because we are typically asked to start simulations with some assumed set of parameters, fleet, whatever today, and how is that going to change over 100 years, 200 years.

Or, as I like to think about it, since an average

U.S. President administration, has been five years, so when we do a 200 year simulation, that's 40 presidential administrations. And, we know how likely it is that the same policies and same technology drivers are going to be constant over 40 presidential administrations. So, we know we want the capability to change all these sorts of things over time.

This is a graph I showed a year ago. This is our basic layout of the model, starting with uranium, going all the way to different disposal options, thermal reactors, fast reactors, mixes thereof. Recycle loop or loops. We can have various options on material routing, which is our word for telling the model what reactors are feeding what separation plants, what separation plants are feeding what reactors. So, we've got a variety of flexibilities there.

But, no matter how much flexibility we add to this model, we always find somebody who wants to do a calculation that goes beyond the flexibility we have, guaranteed. We put out a new version a year ago, and within a week, we had a guy in Singapore, and somebody on the East Coast saying oh, well, could you change it to do this? So, no matter what we do, someone wants more.

We allowed the user to specify separation streams going into different waste categories. We don't use that as much as I think we should, but that's a set of options.

I've been trained not to point lasers over at the audience. That’s generally not a useful thing to do.

So, we can have up to ten reactor types, and I’ll tell you in the next talk how we adjusted the model. Maybe I’ll go ahead and do it now. But, we can set up a scenario so that you’ve got mixes of fast reactors, heavy water reactors, HGTRs, whatever you want.

Routing, we capture the routing story in two places. One is where you send separation products, and the other is how you are routing the reactor outputs to separation plants. And, so, you can change that, set that up as matrices.

Now, we’ve been involved with the MIT code benchmark, IAEA benchmark, more benchmarks than I can probably remember, and my colleagues and I have decided we ought to share a few of those thoughts with you today.

Benchmarks and comparisons always take longer and require more iterations than you planned, guaranteed. You always start with general specifications, and then you require additional iterations with more details to resolve differences. I’m seeing some heads nodding over here. Guaranteed. Specifications always cover only a minor fraction, typically a minor fraction, of what the model requires as input. And, we’ve already had some of those discussions today. And, only cover a portion of what a model can provide.

I'm sure you've already showed us from the NNL model things that weren't asked for in this specification, and I'm sure that's true for all the models.

The problem is you can only do comparisons on the features common to all the participating models. And, even with this specification, some of the things in the spreadsheets you showed me yesterday, I guess it was, some of the models, some of the people were able to do certain things and some were not. Specifications are often written from the standpoint of one of the models involved.

And, what you find when you get into the details of specifications, particularly for the more complicated scenarios, is that there are different mindsets that were behind each model when it was created. As I'll say more in other presentations, the VISION model, because of what our customer wanted us to do, is really focused on the separation plant. So, we define routing from the standpoint of how does a separation plant pull in used fuel, and where does the separation plant send things to. So, the NWTRB model is more waste-centric. Ours is more separation-centric. It's not a yes or no, good or bad, it's that that was the purpose of our model. And, almost guaranteed, a set of specifications that might look consistent from this perspective, will turn out to be inconsistent from another perspective.

This will be the last slide of this part of the meeting. VISION, we do not model hundreds of reactors. We model up to ten reactor types, and in this case, PWRs, BWRs, with 40 and 60 year lifetimes.

We started the calculations in 1960, so that we would show the build-up of fuel up to and beyond 2010. We don’t see any true steady state, so one of the specifications you heard was a steady state calculation. We instead just carried it as constant as we could. As always, retirements, builds, replacement reactors, isotope decay, isotopes that we track are decayed in any place that they could stay in the model for more than a half year. And, so, that is all taken care of. And, we don’t do reactor physics. We incorporate recipes, input/output recipes.

This has several things. It means that I don’t have to know all the reactor physics that some of my colleagues do. In particular, it lets me take advantage of the best calculations that have been done in our program by whoever has done that. And, we’ll talk more about the ones I’ve used, these calculations, later.

We do not have a set of recipes on re-enrichment, so that part of the specifications, I did not do. And, as I mentioned, we don’t work at the level of fuel assemblies. So, we’re looking at overall mass flow.

And, I’ll stop here. We’ll pick it up later on.

ROWE: What kind of time step do you use?

PIET: A quarter year. We can run with more or less than that, but we find on our desktops, VISION runs 200 year simulation in about six or seven minutes. My laptop takes three times that. So, that tells me I need a new laptop.

LATANISION: Latanision, Board.

I just want to understand a point you made. You distinguished the NUWASTE activities being mass-centric. You said your focus was separation-centric.

PIET: In terms of how we structured the model. Now, we've got all kinds of different waste-related outputs, some of which you will see in the later talks.

LATANISION: But, it sounds as if they're both mass balance.

PIET: Oh, yes. We're fanatic about mass balance.

LATANISION: Okay.

PIET: I didn't want to get--I'm glad you asked that. We're fanatics about mass balance.

LATANISION: Okay, good.

PIET: And, when a new version, we're testing a new version, I'll go to my fellows, who are programming, if I don't see a mass balance, I call up Jake and say Jake, we're creating mass, this is interesting, but I don't think we really want to do that. So, we do all that.

LATANISION: Okay.

PIET: But, the routing, as you get into more complex scenarios, you won’t really see it so much in this set, how you’re specifying what goes where in a fuel cycle, that’s where I mean we’re separation-centric.

LATANISION: Okay.

PIET: Because that tends to be the bottleneck in scenarios. If you do not have enough separation capacity on recycle scenarios, things fall apart real fast.

LATANISION: Got it. Thank you.

KADAK: Andy Kadak, Board.

I’m curious as to how detailed you model the separations. Is it a black box, like you’re assuming a state of the art, La Hague Enrichment plant, and you’re saying this is how I’m going to partition my waste streams, based on what they’re able to do? Or, do you do as the Waste Board guys did, isotopics, they can separate anything?

PIET: Again, no matter how much we think we get, given ourselves enough flexibility, someone dreams up a new case, but we do allow the user to define that separation performance. And, so, if you want to put in really advanced ideas, we can put it in. But, it’s basically in the form of a matrix. So, all the streams coming into a separation plant, whatever sets of fuels, and then do I want the lanthanides to go here, and Group 1A, Group 2, 2A, someplace else? Fine. So, I can put in there whatever loss fraction I want, I can put in there however I want to divide up the fission product streams, or keep them all together.

KADAK: But, technically, do you try to replicate a real plant, or do you just, you know, I'm not going to say arbitrarily, but making--

PIET: It's a matrix. So, I can put in a garbage matrix that's totally nuts.

KADAK: Have you validated any of those?

PIET: What we do is we get the best data we can from the separation campaign within the fuel cycle program. So, we've gotten data from the aqueous guys, the electrochemical guys, gone back to some of the data with AROX, the so-called approach, melt refining, so we've pulled data from the literature, or from the current experiments.

KADAK: Now, I think you participated in the MIT benchmarking. Perhaps it's not too early to talk about the results of that. But, I hope it's--

ROWE: The report is out.

KADAK: Sorry?

ROWE: The report is out. It's available.

KADAK: I know, but I don't know whether this is the right time to say how well you're doing it, or later.

ROWE: Later.

KADAK: Later? Okay.

PIET: Did I answer your question?

KADAK: Yes, thank you.

SHWAGERAUS: What was the question?

KADAK: Are you familiar with the MIT--

SHWAGERAUS: Yeah. I have the report here.

KADAK: Maybe later you can explain how the benchmark worked out. I guess AREVA did one, INL did one and you guys did one.

SHWAGERAUS: Our one and INL.

KADAK: Okay.

SHWAGERAUS: Not AREVA, CEA.

KADAK: CEA, okay. Perhaps maybe later you can talk about that result in the context of what we're trying to do here.

SHWAGERAUS: Oh, yeah, I can. Maybe tomorrow.

MOTE: Maybe at lunch time, we should talk about whether that's something that we build in as we go through these results, or make a quarter hour somewhere that we just run through that as an issue.

KADAK: What I'm seeing is there's very different models and approaches to models. And, we may be comparing apples and oranges in this.

MOTE: Well, what we tried to do was give you the same scenarios.

KADAK: No, I understand. I understand. But, what I'm saying here does not calculate number of fuel assemblies, does not--I mean, there's certain things that these models maybe are not capable of doing, that our model was capable of doing. And, we want to be sure that if there's other information out there that's of use in terms of system-wide assessments of fuel cycles--

MOTE: Well, maybe Gene, when you run through your results, either as part of your presentation or afterwards, maybe just make some notes on that?

ROWE: Yeah, well I think, you know, Andy, I think that the point I tried to make, and I think Steve made exactly the same point, is that the model was developed for a specific purpose, and those purposes were quite different.

KADAK: No, I understand.

ROWE: Okay. And, the way I looked at this is you've got a black box, okay, you've got input, you've got a calculation, and you've got output. Okay? What I see that the purpose of this exercise is to validate that black box. Okay? What kind of output and input is really dependent on what you're trying to accomplish. So, I'm hoping that we can validate that calculation method that says the results I get are a reasonable representation.

MOTE: Let's talk at lunch about whether to build that in or make it a separate few minutes just to make that comparison.

All right, Gene, are you presenting the overview of the--

ROWE: Stefano is going to talk on that.

MOTE: Okay.

PASSERINI: This is Stefano Passerini from MIT to describe the--what's the name again? I've forgotten.

ROWE: CAFCA.

PASSERINI: CAFCA, yeah, okay.

SHWAGERAUS: By the way, Stefano also tried to do a TSPA analysis of the repository when he was a student of mine.

PASSERINI: I got close.

Well, first of all, we're going to give a presentation, introduction of the CAFCA code. CAFCA stands for Code of Advanced Fuel Cycle Analysis. And, it's a code that was developed at MIT starting a few years ago, and right now, the latest version is developed and coded in System Dynamics-VENSIM platform. And, CAFCA is the tool that basically was used for the MIT Future of Nuclear Fuel Cycle Study, giving all the results and all the metrics that were analyzed.

And, as an objective, CAFCA, the objective of CAFCA is to define, describe and assess potentialities and impacts of alternative nuclear fuel cycles. So, it's not exactly, the focus was not waste management in this case. It was more in the fuel cycle and alternatives, as we were talking about that before.

So, the main features of the code as an input CAFCA takes from one side, assumptions in the energy scenario, and particularly energy growth rate that can be specified by the users, and for the case of this benchmark, basically there was no growth rate in the U.S. nuclear fleet. And, on the other hand, takes as an input, fuel cycle strategy that can be specified, so once through or recycling, and also the reactor technologies that are available, and when they are available, over time, for example, light water reactors, but not only, we also have fast reactors.

And, as outputs, we have a few metrics that are already implemented, so of course capacities over time, and mass balances, and the nuclear waste streams, and uranium consumptions, also economics and other metrics that we are currently thinking of implementing in the code.

Those are the fuel cycle strategies that are actually available, currently available in CAFCA, and the corresponding reactor technology that can be activated and linked to the different fuel cycle strategies. As you can see, it's basically concentrating on light water reactors, using uranium fuel or mixed oxide fuel.

We have also currently, or recently included the RBWR that was also started at MIT. And, we then have metal and oxide fueled fast reactors, and both are, the designs for the fast reactors are for sodium cooled fast reactors.

KADAK: What's an RBWR?

PASSERINI: The RBWR is the reduced moderation boiling water reactor. So, it’s a design coming originally from Japan that aims at having basically a conversion ratio of very close or equal to one for a boiling water reactor by having a very high fraction into the core.

So, main assumptions are, modeling CAFCA, as you will see, like some general ones, and then in the following slide, some of the more relevant for the purpose of this benchmark. So, CAFCA works discrete time and/or times that are one-eighth of a year, as was already asked before, and it’s a continuous flow code in terms of mass balances, so we do not analyze batches or fuel assemblies. We have just streams of mass going in and out of the reactors, single units, and through the reprocessing facilities. And, we only have inputs and outputs for equilibrium core, so we do not have start-up cores currently modeled into the code.

And, in our light water reactor fleet, the code does not distinguish between P and BWR, so we only have inputs for general light water reactor code. So, the distinction between the two for the purpose of this benchmark was done not through CAFCA, but through Excel by applying, as I will discuss later, some fixed vectors that will distinguish the mass between P and BWRs. And, also, we have one standard size right now for the light water reactors, which is 1000 megawatt electric.

CAFCA does not do isotope tracking, and similarly to what--we do not have like decay implemented for the isotopes. And, similarly, the spent fuel composition is fixed, so similarly to what was said before about VISION, we have recipes ready, so for input and output out of the cores, we have composition in terms of plutonium generated or minor actinides generated inside the core, transmuted inside the core, and, therefore, they can be taken out, but we don't have single isotope tracking or reactor physics calculations to calculate the actual composition of the fuel.

So, the calculating of this again was done externally using CASMO for the purpose of this benchmark, not directly through CAFCA. As you can see, there's a composition for the purpose of this benchmark was done using CASMO, and Excel was used for other numerical data analysis needed to give the results that CAFCA is providing into the metrics that were asked for this benchmark. CAFCA takes into account, decommissioning, as I'm sure also other codes do, and the distinction between the number of units of PWR and BWR were assumed constant over time. So, basically, our assumption was to just replace a PWR with a PWR, and a BWR with a BWR over time.

And, for the new assemblies, since it was given composition and burn-up and enrichment for the existing assemblies in storage and for the new assemblies starting with 2010, our reference to translate the information from mass into number of assemblies was done assuming that the PWR fuel assemblies, we take as a reference, the AP1000, 17 by 17 fuel assembly. And, for the BWR fuel assemblies produced or used after 2010, we use the ABWR, 10 by 10.

MOTE: Stefano, can I ask you a question just before you move off that slide?

PASSERINI: Sure.

MOTE: Your third bullet down there says PWR and BWR number of units assumed constant over time.

PASSERINI: Yes.

MOTE: On the previous slide, you said there’s no distinction between Ps and Bs.

PASSERINI: Yes. So, that’s how we--so, CAFCA does not make a distinction, but when we have the results of the mass flows, then we simply separate it to, using the constant fraction between P and BWRs. From the input that you gave us, we have the composition of the fleet basically, and we calculated that 66 percent of them are PWRs, 44 around are BWRs, 34 BWRs, and for all the mass flows were divided like using that fraction through the entire scenario.

MOTE: So, what you mean by no distinction is that you set it up with a mix, and then you don’t cut anything beyond that.

PASSERINI: No, basically CAFCA does not distinguish between the two, but then we separate the streams of flows using Excel after the calculation was done.

MOTE: Okay.

PASSERINI: So, in CAFCA, we don’t have explicit distinction of the type of units among light water reactors.

MOTE: All right, thanks.

PASSERINI: And, to give you an example, a quick example, that’s one of the plots used by CAFCA in this case, it’s the spent fuel generated through just the fleet of light water reactors when they’re recycling, and you can see that’s the steady state value. As again I said we don’t have single assemblies, so that’s cumulative value for 100, more or less, reactors. And, then you see these peaks are due to the decommissioning of the existing fleet, and the same type of shape is reproduced 60 years later, as we assume that all the units can operate to 60 years, and also the current units will be allowed between the year’s life extension. And, that was just to be sure that we were taking into account correctly the mass flows due to the decommissioning of the units, so all the units are discharged at once.

And, we will discuss this later, but basically, this is more about the spent fuel reprocessing rate in Scenario 5, so we have the two capacities. But, we’re going to discuss that later, but basically, once again, CAFCA only takes into account the mass balance and not the units, and you can see how the reprocessing facility can accept and reprocess the given fuel.

And, that’s it. Are there any questions?

ROWE: I have a question. Gene Rowe.

When you calculate the isotopic content, you assume a certain mass is discharged?

PASSERINI: Yes.

ROWE: And, then, you ratio the mass, a certain percentage of the mass is P and a certain mass is B.

PASSERINI: Yes.

ROWE: And, then, you use CASMO to get each of those masses.

PASSERINI: Yes.

ROWE: And, the Bs and the Ps have different assays?

PASSERINI: Yes.

ROWE: Okay.

PASSERINI: But, what was also kind of easy under that point of view, because the original that you specified for the new fuel basically was very similar. So, that kind of, I think, gave us some consistency in like taking the mass flow and then dividing it into the two fractions.

ABKOWITZ: Abkowitz, Board.

Just in listening to your presentation, is it fair to say that what CAFCA is trying to do is act as a screening tool that looks at a number of advanced reactor technologies and compares it to LWR world, but not really trying to get to a certain level of fidelity? Is that fair to say?

PASSERINI: Well, I think we have a level of fidelity, because we have, of course, some--reactors cannot be built without, for example, having separated mass or having some conditions that are specified into the code. But, yes, definitely the purpose of the code is more to compare different fuel cycle alternatives, definitely, not to go into the waste management.

SHWAGERAUS: Assessing the impacts of different reactor technologies on fuel cycle was definitely one of the main or key points of working with the code to, for example, for the future of the fuel cycle study. So, it's not separation unit oriented, but it's, rather, impact of reactor technologies on fuel cycle.

KADAK: Kadak, Board.

You treat the reprocessing options also as a black box?

PASSERINI: Yes. And, once again, we specify what goes into the reprocessing facility and what goes out in terms of like efficiency, if you want, or separation. But, you can specify.

KADAK: Right. But, have you also benchmarked it to practicality in terms of reprocessing alternatives? You've looked at metal fuel, for example, and I'm wondering how you treated that efficiency.

PASSERINI: No, right now, we didn't look at very different data for that type of--or for that side of the FT fuel cycle. So, right now, you can specify the parameters for the reprocessing, but we haven't studied them more than what's in the fuel cycle study.

SHWAGERAUS: Yeah, let's say it's a matter of benchmarkings, it's a matter of input, it's whatever you specify, the code will calculate. There's no internal--

PASSERINI: Exactly.

SHWAGERAUS: So, it would give you whatever user specified separation efficiencies you would put in.

KADAK: But, do you have some reactor physics fidelity, for example, when you looked at the breeder options, and those?

PASSERINI: Yes, because very similar thing to what in this case what VISION is doing, we take the best available recipes for input and output out of different type of reactors, and we use them in the fuel cycle code. So, it's not something that's done inside the code, but we take the best outputs available.

GREGG: So, if you are modeling a breeder scenario where you are reusing the fuel continually, say after the third or fourth time, and the fuel is going to change isotopically because you're reusing it, can that be accounted for in

CAFCA? I mean, like if you're using a recipe, it sounds quite--and, over time, yes, so each time the fuel gets through the core you need to have another recipe. Can you account for the change in isotopics?

PASSERINI: No, under that point, no.

PIET: Let me answer your question. In our case, we do, although we use fixed recipes, we keep track of how many times material has gone through a reactor. And, so, in a multi-recycle case, we keep track of the fact that the composition is changed, and how much mass has gone through once, twice, third, fourth, whatever.

GREGG: Okay. So, you use the ID to kind of choose which recipes?

PIET: Yes, and, the mix at any given instant in time.

GREGG: You could actually calculate that.

PIET: Yes.

MOTE: All right, thank you Stefano. I realize that in a male dominant society, we've been very un-gentlemanly and we're leaving the lady until last. So, what I'm going to suggest is that when we present the results, we alternately go down the list that we have and the way we've presented them, and the next time, we go up, and the next time we go down. So, Marie-Anne, then you get your turn at being first, along with all the others. Okay.

BRUDIEU: Good morning. I'm Marie-Anne Brudieu. I'm with AREVA and I'm from Paris. The goal here is really for you to understand me, so if my French accent is too much for you, just raise your hand, and I'll speak slowly. You'll have a translator, just to translate everything I say.

Okay, I've been joining this group, working with you guys quite recently, so I haven't been the one doing this work. In case I can't answer one of your questions, that's fine. I will talk to a couple of people and be able to give you answers tomorrow.

So, the first thing to know is AREVA is really focusing on the recycling activities. And, we are not speaking here about the overall, you know, few strategies, this is really to respond to the questions asked by the Board members.

The recycling model that we have includes a user interface and it's really made to be easy to change a couple inputs, so we can check a couple scenarios and see what comes out of it. Basically, we use Excel calculations to do plus and minus and divisions. And, then, the CESAR code, which is the equivalence that we use in France as ORIGEN to have isotope calculations.

All the data that we have is really based on operational experience at La Hague and MELOX facilities. So, the purpose--won't have to ask the question about benchmarking here.

The model that we have today is quite flexible, and so it can be easily modified for future applications, modified scenarios, revisions, et cetera. The input data for task 2.4, which we will be talking about tomorrow, is related to outputs from tasks 2.1 and 2.2. However, we are not presenting this workshop, the results for the first phases because of lack of time, and we were quite certain that you guys could do it very well on your own. We're really focusing on the whole recycling, where we feel AREVA has the most added value.

So, here is the model that we have. If I move, I have to use that. Right? So, I have a pointer? Perfect. We do have high tech. So, this is the input, and you have a printout that's like a big sheet of what our model looks like. The number of reactors can be changed in terms of how much electricity--everything that's in blue can be changed. So, that's the actual user flexibility that we have on the software. And, based on how much energy we produce, it calculates the discharge, and then we can choose how much cooling time we want. So, we can have 50 years cooling time for this model. We can also modify the model to have any other type of cooling time.

And, also, we take the input from the legacy fuel that can be cooled 25 of each year. If you come back on the red arrow here. Okay, then you can go here. We also wanted to give you some additional data and results that we don’t necessarily usually expect to calculate or can calculate very easily, but the model includes the gaseous release from a recycling plant based on what type of fuel you’re going to bring in there. And, that’s very important because today, we don’t do that much recycling of other work, you know, we have La Hague in France and a couple facilities in the UK, but then if we don’t stop doing that, which, you know, would be a good idea, obviously, we’ll have to start at this point to look more closely.

Now, the next part of this scenario here is the process waste, okay, and that’s an outcome, so that’s why everything is empty, we talk about the results tomorrow. The goal is really to say hey, you know, at La Hague, we have all this data, and so we know for that type of--what kind of vitrified waste is going to come out, or what kind of compacted waste is going to come out. And, then, that gives you the realistic input on what’s going to be going into the repository, especially vitrified waste, or compacted waste.

Other fission products and actinides are being calculated, and that’s using CESAR code. We didn’t do benchmark as AREVA, but the CESAR code was developed and used by the CEA, which is the French national labs. So, they are actually doing benchmarking on that.

And, then, we should go here, let’s not forget that when you go into recycling, and whatever you do, you should actually--you're going to make different types of waste, and that's what we call--waste, it's low-level waste. We also use the data, and the experience that we have at La Hague, to take this into account. So, when we calculate the amount of waste that's going to go into your deep geological repository, or a phased repository, you don't forget anything. Everything here is taken into account.

That is like, you know, not comprehensible, CBF-C2, CBF-C0, et cetera, these are the types of waste packages, drums that we use at La Hague, and it depends on the level of the waste that we are producing. These can seem very minor altogether when you're looking at the very big picture, scenario, in terms of lifecycle, et cetera, but when you have to face actually the fact that, well, you need to take care of this waste, it's always a good thing to have been thinking about it ahead of time.

Okay, then to what maybe interests us more is here. So, this is what comes out of the separation of this unit in the recycling plant, and the fabrication of the MOX S&Bs. So, here, you can choose actually what percentage of plutonium you're going to have in your MOX. There is also a calculation that doesn't show here on this part of the sheet, but that's in the Excel sheet, of what would be the percentage of plutonium you need to have in your MOX assemblies in order to have the equivalent energy prediction in the same reactor. So, that can be anything between 9 percent and 14 percent.

We also have the enriched uranium, recycled uranium, the enrichment, and this is going to be leading us to actually how much uranium we save and are going to use. The MOX assemblies are fabricated using plutonium and natural uranium. And, then, we also have a calculation of the natural uranium tails that we're going to have.

And, that's about it. So, everything else in blue is data you can change. Here, you see we have 4.4 percent. That was from the scenario, and that also leads us to having a very standard--we don't play here on different types of reactors, and different types of energy consumptions. Okay? This is really to see what type of waste we're going to produce with the various basic scenario.

The green arrow at the bottom, that's like the exit one. And, then, I think I'm going to talk about models--tomorrow, showing the results.

Thank you.

KADAK: Kadak, Board.

The reason Marie-Anne is so sensitive about benchmarking is she did a thesis for me which--

BRUDIEU: Yes.

KADAK: But that's okay. But, it sounds like your model is perhaps the most detailed of all of the models for trying to figure out waste streams, which is our interest area, as well as high-level and low-level waste streams.

Now, you said you ran the scenario that we had identified. But, you do count fuel assemblies, or not? You did not do that part, I guess, right?

BRUDIEU: We do count fuel assemblies, you know, at the end. But, we didn’t do what you call Phase 1, 2 and 3, where you get how many fuel assemblies, we have originally. Basically, we actually work more in terms of metric tons of heavy metals, because that’s really what matters when you start, you know, doing the recycling, is how much material are you going to put in there.

KADAK: And, you said this model is developed by CEA?

BRUDIEU: No, that model is developed by AREVA, but in order to have the isotopic compositions, we used the CESAR code, which is the French version of ORIGEN, and the CESAR code was developed by CEA. AREVA, you know, is--we do have R and D, but our main goal is not to do, you know, national type of R and D, so we have very close relationships with the CEA, which is the French national labs.

KADAK: Thank you.

ROWE: So, you do the calculation for the RepU UOX assemblies, the percentage of U235 is an external calculation? And, is that based on the isotopic content of the separated material? And, the same question for the MOX assemblies. You’ve got a percentage, okay, is that an external calculation, and is that based on the isotopic content of the separated material?

BRUDIEU: Yes and no.

ROWE: Which one is yes and which one is no?

BRUDIEU: I’m not 100 percent sure I understand the answer you’re looking for. But, what happens is that we say okay, we have that type of fuel, you know, that comes out that year on its five year old. Then we do an external CESAR calculation, and then from that CESAR calculation, that brings up all the isotopes. We put that as an input in this model.

ROWE: So, you actually put the isotopic content--

BRUDIEU: In this model, yes.

ROWE: And, then, it calculates the plutonium percentage?

BRUDIEU: Yes.

ROWE: I thought that was a blue box?

BRUDIEU: With that percentage here, you can actually say hey, that’s what’s calculating and I put it in there, or I choose to put more plutonium because I want higher--

ROWE: So, that’s a calculated drive, but you can change it?

BRUDIEU: Exactly.

ROWE: Okay. The same with the uranium, U235?

BRUDIEU: Yes.

ROWE: Okay, thank you.

WORRALL: I just wanted to check. Is the code or the model you're referring to, is it COSI? This isn't the COSI code, no?

KADAK: No.

BRUDIEU: No.

WORRALL: I'm just interested to know--

BRUDIEU: I don't know the COSI code.

WORRALL: Oh, you don't? Okay. It's just that any fuel cycle modeling from AREVA or CEA usually is presented using the COSI code.

BRUDIEU: Okay.

WORRALL: And the classic multiple recycle options and EDF and CEA and AREVA presented usually with COSI. So, I was just interested to know. Then a general question then why this kind of--this is more of a spreadsheet?

BRUDIEU: Yeah, this is actually more of a spreadsheet model that's really taking, you know, I mean macro, obviously, but that's really taking the input from CESAR, you know, puts on the transformation that we have as internal experiments from La Hague and MELOX and what we calculate every day, you know, to make the company work basically. I can ask the question about COSI.

WORRALL: Yeah, I was just interested to know why the decision was made then to use, to develop a new let’s call it model or tool, or whatever you wish to call it, rather than the standard AREVA COSI.

BRUDIEU: Okay, it’s tough to answer today. I’ll try to get the answer for tomorrow.

WORRALL: Okay, yeah.

BRUDIEU: What I can tell you is this is not designed to be an overall fuel cycle option, like I would guess COSI, we do if it’s, you know, CEA and EDF, and when I work with CEA and EDF it’s to communicate in what--how much recycling, and do we want to do multi-recycling, multi-MOX, et cetera. The goal of that is really to say look, if you have this very external scenario, what’s going to come out of it, how much waste are you going to have. So, we use, let’s say, maybe the experience of the engineers who might have been working on COSI, so I’ll try to find this out.

WORRALL: Okay.

BRUDIEU: To bring results. That’s more relevant to waste management.

WORRALL: Okay, thank you.

DUQUETTE: Duquette, Board.

The French are more advanced than either the UK or the US at the present time in almost identifying a site for actual waste disposal. Does your model take into account how much waste would have to be--what the accessibility for getting waste to the site is at the present time? How much has to be stored, for how long, and so on and so forth?

BRUDIEU: No, at this point, it doesn’t include the interim storage, transportation logistics, to find a repository. Actually, we do have a--with a site, that was not complete, or finalized yet, and benchmarked to action, you know, data, so we decided not to present it here today. But, we can definitely add this and get back to you.

DUQUETTE: So, that box that was over on the left, that’s processed waste, for example, that one right there, when you do those calculations to go to the repository, you don’t have any numbers yet that indicate what the arrival rate at the repository would be, how much would have to be stored, and how often, or anything else?

BRUDIEU: No.

DUQUETTE: Okay.

BRUDIEU: We could do that, we started doing it, but it’s not here today.

DUQUETTE: Okay, merci.

MOTE: Not only did Marie-Anne give us a nice presentation, you brought it in about 20 minutes early, as well.

So, we are at the end of what was planned for the morning. That doesn’t mean we need to stop here, but we certainly did get a lot of value out of the mixing at the early break. Are there any things that we should discuss now in the context of understanding what the codes do? Is there anything that’s come out of seeing the AREVA presentation, after the NNL presentation, were there observations about fundamental differences, and things that we should take into account in moving forward in discussing results? Dr. Kadak?

KADAK: Yes. I think it would be great if each of the presenters could summarize what it is that their tool is designed to do, okay, as a mission. And, then, we can kind of see what we are looking at. Clearly, Marie-Anne talked about the reprocessing for MOX as a process. We got that model well. MIT was kind of looking--and, tell me if I’m wrong.

SHWAGERAUS: Yeah, as I mentioned in one sentence, it’s assessing various reactor technologies and their impact on the fuel cycle, the flow rates of various materials, requirements for natural uranium, transuranic elements, storage requirements, where they are in different fuel cycle facilities, waste production. So, reactor technologies as they impact all these matrix. That’s the mission of the code.

MOTE: Steve?

PIET: We’re looking at fuel cycle options, and the impact on all your favorite metrics, other than cost. We used to have cost in here, and we looked at slides the last couple of years, but everything from uranium, some of the proliferation metrics, waste. One thing you said that I guess I have to disagree a little bit with is we can take calculations into how much goes into Class A, B, C waste, transuranic, greater than Class C, high-level waste, the specifications for these calculations didn't ask us to do that, so I didn't dwell on that. But, all that information is there. We get information on waste form density, and so forth, from people like John Vienna sitting behind you. So, we pull all that type of information in there. So, we look at the full range of metrics for essentially the full range of options. The one exception is we don't have thorium fuel cycle as an option.

KADAK: Between what you've just described and what MIT has done, how do you differentiate those two?

PIET: Well, although some of us are MIT grads--

KADAK: More than we should feel comfortable.

PIET: Yes, and I was disappointed that Kazimi wasn't here today because he was both my master's and doctoral professor, so that would have been a little more fun for me personally. But, I would say we're integrated with the whole fuel cycle program, and so we have to work with the rest of the program in how we make their data work together in a fuel cycle integrated picture. That's one difference.

The other is we do quite a lot of invested effort into being able to transition technologies year to year, if that’s what a particular simulation needs to do, and tracking all the different isotopes and isotope decay. So, it’s fairly detailed, and drives some of my programming buddies crazy.

KADAK: Okay.

GREGG: Well, ORION is fairly explicit in how it tries to model the fuel cycle model, so it looks at individual reactors, it looks at individual fabrication plants, it looks at individual process plants, and you define how that reactor is. And, the models which we got in there to calculate the decay and the transmutation are very generic, so with the transmutation part of it, we have essentially got a version of ORIGEN or CESAR or FISPIN in there, which calculates the spent fuel inventory as it is, using cross-sections which are generated from either CASMO or ECCO, depending if it’s a light water reactor or a fast reactor. So, it’s very generic in what it can model. It can model a fast reactor system. It can model a multiple reuse fast reactor system. So, the fuel varies over time, or if the spent fuel varies over time and you reprocess it, then it correctly takes into account the change in the plutonium factor, for example, as it goes around the system, because just like NUWASTE, for example, it has in there result coefficients which the user can define for each reactor. And, they are used internally by ORION to work out what the required plutonium content will be for the fuel, for example. So, all that is taken into account.

KADAK: But, you’re not looking at alternative reactor design options?

GREGG: Yeah, that’s no reason why you can’t use ORION to do that. I mean, obviously, you can’t design a new reactor in a code like ECCO or CASMO simulations to do that. But, it takes the fundamental output from these very sophisticated mathematical models in ECCO or CASMO, cross-sections, and those cross-sections are used to basically do a zero dimensional transmutation calculation. So, the physics is very good, and it’s what you need to calculate the spent fuel inventories exactly.

WORRALL: What I tried to say is that for me, that’s why I asked about COSI, is that I say there’s kind of two levels of fuel cycle assessment tools, let’s call them. I think what we’re hearing here is that the two levels, the two levels are that you have a model so in many ways, the AREVA approach is a model. It’s not a tool. It’s always been hard wired, semi-hard wired to address this particular task.

A COSI or an ORION is completely flexible. You tell it what the fuel cycle is. It doesn’t matter if it’s a single one atom model that just tracks that single atom, or it’s the entire nuclear world being modeled. It’s completely flexible in that sense. So, as Robby described, there it doesn’t matter whether you kind of take a reprocessing plant of any type and set different reactor types, you put them all together, however you join them together, it will model it. There is no hard wired, you know, tied down kind of approach.

So, that’s the difference and the reason being is that in the same way AREVA has looked at fuel cycle modeling, the questions that get asked, you know, the UK has literally looked in the same way France probably has, has looked at almost every single fuel cycle option the world could consider, because we have tried everything from gas reactors to fast reactors to MOX to thermal, so we have to model all of those. So, we haven’t developed a model that’s on the shelf. We have a tool that can model the scenarios.

KADAK: And, it also looks at waste streams?

WORRALL: It looks at everything.

KADAK: Okay.

WORRALL: Absolutely. And, basically, whatever you tell it is the feed material into a reactor, for example, it will then look at the transmutation, have that get transmuted into whatever the stream out of that is. When you put it into a reprocessing plant, it will then--you tell it what the separation factors are and what the efficiency of the separation is, and therefore what is a waste stream, what is a plutonium stream, what is a uranium stream, what is a high-level waste stream. So, it will explicitly track each of those.

GREGG: It works by mass. So, it tracks mass, in fact it tracks mass of every single nuclide which it gets to track. But, it doesn't necessarily mean that we don't track the number of assemblies, because prior to reprocessing the number of assemblies, which you've got, it will simply be the mass of the fuel divided by the mass of the assembly, all the assemblies from the same mass, which in this scenario, that was the case. But, after reprocessing, which our code models, you no longer have an assembly, you just have a mass of uranium and you have a mass of plutonium, which is why we don't track assemblies per se, because there's no--well, once it's reprocessed, it's physically impossible.

PIET: Yeah. I think you'll find, and the international benchmarks will bear this out, that COSI, ORION, VISION are all dedicated to looking at all matter of different cases that someone dreams up and asks us to look at, it tracks the whole story down from uranium to waste management. There are some differences in how this little part or that little part operate, but they're really tasked to do similar things. And, again, we go back and forth, and we'll learn from each other, but they're tasked to do similar types of things.

KADAK: Thank you.

ABKOWITZ: Abkowitz, Board.

I want to pick up on Andy's line of questioning, perhaps asking a similar question in a slightly different way. As you know, we're Nuclear Waste Technical Review Board, and so the tool we've been working on is waste management centric, and we've been trying to do this at the finest level of resolution, at least in the LWR world.

So, I'd like to go back through the other four participants that are here, and have you sort of try to position your tool relative to being waste management centric, in terms of are you able to run a waste management analysis at the level of fidelity that we're trying to do, and have done so? Have you not done that, but you have the capability to do that? Or, are you looking at it at a higher level of resolution, where you're dealing with it more like as a lumped parameter type of thing? I'm just trying to get my bearings. So, maybe we can start with Marie-Anne and move our way across.

BRUDIEU: Okay, I feel terrible. I did not listen to the question. I was talking to--I'm asking the question for the COSI--

ABKOWITZ: Okay. Okay, no problem, let me ask again.

Essentially, because of our focus, I'm trying to sort of position on on the landscape where each of these other tools are. And, my question is at the level of fidelity that we're modeling waste streams, is that something that your model or your tool can do, and you've applied it that way; can do it, but you haven't really used it for that purpose up to now; or you do it at sort of a more--at a higher screening level where you deal with it more as a set of lumped parameters, I guess I would call it.

BRUDIEU: The model as Robert, you know, mentioned was really designed as a tool to model the waste streams as asked by the NWTRB. And, I would say in terms of--it's maybe a small part or piece of what one of the larger, you know, coded models would be, really focusing on the details of the streams. I'm not sure I'm, you know, answering your question here.

ABKOWITZ: Well, we'll talk more later.

BRUDIEU: Okay.

SHWAGERAUS: CAFCA right now, I would say, is a lumped parameter code. It creates in a fairly approximate way fission products, minor actinides, and plutonium and uranium, with no internal transformations between them. They're all based on look-up tables. There is a plan to become more--to move to the next level of fidelity, and to account for important isotopes, maybe not as detailed as thousands of isotopes, but more of a VISION type approach where you concentrate on groups of isotopes that are important at various stages of the fuel cycle, including internal capability of aging or decay of these isotopes.

And, possibly we were discussing also something of a simple linear reactivity based reactor physics model that would tell you as isotopic changes with time, you would need different amounts of plutonium to get certain energy from your fuel assembly, which you cannot predict up front. It's a dynamic property that the code should have the capability to calculate. It doesn't have this capability right now, but there is a plan to move in this direction.

PIET: Waste itself is a very broad field. I'll differentiate two types of assessments of waste and what parts of that I think our tools can use. DOE RW had a tool called the Total System Model. That tracked individual assemblies from every existing plant, where they were, and when they would go to Yucca Mountain, whether they'd be cool enough to go directly in, or have to go to aging pad, and so forth and so on. It was not an option comparison tool. It was a management of the fuel cycle model. None of the models you're talking about here can do that, to my knowledge.

What VISION can do is make use of the best available data and sometimes guesses--sorry, John--yes, very educated guess, very smart, educated guesses, of waste performance in terms of, gee, I need to make the waste loading for this type of waste, from this type of stream, you know, X kilograms per cubic meter, whatever. You take those data, and you want to look at what that does in terms of an overall fuel cycle over time, VISION will do that.

So, some of these questions that you're asking, you might want to reask us tomorrow afternoon after you've seen the various presentations and what types of information different models have generated already. But, VISION is not a management of the fuel cycle model. It is a tool to look at fuel cycle options over time.

ABKOWITZ: Let me just add a quick shout-out for the Board. TSM, we are pretty sure, was developed at the request of the Board because there was no tool that DOE had available that we could see that had any systems integration understanding between waste acceptance, transportation, surface facility handling, and the repository. And, we happen to believe that it's a very nice product, but, designed really more for logistics planning, I believe.

PIET: I'll mention we have a complimentary tool division that we call FIT for Fuel Cycle Integration and Trade-Offs, and it does do some of the chemistry, one of the questions earlier, and it's looking at the accumulation of impurities as you recycle fuel, what impurities do to waste streams, to recycled fuel, and so forth. So, it's a companion tool division. If we tried to put all the complexity of both models in one place, I'd have some people trying to, you know, kill me, or dump me out the window.

MOTE: Greg?

GREGG: ORION tracks every nuclide, and when it comes to partitioning the fuel, the spent fuel in a reprocessing plant, for example, what we can do in ORION is to find what we call a transfer coefficient for every single nuclide. So, we could, for example, say that 99.99 percent of plutonium 238 goes into the plutonium stream, the other plutonium nuclides, if we wanted, we could state that 50 percent of the krypton goes into the same stream, if you wanted, you know. So, it’s very dynamic from that point of view.

And, also, what we can also do is we can define additional streams on top of that. So, if the high-level waste stream, which will in effect have all the fission products, and 0.01 percent of the minor actinides, in fact, all the minor actinides, and .01 percent of plutonium/uranium will go into that stream as well. And, we can then define how many canisters and what the volume of the high-level waste will be after vitrification, and all that can be defined in there, and that will be another stream, which will be accounted for in ORION.

MOTE: Thank you.

ROWE: I think the thing that differentiates NUWASTE from all the others is what the objective is, and first of all, we are trying to model the US nuclear fleet. Okay? And, we’re looking at feasible options in the US, and what impacts implementing one of those options has. If we look at storage, if we look at dry storage, we look at repository, and we look at reprocessing, we don't look at any advanced reactors because advanced reactors, we are all going to be pushing up daisies by the time these things come around.

ABKOWITZ: With the climate change, it will probably be some other vegetation.

ROWE: So, I think our model is much, much simpler than I think most of the other models. But, that's because what our objective is is to actually look at the waste for various realistic options, using the US fleet as the basis for those calculations. I think that's what separates us from the rest of the models.

MOTE: Well, I'm going to take the Chairman--

KADAK: One very quick follow-up.

MOTE: Very quick.

KADAK: For tomorrow, one of the concerns that we have is the, not so much the high-level waste disposal, but the low-level waste streams, and Marie-Anne brought this up in her chart, and we're trying to reconcile, NUWASTE has a tracking system of low-level waste, I don't know if your results are going to talk about that, but I think that's a very important question as we look at fuel cycles. High-level waste you could easily say well, we'll vitrify, it will go away. But, the other stuff won't. So, if you can think about for tomorrow when the results are presented, if you can add a little bit about the volumes of low-level waste by category, that would be very helpful.

MOTE: I was going to say that I'll take the Chairman's prerogative, but as I don't have the only mike, I couldn't do that. I was going to say we have a couple minutes left, we don't, but I'm going to choose to overrun by a few minutes. There are two people, and this is really into the public comment time now, there are two people in the public area, that is the observers, both of them happen to be called Alan, who are both here, and we on the Board know them very well, they're both code experts.

Allen Croff is sitting over here representing the Blue Ribbon Commission--or, not representing, he's here because of the Blue Ribbon Commission's interest. And, Allen is the god father, grandfather, father, half a parent of ORIGEN. And, Alan Wells is sitting over here, who is formerly from industry, from one of the cask designers, NAC in Atlanta. And, Alan has used codes and this Allen over here built codes, and I would like to ask either of them if they want to make any generic--not generic--any observations, generic, specific, comparative, on what we heard this morning.

Because after the lunch time now, we're going to get into results. So, if there's any scene setting that you guys would make from observations of this morning about, I see in this code something that will necessarily give us a different flavor, and if you’re aware of that going in, you understand the results better. Is there anything that you guys saw this morning which would put things into context for the rest of us? There’s a mike over here. I didn’t mean to put you both on the spot, but this is informal. So, feel free to--

WELLS: Since Allen Croff is here, if I say anything wrong, he can correct me. But, this is Alan Wells. I’m a user of these codes, and have been for many years, and Alan Croff helped me. He probably doesn’t remember, but I do in past years.

What we’ll see here is references to codes like the use of CASMO versus codes that are based on ORIGEN, and some various versions of ORIGEN have been created over the years. These basically end up with isotopic contents that are similar in nature, not exactly the same, but quite similar. What really matters in use of things like ORIGEN is whether or not you have properly set up your libraries and you have good control over your inputs. You have to make sure that you’re modeling things correctly.

Fortunately for us, there has been a lot of work with ORIGEN and validation of its results over the years, and it is part of the systems that Oak Ridge has been developing for years that are culminating in some more powerful tools that can be used in things like advancing the NUWASTE code into fast reactors, that sort of thing.

You will see some differences in terms of what the exact isotopics might be if you got down to that level of detail. But, in general, they're going to be about the same. And, as time goes on, perhaps we can make some more comparisons of the results.

Andy Worrall in particular might remember that we looked at comparing reactivities of spent fuel from different sorts of conditions, and the GNEP program, he's nodding his head, he remembers. Good. I'm not sure I know what we did. But, we can perhaps spend a little bit more time in the future making sure that the isotopic predictions, especially with plutonium isotopes, are consistent between the various codes. That's doable and it's checkable, and the sort of thing we can handle.

And, Allen, did you have anything? Okay. But, the codes will generate pretty much the same results if we're doing the same thing.

MOTE: Thanks, Alan. Any more comments from the observers? As Mark said this morning, we're not trying to be discriminatory, but just to keep things on a track where the participants have the early discussions, we'll do it that way, but is there anything else from the observers who are not in the presenter groups?

(No response.)

MOTE: All right. Then on the agenda, we have lunch until 1:15. We’re only a couple minutes late, so let’s stick to the 1:15, and we’ll see you back here then.

(Whereupon, the lunch recess was taken.)

AFTERNOON SESSION

ABKOWITZ: I want to welcome everyone back from lunch, and hopefully, your bellies are not so full that it's going to make you very, very sleepy, because I'm sure we'll have that ability on our own to move you in that direction.

The session this afternoon is organized by getting through the first three of the five phases. We'll be doing that in sequential order, and actually we are only allotting about an hour and 15 minutes for each of those. So, we're going to try to move through this at a good pace.

And, I might point out that in addition to the individual presentations, we have put together a spreadsheet which we'll be sharing with you following the last presentation of this session, where we've done our best to try to compare the results where we can all look at them on one screen.

I will add that we may have made, you know, some educated guesses in terms of how to transfer the results as they were presented to us into a common format. So, those of you that are the participants, when you look at how we've presented the results, feel free to intercede and indicate if in some way we have misinterpreted those. But, we saw that as a very important opportunity to look at where we're in agreement, and where there are differences, and then try to understand why the differences are the way that they are.

We're going to go in reverse order from the presentations that we just had before lunch. AREVA is going to sit this round out. As you recall Marie-Anne is going to be focusing on Phase 4. So, we will start with MIT, and then we'll be followed by INL, then NNL, and then NWTRB.

So, whoever is representing MIT, you're on.

PASSERINI: So, these are the results for the metric 1 of the initial scenario, which was more a summary of the data provided in terms of the existing fleet and the existing spent fuel stored at a spent fuel pool or dry cask storage. And, you see the results that we got for the PWR and the BWR type of fuel. And, then translated the same information again using, as I said before--well, actually, some of them were also already given in the file sent to the participants. But, no matter what, like the way we interpreted the information was using like a fixed specter to move from the actual metric tons to the number of fuel assemblies. And, that was it, the total mass of the spent fuel at the beginning of 2010.

When we look at the metric 2 and 3, which was actually the composition of the spent fuel, here comes one of the assumptions that we made that CAFCA does not track isotopes. So, we calculated the composition of the spent fuel, we simply ran CASMO to give us the composition of the spent fuel, the given burn-up and enrichment. And, we assumed actually, and we tried aging of the fuel, which is why you might see a difference in our results for where we got especially the short living--the shortest living isotopes here, especially if you want plutonium 241, which I think is in greater quantity than what other participants got, because of probably the shorter age that we consider for the spent fuel as a whole.

But, other than that, I think they are pretty consistent with what also the other participants calculated. And, again, just see basically twice as much waste from PWR than from BWR, consistently with the assumption given.

And, finally, the Output Measure Number 4, which was a total mass of fission products and minor actinides. Once again, that was calculated using a fixed vector, taking out the input that we were given, or the input from CAFCA and then having a fixed distribution of minor actinides and fission products on the weight percent, and then translated that into the metric tons for the considered scenarios.

And, of course, fission products are in much larger quantities than minor actinides, and also the composition was slightly different because of the slightly different assumption in terms of burn-up and initial enrichment.

And, just to summarize the results of the Phase 1, which is basically the spent fuel at the beginning of 2010. As I said from the given input, we got the fixed distribution between P and BWR, so then we applied to all our mass flows throughout that were calculations also for the following scenarios. And, we just noticed that about 80 percent of the fuel is today in spent fuel pools and about 20 percent was supposed to be already is in dry cask storage right now.

ABKOWITZ: Okay. If there are questions about the manner in which the folks at MIT calculated this set of analyses, I'd like to entertain those now. As far as comparing any results they may have come up with with the others that you see over on the right-hand side, I think we should defer until we've heard from everybody, and then we can enter into that conversation.

Any particular questions about the approach here?

ROWE: No, I'll just make one comment, if I may. This little box on the right that says, "Checked," what we tried to do there is depending on how the data was reported, either as mass or as assemblies, okay--and I can't remember which way--you obviously did it in mass, is we added up the BWR and PWR mass, and got that total in that first box. And, then what that check is is just to check to add the total plutonium, total uranium, and total fission products.

So, the numbers in that little box that says, "Check," should be the same as the numbers in the larger box where it says "Total." And, we've already figured out why NNL doesn't, and it's my understanding, but the other numbers are in very, very good agreement.

PASSERINI: Well, one of the reasons why it doesn’t for us is that, of course, the isotopic composition that we took is fixed, assuming one aging, so of course the small difference can be due to the non-optimal composition of the fuel, representing the entire spent fuel stored. So, that’s why.

ROWE: They’re within a hundredth of a percent; is that right, or whatever? That’s close enough.

ABKOWITZ: Any other questions for Stefano?

(No response.)

ABKOWITZ: Okay, thank you. Steven?

PIET: It really bugs me to aim a laser pointer over someone. I’ll pick up where I left off this morning, some of which I’ve already--it won’t be relevant for Phase 1, but I need to set the stage for talks that come later.

The way I handled the specifications here was to--because of the way the specification was worded, or at least my interpretation thereof, I broke PWR and BWR into 40 and 60 year lifetimes, so that I could match the retirement profile if everything were to retire based on the current set of reactors and what they are currently licensed to do.

In our model, we have the option to use something like what you do with NUWASTE, but with regard to a variable LWR burn-up. In our case, it’s a 4^{th} order polynomial fit to the source of things that you did, and it's good from about 30 to 100 megawatt day burn-up.

So, one of the reasons someone was pointing whether it was flat or not flat, it depends on what range you're talking about and how large a range. In our case, we had it up to the 4^{th} order polynomial, and we don't differentiate between PWR and BWR, so the specs that you gave us, you told us to use a U235 enrichment of this, but in our model, we would use--we had to use a slightly different uranium enrichment. So, one of the things that will be different about our numbers versus perhaps yours is that we used a different uranium enrichment to be internally self-consistent.

ROWE: Just for clarification, the reason we made those specifications, we all know that that has a huge impact on the spent fuel assemblies.

PIET: Right.

ROWE: And we just took data out of the open literature of burn-up versus--so, basically, it's a linear relationship, and that's where the numbers came from for the specification.

PIET: The other thing I'll point out here, because you've asked questions about some of the details over there, is that this effort, which was done by a grad student, and I know that the grad students that are here never make mistakes, I'm just positive of it, but here, a mistake was made and U234 was not in the input DEX. Now, it doesn't make much difference, but our U234 numbers, particularly on the input side, will be off.

Now, I'll take the history of reactor start, so that I get the correct history of reactor retirements in later phases. A constant 90 percent capacity factor, constant burn-up specs. Well, that all multiplies out to 50,000 metric tons in the year 2000. We normally start our simulations in the year 2000.

But, we know what happened in the year 2000. That was 42,600. So, in all of our calculations, I kept the reactor start data to match history. Therefore, I have the right reactor retirement, 90 percent capacity from this point on, from 2000 on, and the specified burn-up after 2010. But, I had to fiddle with the burn-up prior to 2010 to make the number self-consistent.

So, the next three slides, I'll talk about real quickly. First, I start off with here's history, up to 2002 when the database was terminated. This is what the US fleet did on average, PWR and BWR for burn-up. The specs would call for that to be modeled with constant 32 and 39 megawatt day burn-up. And, at least in our model, that doesn't give me a self-consistent set.

So, what I did was I took a histogram, in green for BWR, black for PWR, to approximate historical data. It's not a great approximation, but it was close enough. So, this is in a bunch of spreadsheets that I've also provided, so here's burn-up, here's the U235 enrichment as a function of burn-up, the capacity factor that I used, because it varied with time as well. So, if you want to get a more accurate picture of what the inventory is at a particular point in time, you've got to know how long stuff has been sitting around.

So, this graph is used fuel versus time, going back to the beginning of commercial operation. And, I was able to pretty much peg where the US was in 2000, and the number that you folks gave us for 2010 blended off on the BWR, but this gave me a warm fuzzy that the shenanigans that I pulled earlier were roughly correct.

This is the electricity, again, taking the fleet and breaking it into two pieces. Now, Phase 1, you asked us to provide what we would project at the end of 2009, or beginning of 2010, so that's our number. We typically model, for sake of simplicity, how much fuel is in wet, or could be in wet versus dry storage, whether it's aged ten years or more than ten years. So, we know, of course, that that's not what we have in the US today, but that's what we could have with this criteria.

I don't know whether you're avoiding the laser pointer or looking back to me. So, let me pick on the other side. If I sit here, maybe it won't shine on you.

One thing I want to point out, by the way, you've got metric tons here of assemblies, it should be clear that this is metric tons of initial heavy metal. So, it doesn't include the mass of the zirconium and steel and all that sort of stuff.

So, this is the break-down by isotope. We actually tracked 30 Americium isotopes, 6 curium isotopes, 1 Berkelium and 4 Californium on this scale. Of course, the mass of these is peanuts. What else could I tell you here? So, here's the break-down, uranium, plutonium, minor actinide. We have actually the entire actinide decay chain in there. Any isotope that's got more than a half year half-life, we keep track of in the decay.

Fission products. This is going to be almost impossible to read. But, I've grouped for purposes of this slide the volatile isotopes we keep track of, tritium, Carbon 14, the rest carbon, krypton 81 and krypton 85, and all the rest of the inert gases, we just have as a lumped parameter.

A favorite one, long lived isotopes, technetium 99, the rest of technetium, iodine, and all the other halogen mass we put together. The alkali and alkaline earth metals, rubidium, strontium 90, cesium 134, 135, 137, barium, all that together. These are, of course, the isotopes that really cause heat in waste. The transition metals, zirc, ruthenium, palladium, selenium, and so forth, and then all the transition metal mass together.

Andy, one of the things you asked about was how we deal with waste. Actually, I simplified this. This other category for transition metals, we break into two. One is moly, ruthenium, radium, palladium, and then other, and we make that distinction because those elements, those four elements that I rattled off, constrain how much glass you have to make, the solubility of waste products in glass. So, that's one of the types of things we have done in the model, and how we structured it to deal with waste management problems.

And, then, our friends the lanthanides down here, cerium 144, holmium 166, and then the rest of the lanthanide mass is a lumped creditor. So, we can give you the break-down in such a fashion. And, in the end of year 2009, it's 2000 tons of fission products. So, I think that ends my Phase 1 study.

ABKOWITZ: Any questions for Steve in terms of the way the calculations were generated?

KADAK: Just a question on the tons, that's not in any waste form. It's just stuff of these elements, isotopes?

PIET: Correct. Now, what VISION allows us to do is we start with tons or mass of waste. Then, any waste form is going to be less than 100 percent waste load. So, it will also calculate, if I give it the relevant input data, tons of waste form as opposed to tons of waste, which is why I was pointing out over here that this is heavy metal, so this is waste. We differentiate waste versus waste form, and then the volume of waste form, and we can go as far as packaged waste. But, every step past this, those next three steps, VISION will do it, many of the codes will do it, but you've got to have input.

And, you know, if I'm talking about mass of packaging, volume of packaging for used PWR fuel assemblies, sure, I can go pick up that number. I start talking about aqueous process X and aqueous process Y and pyro processing Z, I have to dream up numbers that don't always exist, especially when I go into low-level waste, VISION will calculate all that, but I worry quite a bit that it's garbage in, garbage out.

KADAK: Kadak, Board.

There was a guy, Dirk Gomber?

PIET: Yes.

KADAK: He tried to put together an integrated study of that. How far does VISION go to do that? I know he had codes obviously to do it, but he did high, low, waste volumes, waste streams, and all that.

PIET: VISION incorporates all those numbers, plus any updates since his untimely death two years ago.

KADAK: Right. So, you're saying VISION--was the output included in his study on waste streams?

PIET: His study was static, and then we took--I worked with Derek quite closely, and we did a study for GNEP, which had some dynamic systems analysis, something or other, DSAR is what we called it, and we used his numbers and calculated those sorts of numbers for the GNEP scenario. So, VISION will do that.

KADAK: Okay.

PIET: But, it gets real tricky when you say--you know, some of my reactor physics colleagues think that you specify a reactor or a fuel cycle option by saying reactor this and fuel this. No, you haven't.

Until you tell me what your waste management strategy is, you haven't told me what a fuel cycle is, because I might throw all this into glass, I might put some of it in a metal waste form and some of it in a glass waste form, capture the volatiles this way or that way. I get radically different answers, and none of the computer codes that you've got here today can differentiate those without having the right input. So, you have to make assumptions on taking this into such and such a waste form, ceramic, glass, whatever. I'm dealing with solubility problems or I'm not. VISION will do what I tell it to do most of the time.

Now, we have a different computer code that doesn't do time dependence called FIT, where we've incorporated what the system--I mean, the separation guys and the fuel guys and so forth have given us, and the glass waste form modeled by John behind you, that gets more into the chemistry than VISION. VISION is a time dependent model. FIT, and some other things, are chemistry models. So, you have different models for different purposes.

KADAK: Okay, thank you.

DUQUETTE: Duquette, Board.

This assumes that we're going to use the same fleet we have now, and you're retiring the reactors that are online right now. Your model does or does not take into account advanced reactors, new license, possible new licenses, increased capacity, or anything of that nature?

PIET: Our model can do all of that. Now, for these specifications, as you will see in future parts of this talk, we kept the total model nuclear generated electricity constant. But, to most of us in the fuel cycle program, those are the boring cases. It gets much more interesting when you start throwing in MOX or HTGRs or HWRs.

DUQUETTE: Exactly.

PIET: But, we'll do any of those with whatever lifetime you want to put in there. So, we can run all those cases, or not.

DUQUETTE: Okay, thank you.

ABKOWITZ: Eugene?

SHWAGERAUS: Shwageraus, MIT.

Can you go back to your slide where you showed enrichment versus burn-up? One of your first--

PIET: This one?

SHWAGERAUS: No--yeah, where the correlation is between enrichment and burn-up. Yeah, this one.

There's one more degree of freedom, and I was wondering how it's handled in the code. It's fairly linear if you assume sudden reload fraction of your core. So, you can drive your assemblies with certain initial enrichment to higher burn-up or lower burn-up depending on what's your fuel management.

PIET: Yes.

SHWAGERAUS: So, how is that handled in there? Is it, you know, in other input parameters, or it's assumed like a certain fraction of your core is being reloaded?

PIET: I guess a two-part answer. One is normally we just use some input/output recipe from the library of some hundred--a couple hundred now cases that are in our library of calculations done at Oak Ridge or Idaho or Argonne, so we pick whatever is the closest case.

This particular instance, we had a polynomial curve fit to make use of.

SHWAGERAUS: That polynomial has only one dependent and one independent.

PIET: Correct, and it’s kept at 90 percent capacity factor and four and a half year fuel residence time, I think.

SHWAGERAUS: So, the fact that utilities use like batches of different sizes--

PIET: Not accounted for here.

SHWAGERAUS: Okay.

PIET: Which is, of course, why--one of the things that prevent me from matching this perfectly. I mean, to match this perfectly in any of these models, you would have to give it year by year the fleet average capacity factor, so forth and so on.

SHWAGERAUS: Yes, but my point, I guess the main message here is that this linear relationship, you have to use them carefully because there are other things that can spoil these linear--

PIET: I couldn’t agree more.

ABKOWITZ: Anyone else for Stephen?

(No response.)

ABKOWITZ: Okay, thank you. NNL, you’re up next.

GREGG: So, these were the results from Phase 1 for the benchmark. We did something very similar to INL, actually, I mean, that we did benchmark specification wasn’t that specific in what the age of the fuel was going to be. So, what we assumed was each--so, the dates which were given, we were given a start date for each reactor. We were given the total mass of fuel generated by that reactor, all the reactor fleet, and, so, we simply assumed linear interpolation, and this is the total mass of fuel which was generated cumulatively, over the years.

Now, in ORION, this is actually the ORION model which I used for both Phase 1, 2, 3, and 5, and the only difference is, for example, in Phase 1 of the benchmark scenario, the throughputs of the reprocessing facility and disbursed facility are set to zero. So, any material which is generated by reactor fleets prior to 2010, actually 2010, from the BWR and PWR stays in this buffer.

Okay, so in my model, I tracked 2,500 nuclides, and obviously most of those will have decayed away to nothing after a few months. So, really, it’s about 500 or 600 nuclides which are actually tracked. And, all the fuel, unlike INL, I assumed all the fuel was after a 39 year vector in the PWR fleet, and 32 year vector from the BWR fleet, as described in benchmark specification.

And, as for the results, which are on this side, and the reason why there is discrepancy between our results and the other ones is because this is actually just the heavy metal mass, and doesn’t include the fission product mass. So, if you actually calculated what the difference was there, it’s about 3 ½ percent, which is the fission product mass base. So, if you were to include the fission product mass, then those results would be very well identical, almost, to all the others. And, it doesn’t come as a surprise really in the case, because, I mean, that’s the benchmark specification. If you don’t get that number right, then something else is--so that’s the reason. It’s not because I made a mistake, it’s because the results are transposing currently.

And, as for all the other ones, because I’m tracking all the nuclides separately, and essentially 600 really, because it’s all natural uranium, what I have done is I calculated what the--ORION calculates what the fresh fuel composition is going to be using--by soaking multi-isotopes by equation, and, so, that’s taken into account.

That’s about it really on that. I mean, it’s quite a simple scenario, and the results are calculated essentially using FISPIN, and in my scenario--and, in my model, sorry, and I have used essentially what is called a feed objective, so I essentially just inject the right amount of material each year into a buffer, and once it’s in the buffer, it’s decayed using equations, and then in 2010, the results which I have given is the cumulative mass of fuel which is being discharged up until 2010, which is 61,000 tons.

That’s about it, really. Any questions?

ABKOWITZ: Any questions?

(No response.)

ABKOWITZ: Okay. Gene?

ROWE: Actually, we did not do a calculation for this. The input data that we got is based on data that the DOE had within the TSM, and, you mentioned the TSM, where they got data from utilities, so there was no calculation. It was just a spreadsheet. And, if you go to the next slide, these numbers are just arithmetic, adding up the number of assemblies. We estimated the burn-up based on calculations from NEI, so it's very straightforward.

If you go to the next slide, we then calculated, based on the methodology I discussed this morning, for certain burn-up. There's a linear relationship as to what the isotope concentrations are.

And, actually, except for the 241, except for the Pu241, the data is pretty good, it's surprisingly consistent through all of the groups that did the calculation, which is quite amazing in reality. The Pu241, I think the difference in values is due to whatever assumption people made for the age of the fuel for the decayed, because Pu241 obviously has a short half-life. And, I think there's also some issue within the way that we did the calculation, the Pu241--the Pu239, I should say, for the BWR assembly seems to be low, and I need to talk to some of the ORIGEN experts who are sitting in the audience to maybe help me with that. But, the numbers are pretty consistent throughout all of the vendors.

Very simple.

ABKOWITZ: Gene, why don’t you stay up there for just a moment. So, we’ve kind of transitioned here from the results for NUWASTE to the comparison among them. I guess we’ve already explained why INL’s numbers for U234 are where they are, and Robert has indicated how the math works in terms of adding things up for the check.

Do you want to elaborate on anything else that you see? And, I open this up to other people here, participants and the audience. Are there any other things that this table identifies that would be considered perhaps, you know, distinct enough that we want to kind of question how the number got created?

MOTE: Is it worth seeing if there’s any agreement now why the 239--I’m sorry--is it worth exploring now why the 239 numbers may be different?

ROWE: I don’t think so. My number seems low, and it seemed low for the last year, and I’ve had problems with the masses from the BWR assemblies. I think it’s better to handle off-line than try to bore everyone here.

ABKOWITZ: You’re talking about 239 for the BWRs?

ROWE: Yes.

ABKOWITZ: Yes.

GREGG: It’s probably a cross-section thing, because with PWRs, someone is using a cross-section dataset for PWR, and you're going to get fairly--well, you're going to get quite similar results. But, with the BWR, the inventory, which will calculate, depends very much on the cross-sections because then you got, and voided, for example, which you assume in your cell model, is going to vary, and that will have a big impact on your neutron spectrum, and also on the reaction rates for generation of Plutonium 239, for example. So, that probably explains why the BWR, Plutonium 239, and for NWTRB is different from everyone else. And, explains why the Plutonium 239 for the PWR isn't that dissimilar to everyone else.

ROWE: Yes, the Ps seem to be reasonable. The B, the one that doesn't look reasonable, is our value for the 239. The 241s don't worry me because, pick an age, and that's going to change that number. But, the other numbers look pretty good.

GREGG: Because when we did--when I did my FISPIN calculations for the BWR, and I did two calculations actually, I used a cross-section, which we had for a Japanese BWR, in fact, an old one from the 1960's, and then I also did another calculation using a more advanced BWR and fuel design, an ATRIUM--

ROWE: ATRIUM is that one?

GREGG: Yes, an ATRIUM 10 by 10, and the inventories, which I calculated from those two, are significantly different, and it was basically the total amount of plutonium. And, in one of them, the neutron spectrum is much harder, which way it goes, but I think if it’s harder then you get more Plutonium generation.

ARNOLD: Arnold, Board.

Contingent on the same subject, looking at the 240, I see that your number, Gene, is quite consistent with everybody else’s. And, you know, the 239 is the only anomaly.

ROWE: That’s exactly right.

ARNOLD: And, why is the 240 okay, and the 239 not?

ROWE: That’s my question. I don’t know.

GREGG: It will be the fission, not the capture, cross-sections.

ROWE: I don’t know if I used the wrong library or what.

GREGG: Well, there’s isn’t really a correct library.

ROWE: That’s why when we went to the specification, I wanted to do all the calculations with just reprocessing PWRs, because the PWRs, my numbers were funny, and I didn’t want that to muddy the water for all the other calculations. So, that’s the reason that we took and only reprocessed the PWRs. And, I need to get that resolved as to why that’s a little bit low.

ARNOLD: Just as an aside, I bet NASA wishes we could get our hands on the 238. There’s quite a few metric tons.

PIET: I will remind you that the curve fit we have for burn-up is all based on PWR calculations. So, the fact that the BWR numbers that I generated are as close here as they are for most of the isotopes, is more accident than anything else.

ROWE: Yes, I think so. That's again why I wanted to do the Ps. The P, I think the data, everyone has better data on the Ps than Bs. So, anything else?

ABKOWITZ: Well, I would like to ask a question, and this will come up when Nigel moderates the session later on, but is this an area that requires further research and investigation as a community?

ROWE: I don't think so. I think it's something I'm doing, I believe. Okay? And, I can't figure out why, and maybe with Alan or Allen, we can come to a conclusion.

WORRALL: Can I make a comment? One of the things we have noticed over the years is that, in terms of the Sellafield reprocessing, and so on, is that every time any fuel is shipped to the Sellafield site, we're the organization that checks the shipper's data to make sure we receive what we think we received. It's pretty important when you're reprocessing the fuel. And, one of the things you find is the biggest deviation is always in the BWRs. And, it's simply because the BWR is a much more complicated beastie, but also, it's so varied in the fuel designs. Robby is absolutely right, the difference between these, the 6 by 6, 7 by 7 BWR, going to make sure the 10 by 10 is dramatically different. So, that's kind of a level of detail, probably way beyond the fuel cycle model.

But, this raises a really important point now, is that nothing in this is what you're alluding to, Gene, is in terms of are you using the right cross-section, you can ask the question, are you using the right library. And, I think it's a really important question to ask of the US community in a sense, that if the US community is using ORIGEN library that is based on certain premise of historic fuels, and that has evolved into something very different, that people need to understand that, because otherwise people are using a black box, we heard that phrase earlier, they're using a black box, is incredibly dangerous. You've flagged that and you've identified that and you want to investigate further, I think is absolutely right to do so.

And, that's why when Robby mentioned it, when we do our inventory analysis, we can use a standard library, but moreover, it will more often than not, we prefer to actually generate the cross-sections. It's just pretty easy to do so if you happen to know how and have the tools, which is what we do to avoid this kind of have I picked up the right kind of data, and so on. So, I think it's important to flag. The others may be using it in a black box sense, and may actually be, you know, finding problems.

ROWE: Yeah, I'd like to make one statement in my defense. And, that is is that I've been doing these calculations for several months, and the BWR always bothered me. But, I could never figure out why. Based on this exercise and looking at this data the way it is now presented, I've kind of--the flag kind of started waving that it looks like the 239, there's some issue with the 239. So, from my point of view, this already has been a good exercise, because I think it has identified one of the issues that I've had for several months, and I haven't got an answer yet. Anything else?

ABKOWITZ: Well, this begs the question if this is an issue with ORIGEN, is this also an issue--is it CESAR, is that what you use instead of ORIGEN?

GREGG: Well, are you talking about the UK?

ABKOWITZ: Yes.

GREGG: Well, we use FISPIN, which is essentially similar to CESAR.

ABKOWITZ: Okay.

GREGG: And, with FISPIN, you define the cross-section library, whereas, I think with ORIGEN, you choose a cross-section from a set, which is compared into the code, and you can't easily define different cross-sections. So, that's the difference between FISPIN and--

WORRALL: You'll think in a dataset. That dataset is wrong. It doesn't matter what you do in that dataset, you still have the wrong data.

GREGG: I think it's important to also know that--

ABKOWITZ: So, let me get clear--I'm sorry--let me just clarify in my own mind then is there also then an argument that FISPIN might be more a attractive choice for US modelers as well?

GREGG: Yes. Well, to be honest, I think ORIGEN, isn't there a version of ORIGEN where you come to find your own library?

ROWE: Yes, there is. I don't think we need to spend any more time on this. I think we have identified an issue and I think that we need to resolve it off-line.

ARNOLD: Is the discrepancy due to the generation rate of the plutonium, or to its loss by fission?

ROWE: Probably the later.

ARNOLD: The reason I say that, you'll find that maybe some clues in looking at the other plutonium isotopes, not just at the 239.

WELLS: This is Alan Wells, and I've just come off of a couple of meetings as part of a DOE project to look at burn-up credit, and one of the things that we were looking at was the isotopic generation by computer codes. And, there has been a lot of work done recently on especially PWRs, as always, but we found that we could resolve a lot of the differences with the calculations. And, a very similar problem existed. BWRs have always been a problem and Oak Ridge plans to continue to work on them. But, you all have already summarized it as the fact that they're very complex assemblies and they are quite different assemblies when you look at different generations.

But, the path forward for the NWTRB has a number of choices, and one of them is to simply go to the more recent version of the ORIGEN code, which is now available from Oak Ridge. And, I don't work for Oak Ridge, but the fact is that it's available, and in fact I've already talked to Steve that Steve knows the author who now works for Idaho, for some reason. Way too cold for me. But, there's a version which is now called TRITON, and TRITON uses ORIGEN. It's still Allen Croff's original ORIGEN, with some library updates that were done by Bill Harmon at Oak Ridge, I believe, in the mid Eighties.

But, the version that's used is ORIGEN-S. S simply stands for scale. And, what's different here that's important to this group is that the trade in computer code sequence of scale, unlike the older SASH 2H and the ORIGEN-R, which is what I think you've been using, but the--you haven't been using TRITON. See, the TRITON code system short-cuts this problem.

Instead of using an existing computer library of nuclear data that has been fit to a particular PWR assembly with a certain initial enrichment and a certain operational history, for example 3 ½ weight percent initial enrichment, 35 gigawatt days per metric ton, an analyst at Oak Ridge would sit down and would create a nuclear data library for ORIGEN with those characteristics. And, then, they came up with a number of different libraries, and they indeed did some work with fast breeder libraries and heavy water reactor libraries, and stuff like that, which aren't used very often these days.

TRITON takes the other approach. Given that computers are much more powerful today than they used to be, and we can afford to ask the computer to do more of the work, Oak Ridge has developed a system called CENTRUM, which means something to them, but not to me. It's just an acronym that talks about the fact that it takes the original raw data nuclear libraries from computer codes like MCMP, which have a compact version of the evaluated nuclear data files, and it takes that very complex, very large library, and it does a bootstrapping calculation that says if I have an initial fuel enrichment of some value, and I were to burn a little bit, I would then have cross-sections that would change in some way, not in the cross-sections, but the isotopic inventories would change a little bit. And, it starts working its way into the problem and it creates a cross-section library that is appropriate to that particular problem. And, then, it uses that library for that depletion and time step.

So, for example, the guidance from Oak Ridge is, I think, something like no more than 70 full power days that you would do in a burn cycle, where the burn cycle may be 335 and you're doing it in steps of 70. This new code system goes in and creates a nuclear data library that's representative of what's burning in that assembly during those 70 days, pretty much near the mid point, it tries to take it about 35 days in.

And, then, for the next step, it creates a new nuclear data library. So, what you're doing here is you're trading off computer resources in terms of time. But, you're getting a library that's tuned to exactly the case that you want to do. So, in that sense, you're able to be more representative of what your code has been in CESAR, too, that you just get better stuff. But, it's part of SCALE, so it's not anything special.

MOTE: I heard what you said then, but one of the issues that we heard before was that in modeling a BWR, it's not so much you don't know what the fuel is, but you may not know what the void coefficient is, as there's other things in a boiler that are particularly difficult to model. So, if the code change to TRITON makes a step forward, how much does that improve it? Because if you have other unknowns, it may be that you improve on one small parameter by a great amount, but it still leaves it with a big noise bound overall. Can you tell us in the context of how important that step is, given the uncertainties and a big unknown?

WELLS: First of all, we kind of improve things with the PWRs right off the bat. As part of the other work that's been done, again, I don't work at Oak Ridge, I simply use their stuff, but they have looked into coming up with models that are more representative of BWR fuel in recent years. So, there is some guidance on what we should be using in terms of void fractions, and not only void fraction, but the void fraction as a function of the assembly.

So, we were talking about, at lunch time, there with Andy about the fact that there have been some good results when you do three dimensional calculations. That may be a little bit overkill here, but we can certainly do bottom of the assembly and on top of the assembly, and things like that, because that's pretty straightforward.

The point here really is merely that without deviating from using the SCALE code system, which is the staple of the US community, we can improve the calculations. And, it's fairly straightforward. So, I can work with you and we can set it up, and you can run all the calculations.

GREGG: Also, can also have a bottom to that, COSMO simulated model which calculates the spent fuel inventory, and so do an analysis for the whole core, and then from that, so, I say from that, it may be exactly what the voidage is in the core and it uses those to calculate what the cross-sections are. And, from that, you calculate a very--it calculates a very good inventory for the assembly, taking into account things like how voidage varies actually across--of the core.

WELLS: All right. We'll be talking about this over the next couple days, and on Wednesday, and certainly the Board can decide which path they want to use. But, there are a number of options, all of which there's ways to work.

You were going to say something, Steve?

PIET: At the risk of upsetting any reactors, this is--I think the reactor physics part of all this is the best known. So, you eventually have to figure out what exactly are you looking for in terms of what outputs, and what uncertainty is acceptable or not acceptable given those purposes. I think you will find that the chemistry, waste form loading, and so forth you will find much larger uncertainties than any of the reactor physics.

ROWE: Well, I'll take that a step further, and that is the biggest uncertainty that I've found is the waste stream. And, we've assumed a constant waste stream, which means that the US is going to build 100 new nuclear power plants between now and 2050. I don’t know if that’s a good assumption or not. But, that’s the assumption that we made. And, you change that assumption, and these numbers change drastically. And, like you said, those changes completely outweigh the physics, completely. Even as much as this one looks strange, it has extremely small impact on the answers that we’re looking for.

WORRALL: Can I just make one comment?

ABKOWITZ: Andy, yes.

WORRALL: I totally agree with that. I think it’s important to think about if you’re looking at this on a much larger scale, then don’t get involved in the detail. I totally agree with that. However, one small point is that if you can improve on something and it’s easy to do so, then let’s do it. This is a slightly different approach, and I apologize to the NRC guys sitting behind me, but in the UK, the nuclear regulation, in the UK, the NII has a philosophy that says a utility or a licensed holder is only a good license holder if they continue to demonstrate improvement. Okay? So, this idea of sticking with an ORIGEN version-7.3 years ago in the UK doesn’t fly--it doesn’t fly in the UK. And, I’m being a little bit facetious when I say that, but it’s an important point to make, is that if you have something that’s better and easily achievable, as Alan was just describing, and is well known, then by all means, please, let’s use it. So, you can instantly eliminate that as an uncertainty in a problem, and move on to the next one and you can concentrate on what is important.

PIET: Agreed.

ROWE: Okay, I think that horse is dead.

ABKOWITZ: Okay. Are there any other horses in Phase 1, which apparently was the softball from this exercise. So, we’re already off to a pretty passionate start here.

ROWE: Why don’t I go for Phase 2 since I’m already up here?

ABKOWITZ: Well, I’m just going to turn the Baton over to Nigel Mote, who will be moderating this session.

MOTE: I was going to say the same thing, Gene, we’ll go in reverse order. So, if you stay up there, and we’ll get the next horse out, you can ride that one.

ROWE: In this one, why don’t you put the other spreadsheet up over there also, the 2.2.

This one is a--I explained in my discussion this morning, we have very simple average calculation for the number of fuel assemblies that are discharged. Okay? Very simplistic. But, if you average it over the lifecycle of the reactor, it gives reasonable results. We’ve kind of benchmarked it against any independent-data, projections, and we get reasonable results.

As far as the radionuclides, you can go to the next chart there. This doesn't say much. It just gives the numbers, and if you go to the next slide, Bill, the isotopic content, which is similar to the values, should be the same as those values over there. You see something similar in the plutonium, still seems the BWR number seems to be a little bit strange. I don't want to go through that discussion again. But, in general, again, I'm reasonably pleased with the consistency of the results that we've gotten. It's remarkable that we've got five organizations doing it completely different, and yet we came up with numbers that were quite reasonable.

So, I think that's my only comment.

MOTE: Okay. Anything?

(No response.)

MOTE: Okay. Do you want to speak from here?

GREGG: It's the same presentation as before.

Okay, so we're pleased to--the point of it was to calculate what the spent fuel inventory would be as of 2100, and, from the current reactor fleet and from the future PWR and BWR fleet.

So, my scenario, and I assumed that all the fuel discharged from 2010 onwards from the current reactor fleet, and the future PWR fleets was 55 gigawatt days per ton, as given in the benchmark. And, also, I assumed that the new build fleet would come online when the current reactor fleet goes off-line. So, that basically means that the first unit would come on line in 2012, next year, we haven't got much time really, which is obviously unrealistic. But, from the point of view of benchmarking, it doesn't really matter.

Now, it's a bit tricky to understand but there is limitation in ORION in how it does its fuel management. And, basically, any reactor in ORION, fuel has to be discharged every time step, and the time step is one year. So, basically, that means fuel has to be resident for an integer number of years, and the cycle is twelve months. So, in order to model an explicit burn-up of 55 gigawatt days per ton, I can't do that without fudging my model slightly.

So, in order to model 55 gigawatt days per ton, what I need to do is for the PWR fleet, assume that a total time of five years, and for the BWR fleet, a total time of six years. And, then, in order to be sure that the yearly spent fuel mass discharged from the PWR and BWR fleet is correct, as is the burn-up, I needed to change the core mass, which is fine, it will calculate explicitly what the mass of fuel per year is going to be, because that's quite a simple calculation to do. But, it does mean that when the reactor is taken off line, because I've changed the core mass by a small amount, means that my final discharge, in terms of mass, will be slightly wrong. But, it's tiny compared to the total mass of fuel generated over 60 years. So, that's not really a problem.

So, as for the results, the stuff as of 2010, and the inventory is obviously going to be decayed for a further 90 years, this is the inventory as of 2100. But, I need the fuel which was discharged from the reactor before 2010. In fact, this first one, I've actually seen the results, at least the other people's. The results tend to be in agreement with everyone else.

That's about it.

PIET: Okay, do you want to pull up the Idaho one?

We'll talk about this slide that I flashed up very quickly before. Because I divided the current fleet into PWR, BWR with 40 and 60 year lifetime, as of 2010, so then what the model does is it--I told it to assume per the specifications, that our future reactors are built with 60 year lifetimes, so the fraction of the current fleet and it's 40 year lifetime, those retire of, according to their respective start times.

One of the reasons that the numbers bounce around a little bit here is that I took the current fleet, and I have to give VISION what the average capacity of each reactor in that cohort of reactors is, and so it's four different numbers. So, when VISION sees a 40 year reactor lifetime retire, it tries to keep the electricity constant, but it can't quite do that because it's due to slightly different size reactors, just based on the current reactor fleet.

So, this number bounces around a little bit. The fraction between PWR and BWR bounces around a little bit. But, it's because you can't exactly keep things constant in a dynamic model, unless you really go in and hard wire it to force it to do that.

So, here's where VISION calculates out at 2100, and then you go for the Delta, and it's about a 2,000 ton per year output, given a burn-up of 55.

So, this is the type of table that I showed before, but here, it's 2010 to 2100. The numbers are higher, of course, because all of this is 55 burn-up material. The fission product fraction is higher than most of what's in storage today. And, again, the same type of table that I showed before with all of our favorite isotopes.

And, again, I point out the waste management strategy, assuming--you have to decide, am I going to take things apart, am I not taking them apart. This does not include, for example, the mass of steel and zirconium that's in the core, and that's a non-trivial amount of mass, and will vary for different reactors and different reactor designs.

So, that's it for Phase 2.

ARNOLD: Arnold, Board.

The difference, you go back down to our friend the

Plutonium, you’re considerably higher than everybody else, and Gene is right in line. I’m looking at the BWR masses over in the right-hand side. So, the anomaly has moved from Gene to you.

PIET: And, maybe tomorrow it will go someplace else. No, we’re using, for all these calculations, correlations for a PWR as a function of burn-up. And, so, the BWR numbers I know will be off more.

ARNOLD: Okay. But, Gene is right on, right in the middle with at least the other three, yeah.

ROWE: Well, the reason could be is that there were two different fuel ages--two different burn-ups, I’m sorry. The initial burn-up of the stuff in storage now was 32, and--gigawatt days per ton, and the burn-up for the future assemblies is 55. So, could be somehow correlated to the calculation associated with the burn-up. The lower burn-up, there may be more error than in the larger burn-up. That’s what that looks like.

MOTE: Eugene?

PASSERINI: So, you would have our results for the Phase 2. So, we have the number of fuel assemblies discharged through 2100. Those are just the numbers, not including the numbers that I already presented for Phase 1. Those are just the ones from 2010 to 2100, and again I put here again that the reference--so, what we did, we calculated the mass, as I said before, and then we translated that into a number of assemblies based on the assumption that we made. AP1000 for the PWR and the ABWR for the--to replace the existing BWR fleet.

But, again, I think it’s probably more interesting to look at the isotopes which were the metric 2, 3 and 4, I think. Yes. So, in this case, one of the things we wanted to do, since CAFCA is not able to do isotope tracking, was to provide those numbers for different aging of the fuel after discharge. We didn’t have too much time, so I only have like probably the less one, which was the first one, the first test was just 100 days, and you see that because we have a high mass at 241 compared to all the other participants. So, it was lack of time, but we will present I think tomorrow other vectors with the same burn-up for the last two scenarios, having different aging. So, I think the number will be more reasonable under that point of view. But, other than that, yes, the absolute number looked consistent in terms of the total mass discharged from the fleet over 2100.

And, once again, the numbers for fission products and minor actinides, again, almost the same composition in this case because we specified basically the same burn-up in this case compared to the fuel that we had until 2010.

And, again, that’s the summary, that’s basically the mass flow that CAFCA calculates. So, for the steady state for 100, let’s say, PWRs or LWRs, I should say, CAFCA sees 19.5 hundreds of metric tons are discharged per year, and then to that, you have to add the decommissioning of the units. But, this number, 19.5 hundreds of metric tons, will be also relevant for the following scenarios when we add capacities for reprocessing and disposal. But, that’s basically what CAFCA calculated.

KADAK: Could you go--let me, while you’re on that side, why are those things jumping up and down, the discharges?

PASSERINI: Because those are the discharge for the entire units when they are decommissioned. So, this is a steady state for a year, what your fleet is discharging, and then when you have to retire your existing fleet, you discharge at once the entire core for several units at a time, because some of them are assumed to have the same age.

KADAK: Okay.

PASSERINI: In our assumption.

KADAK: All right. Can you go back to I think the second slide?

ARNOLD: Just a minute, just before you leave that, why isn’t there a corresponding dip there for start-ups?

PASSERINI: Because that’s just the total mass discharged per year. That’s the mass coming out of the fleet as a spent fuel form. That’s why you don’t see--that would be natural demand of uranium consumption, if you want, but in this case, you don’t see it because that’s only the discharge out of the reactor. That would be basically what would be an input tomorrow for the other facilities that we will include in the benchmark case.

KADAK: So, those are like full cores?

PASSERINI: Yes.

KADAK: Instead of--

PASSERINI: Yes. Yes.

KADAK: Okay. Now, if you’d go back to your second slide where you contrast--that one.

PASSERINI: Yes.

KADAK: That’s an interesting message, if you look at those two numbers. And, that’s why I don’t really like masses as a unit of measure for all this stuff, and that’s number of assemblies are things we have to transport and process and handle, and you’re saying the BWRs have what?

PASSERINI: Yeah, because that’s what I took the number for, so if you look at the design for the APWR, it’s larger reactor site, linearly extrapolated the number to match my reactor site, which is just 1000 megawatt electric. But, the design of the core is 872 fuel assemblies, compared to just 157 for AP1000.

KADAK: All right. And, the heavy metal discharged from that, if you convert that to heavy metal or whatever--

PASSERINI: Here, basically, once again it’s basically one-half, because as I said before, the fleet is 66 percent, basically PWRs, 34 percent is BWRs, and they have the same burn-up, so basically the numbers get very close to the same proportion.

KADAK: And, the casks can handle about three times as many?

ROWE: Andy, the masses are over on this also. Do you see where it says, “Total generated,” and it’s number of assemblies and mass of assemblies.

ARNOLD: Okay. But, you’ve changed the mix of electricity generation by that choice, because you’re replacing--yeah, you’re replacing an 1100 megawatt BWR with a 1300 megawatt--

PASSERINI: No, see here, so, that was the original number, so for 1300 megawatt electric, you have 872 fuel assemblies. So, I linearized it down to 643 to match my reactor sites, and that’s the same for the PWR. So, 157 to 134, linearly extrapolated to match up my one gigawatt electric size of the reactor.

ARNOLD: So, you have the same electricity generation from BWR as PWR?

PASSERINI: No, that’s just for one--

ARNOLD: No, you keep the same generation mix?

PASSERINI: Yes.

ARNOLD: Yes, okay.

MOTE: Thanks, Stefano. In this table on the far screen there, we’ve picked out a few anomalies--anomaly is the wrong term--we picked out a few areas, primarily the Plutonium results from the boiling water reactors where there are some identified differences. We’ve also already acknowledged that there are differences in the U234 content of the spent fuel. But, there are some other over there that I saw that maybe is worth exploring.

We talked about--and, these may be common causes, but I’m not sure of that. In the--when you talked about the low 234 there, there’s a similarly low 238 in PWR? We’ve got 26 here. That’s only about 50 percent of the 238 content of the other spent fuel characteristics. Did you make a comment of the cause of that, because I don’t recall any concept I have of why that would be low?

GREGG: I think there is a difference in PWR mass, and I think the total mass of fuel very much depends on what Steve assumed for your new build fleet. So, I think when I did my result, and when I did my calculations, I just assumed it was a replacement of the old reactors with the same ones. So, the power density which I assumed for the PWR fleet I think was down to 33 watts per gram, and had I done it differently, I could have assumed power density of 1000, which means--

MOTE: But, isn’t that the same as the other--for the other participants?

GREGG: Well, it wasn’t defined, the power density of the cores weren’t defined for the new build fleet in the benchmark. So, that was kind of left to the participants to choose.

MOTE: I guess I’m not tuned into that. We talked about 241 in the boilers, but we’ve also got the same issue here with 241 in the PWRs, MIT and INL are very significantly different.

ROWE: I wouldn’t get hung up on the 241 because of the decay.

MOTE: Okay, yes, that could well be. I’m not hung up on it. I was just thinking that if I can identify now where there are differences, it may be that something will jump out at me and go okay, we know what those are. We don’t need to try and deal with them now.

ROWE: Yes, when we get into Phase 3 when we have specific time, fuel ages, then I think those problems go away.

MOTE: Absolutely.

ARNOLD: Nigel, there’s also big differences in the fission products and minor actinides.

MOTE: Yes, assuming the--

ARNOLD: Yes, that’s a big difference.

ROWE: Well, that was my error. I misinterpreted the NNL results, and, so, actually if you took those numbers and divided them almost in half, then the numbers come out right. But, the way that they were presented and the way I read them, it was Saturday morning and--

ARNOLD: British English is different.

MOTE: There was no blue moon around?

ROWE: Well, as my old Japanese friend used to say, “Sometimes even the best monkeys fall out of trees.”

MOTE: Okay. Well, I think that probably covers then the differences on that. With regard to--we ought to get to them later.

Anything else on this set of scenarios, this phase of the analysis?

(No response.)

MOTE: Well, we’re bringing this one in early. I suspect the later ones are going to take a little longer to discuss. Why don’t we take a 15 minute break now. 10 to 3:00, start back again.

(Whereupon, a brief recess was taken.)

ABKOWITZ: Okay, we’re ready for Phase 3, and we’re actually well ahead of schedule at the moment, which means we may be the first ones to go downstairs. I would have said to the bar, but since it’s transcribed, well, now that I’ve said it--so, we’ve got actually four participants in this exercise. Scenario 2.3, the spreadsheet that you see on the right-hand side over here is incomplete, and that’s in part because two of the presentations actually have their output as graphs, and we'll need to somehow do some tap dancing here as we go through the presentations. Perhaps you can identify where on the graph you want to be, so that it coincides in some fashion with the information we have in these tables.

Consistent with the pattern that we've gone through up until now, we're going to reverse the order for this particular scenario. This is the impact of repository disposal. We will start with Stefano representing MIT's approach.

PASSERINI: So, that's our result for the scenario that has the basically the opening of a repository in 2040, to the end of the century, and the capacity for the Scenario 1 is 1500 metric tons per year. For Scenario 2, is 3000 metric tons per year.

So, here you see the Output Measure 1, which is just a total mass of PWR spent fuel disposed every year through the end of the century. So, let's first focus on the Scenario Number 1. So, we have 1500 metric tons per year of acceptance rate for the repository. And, as I said before, the steady state value for my discharge rate is already higher than that because it's 19.5 hundreds of metric tons per year. So, I'm not surprised, I can saturate the capacity of the repository steadily from the opening to the end of the century.

Here is a thousand, because as I said before, I split my mass rate, basically two-thirds is PWR, one-third is BWR. So, two-thirds of 1500 is like a thousand. So, we have the PWR that saturates until the end of the century, and the same for the BWRs in the second, still the orange line, Scenario Number 1.

And, if you actually, yeah, I didn’t provide the data for the table, but for this case, it’s easy because we have 1500 times 60, that’s 90,000, and that’s basically exactly the results that you see here. So, we discharge every year more fuel than what can actually go into the repository. So, no surprise, the sum here is basically 90,000 also for my case. Scenario 1.

So, for Scenario 2, actually, we have now 3000 metric tons per year that can go into the repository. And, as I showed before, that’s the discharge rate from the reactor fleet that we have. This is higher than what we discharge every year. And, as a caveat, in my scenario in this case, I took basically, I probably misinterpreted the instructions. So, when it was said to use the fuel, spent fuel discharged in Section 1.2, I basically only considered this one, without disposing the spent fuel legacy that we already have. And, that’s why, as you see here, I do not have enough spent fuel to saturate to the end of the century, also the capacity of Scenario 2.

So, in 2085, basically, I’ve kind of run out of spent fuel, because I’m not disposing the spent fuel legacy, and, therefore, I can only keep going until 2085, and then I have to drop down to the steady state value of 19.5 hundreds of metric tons per year. So, my number here will be not exactly twice as much as here, but will be smaller because I did not assume to be disposing also the spent fuel that we had in the beginning of 2010. And, that’s why we have the drop here.

Same for BWR, the results are just killed basically, so this is basically half of what you’ve seen before, because again of the fixed proportion between P and BWRs, and those are basically the summary.

So, the annual spent fuel discharged for the entire fleet, excluding decommissioning, so the steady state value is 19.5 hundreds of metric tons per year. And, therefore, the spent fuel discharge rate saturates the disposal capacity for Scenario 1, no matter what. And, it does the same until 2085 for the Scenario 2, not taking into account the spent fuel. Otherwise, it would be just the same here as you see, 90,000 and 180,000, as a result.

ABKOWITZ: Any questions for Stefano in terms of how the MIT approach to this problem was done?

SHWAGERAUS: The original interpretation.

ABKOWITZ: How should you have done it?

SHWAGERAUS: Yes.

ABKOWITZ: Well, Gene, do you want to answer that?

ROWE: Basically, I don’t know. I guess I don’t understand what you mean, what the interpretation is. Is that 1500? You’re discharging about 2000; right? And, you’ve got about 60,000 in backlog, so if you get 1500, as you indicate, you will saturate at 1500. If you take into consideration the legacy fuel, you will also saturate at 3000, and it will not go up. So, is that okay?

PASSERINI: Well, put a different way, even with the 3000, you generate enough spent fuel, starting like with 2010, to basically saturate 3000 just until 2085. So, you only have 15 years left to put in if you want, the spent fuel legacy. So, you definitely end up saturating that one as well, if you take into account the results in Scenario 1, Phase 1.

ROWE: This scenario is pretty simple, for lack of a better word. But, again, it’s a progression that we wanted to go for the overall evaluations. It’s pretty straightforward.

PASSERINI: But, that will be the same for me. So, I think the same assumption also for Scenario 4 and 5, so tomorrow, we’ll see that again, have slightly different numbers there, and I do not saturate sometimes what other results do, because I’m not using the spent fuel legacy. I probably just misinterpreted the instructions. That’s why, basically.

ABKOWITZ: Okay, thank you. Steven?

PIET: I got too animated.

MOTE: Oh, okay. Can I just ask a question? I don’t know whether this is something that we should try and do, but if we can, it might be useful. As Stefano now knows that by introducing the legacy waste, his model might be different, his results might be different. What we may want to do is see if he can run that difference tonight, if it’s easy to do. I don’t know whether you can do it from here.

PASSERINI: No.

MOTE: You can’t?

PASSERINI: Yes.

MOTE: Because then we can fill out that table.

ABKOWITZ: He’s from MIT, you know. He may want to do this, I would think, by 4 o’clock this afternoon, don’t you think?

MOTE: If it was Vanderbilt, you couldn’t do it?

PASSERINI: 3:30.

MOTE: Joking aside, it might be useful in the report from this workshop to have the table that we have here filled out because we don’t have either INL or MIT results in here, just because we didn’t know how to interpret them. If the presenters could help us fill that out, it may be good to have this, because in the final session where we look at where we’re going from here, blank spaces mean that we can’t drive any message to either work on or to check off that we’re done. So, it may be good if you could to help us with the numbers to put it on this table here, and say the same for you, because that way in the final session, we can put this up as a complete table.

ABKOWITZ: Thank you. Stefano, are you up for the challenge? We didn’t give you a chance to answer that.

PASSERINI: Yes.

MOTE: He was nodding.

ABKOWITZ: So much for our evening plans.

PIET: The important consideration is that he’s a grad student, and, therefore, what we refer to ourselves when I was a grad student is slaves.

PASSERINI: I know the feeling.

PIET: Okay, the cases specified 1500, 3000 tons per year. The repository starts in 2030. What you will see is 1500, the backlog continues to grow. At 3000, I took the calculation past 2100. The backlog is eliminated in 2115 when one does include the legacy fuel. There’s no limit to the repository capacity.

Now, this is really important. The VISION model sends waste, once it’s old enough, to the repository based on the order of reactors that I define in the input deck. In this case, I happen to pick PWR 40, PWR 60, 40, 60, this is the type of--that should be a B.

So, what it does is it looks at, in a given time step, do I have any of this fuel able to go to the repository. And, I take as much as I can, subject to these sorts of numbers. Only then does it go to the next reactor type. There's isotopic data, but it's in a spreadsheet, and I don't have it graphed.

KADAK: In your selection process, the oldest fuel first?

PIET: Yes.

KADAK: What's the minimum age, is it five years, what do you assume for the age?

PIET: Ten.

KADAK: Ten years. So, oldest fuel first, ten years minimum age, and you're cleaning out as fast as you can, and you do what's in inventory now, or do you take it out of the spent fuel pool?

PIET: In this order of reactor types--

KADAK: Why is that critical to you?

PIET: Because this graph won't make sense if you don't know that.

KADAK: Why did you choose it that way, is what I'm trying to understand?

PIET: Well, the model has a repository.

KADAK: Okay.

PIET: Go back to what I was trying to explain this morning about--

KADAK: Yes.

PIET: And, the mindset one has when you create the infrastructure of a model. We tend to run recycle scenarios, not always, we have to run once through as a cross-check and as a baseline. We don’t get hung up on this reactor versus that reactor sending stuff to repository before some other reactor. So, we just have a total weight that can go to the repository. And, these are all LWRs, so from our standpoint, LWR is LWR. So, all of these, it just happened that I created the reactor ordering in the sequence the way I did. I could have done something else.

So, what the model does, this may or may not make it clear, at 1500, it comes in, it says okay, and it takes the rest of the century and it’s still working on the PWR available inventory, that which is greater than ten years. Green, 1500 BWR, zero, it never gets to any of it. At 3000, it comes up, it starts taking that. Around 2060, it’s now worked off that backlog, it comes down and says oh, okay, all I have available from this point on is here, and I take the remaining receipt rate, and now I start eating into the BWR inventory. And, so, at 2060, I have a key event happens in the model. This is now the generation rate of PWR fuel, and now I start eating into the BWR inventory. And, if I let it go further, eventually, it would get to the two-thirds, one-third sort of generation rate.

So, inventory is a function of time. At 1500, still a straight line. I took the calculation out to 2160. At 3000, there's a break point at 2115, where you have worked off the inventory of both PWR and BWR backlog, and so the growth in inventory in the repository bends over. And, we've got the isotopics, and so forth, in spreadsheets, and I can try to dig up some of the numbers for you tonight.

ABKOWITZ: I think what's kind of interesting about that, if I'm understanding this graph correctly, is that it's going, under these sets of assumptions, going to take us roughly 90 years to get rid of the backlog, just simply because the marginal difference in capacity and what we're generating in a given year is not all that big.

PIET: If I'm not recycling it. And of course this is for a no growth scenario. I, for one, hope we have a growth reality. But, it's a good benchmark. We've generated in other studies, other purposes, depending on what you assume growth is, you get to where you have Yucca Mountains every couple of years, if you don't recycle.

PASSERINI: Just one question. Steve said you are opening the repository in 2030 here. Okay.

PIET: The recycling is in 2040, if I remember.

ABKOWITZ: Now you have an evening assignment.

PIET: Did I get it right?

ROWE: The repository is 2040.

ABKOWITZ: Just student body right by ten years, more or less.

You don’t want to ask him a question because you haven’t presented yet, you know how that goes.

Okay, Robert, you’re next.

GREGG: Okay, so for our Phase 3, I think ORION has the same limitation as VISION. In fact, when it comes to processing material, I can preferentially choose to process material from a particular stream. What I can’t do is I can’t preferentially choose to process the newest or the oldest stuff in that downstream, and the reason why is--well, could you go back two more slides? One more slide. And another? That one there.

Yes, if we look at--this is how ORION works. Okay? So, this here is the new PWR fleet, well, there are quite a few units involved in that. Any spent fuel which goes--is discharged from that reactor, goes into a spent fuel pond, and is cooled for ten years, and then it goes into a buffer. And, if that material is not used, then the material which enters that buffer is mixed with whatever fuel is there already. So, basically, you lose all the historic properties of that material. So, if material goes in there in 2010, if

1000 tons goes in in 2010 and then another 1000 tons goes in there in 2020, you have 20 tons of material, but the only results which we have off ORION is the average inventory, which I guess is the same as VISION.

So, the way I got around that was when it comes to, this is my disposal facility here, which has a throughput of either 1500 tons, or 3000 tons per year, depending on which scenario we were looking at, so, therefore, what I did was this disposal facility takes material from this buffer first, and then that buffer first, which is the fuel from the PWR and BWR fleet, generated before 2010. After that, then chooses to take all the spent fuel from the current fleet, but discharged after 2010, and the BWR fleet after 2010. And, then, once all that is taken care of, that backlog, it then chooses to process the material from the new build fleet.

And, then, the other thing is the process facilities in ORION, the throughput is defined in terms of heavy metal mass rather than fuel mass. So, the reason why there’s a difference here is because I’ve defined a throughput of 1500 tons of heavy metal. But, the actual fuel mass is going to be somewhere between 3 and 5.5 percent higher because of the fission product inventory. So, that’s the reason why the difference is there.

And, then, the reason why the PWR and BWR values are significantly different is due to the way, or limitation, in how ORION deals with spent fuel, and that it can’t process the newest or the oldest. It can only preferentially process material from a particular stream. So, this graph here basically just shows the total mass of fuel, spent fuel, and sent to the repository over time. So, you can see that it will preferentially deal with the BWR fuel discharged before 2010, and then there’s no more in there. And, then, it will then deal with the PWR fuel discharged before 2010.

But, in reality, if you were wanting to process the newest or the oldest, these graphs would be straight lines rather than kinked, as they are there. So, that’s the reason why the results are different. But, in fact, it’s actually a limitation which this benchmark highlighted for ORION, and it’s something I have decided to implement in there, and in fact we’ve got two fuel cycle modeling codes, one which is my own, which I developed, and it’s already implemented into that now. So, if you gave me another month, or this were a month later, you would actually have two results from this.

ABKOWITZ: Okay. We’ll temporarily adjourn until July.

GREGG: That’s it.

ABKOWITZ: I think that this is also another positive that comes out of having a dialogue like this, is identifying a place where you think you can add some rigor to what you want to do.

Are there any questions or comments for Robert?

(No response.)

ABKOWITZ: Okay, Gene, you’re next.

ROWE: I think you will see that NUWASTE handles the repository in a much more realistic way. And, the reason is is because, again, our objective, and our objective was to look at a repository, but I think all the other models, the repository is a completely off-normal thing.

Okay, if you could, could you click on, oops--well, like I say, you can take the engineer out of the field, but you can’t take the field out of the engineer. Okay. If you would click on either one of those, it doesn’t matter.

What we do is--and, then, page down a bit. Okay, that’s fine. Okay, what this is is this is obviously the year, and the number of BWR and PWR assemblies, as well as the MTU. This is the total MTU that is discharged per year, and you will note that it’s less than 1500. The reason is is that--I know a little bit about Yucca Mountain, which is dangerous, is Yucca Mountain had specific waste packages with specific numbers of assemblies per waste package. And, so, what NUWASTE does is it actually calculates only full waste packages. And, so, that’s why these numbers are slightly less than 1500, and if I showed you the run for 3000, you would see that they’re also less than 3000.

And, that’s why this number over here, actually there's 41 years times 1500 should be 61500, so it's a little bit less. But, again, it shows you the fact that NUWASTE considered a repository as the basis for the development of the tool. Okay, you can close that.

This shows you the overall process that is occurring. The dotted line is the amount of MTU that is discharged. And, I indicated earlier that that should be a really straight line, but you can see it's got a couple little waves in it, and that's because it looks at actual reactor start-ups and shut-downs, and actual discharges from individual reactors. And, all the reactors are basically different sizes and there's Bs and Ps, so that's why that line isn't completely straight.

This indicates what the reprocessing capacity is and at 1500, as the other participants indicated, you saturate at 1500, and you can see the red line is the amount of fuel that is--the MTUs that are in storage, both wet and dry. Okay? And, you can see at 1500, since you're generating almost 2000, is that that slowly increases. The purple line is the number of dry storage casks. Again, from our point of view, the number of dry storage casks is an important parameter. So, we actually calculate that based on assumed sizes of dry storage casks, et cetera.

And, again, this curve has a funny shape because of this dip here, and what that is is during this period, okay, you’ve shut down some of the existing plants and you’ve started up some new plants. The new plants have empty fuel pools, so the fuel is going from the reactor into the fuel pools, and then you slowly start filling up the fuel pools and then it starts going into dry storage, so that’s why that curve is shaped like that.

Next one? And, this is a very simple picture, and I’ll show you basically the same picture tomorrow, but for the whole process. But, just as kind of an introduction to this, this is what we call--I don’t have a name for it up here, I took it off--but, this is what I call material balance. And, from this sheet, you can go through and verify every step of the operation to make sure that both the assembly and the mass balance works at every node on this diagram.

And, basically, what the simplicity of this, you’re mining ore, convert it, enrich it, and the enrichment generates low-level waste, and we do talk about low-level waste within NUWASTE--the question came up--and you generate enriched uranium as well as fresh uranium tails. And, from this mass, you generate assemblies, and those assemblies go into the reactor. From the reactor, they can either go to storage, or from the reactor directly to the repository. And, so, this is the number that hopefully that number, 9992 assemblies, is hopefully that number over there. And, it shows the number of assemblies also in dry storage.

Next one? And, this is the same graph, but for the 3000 metric tons per year. And, you can see again, as indicated before, you saturate, because I actually work off the legacy waste, and you can see that my inventory of waste in storage goes down, down, down, down, and I did not take it out to completion, but it will never go to zero because you've got a ten year delay time between the time that you discharge it and the time you can dispose of it. And, you can again see this funny shape in the number of dry storage casks because of the fact that you're bringing the reactors on line.

And, one more I think. This is, again, the same thing. It just shows the amount of waste going into the repository and the amount of Bs and Ps, and the amount in storage, as well as the low-level waste that's generated from each of the processes.

Any questions?

ABKOWITZ: Questions for Gene?

(No response.)

ABKOWITZ: Okay, do we have any more conversation with regard to the spreadsheet over here on the right-hand side?

MOTE: Well, I didn't specifically ask, but, Steve, can you do the same thing? Can you help us with numbers to fill this out? Thanks.

ABKOWITZ: Okay. Is there any commentary from the other attendees, questions?

(No response.)

ABKOWITZ: So, everyone fully understands everything? Okay, well, that being the case, we are quite a bit ahead of schedule, but I'm hesitant to go into tomorrow's program, because we have some people that are working on some things that will be shared tomorrow. And, tomorrow's phases will start to get a little bit more complex, so I think we'll probably use more of our allotted time.

We do, at every Board meeting, provide a period where people can come up and offer public comments that don't necessarily have to be specific to the exercise we're going through, but can also be more general with regard to what the Board is doing in this particular trust area.

Is there anybody--usually there's a sign-up sheet. I have not been provided with anybody that--has someone actually--okay, if that could be provided to me, that would be helpful. And, if there are others that would like to speak after we allow the three that have signed up to speak, just make sure you proceed to the nearest microphone, identify yourself, and away you go. Yes?

BRUDIEU: Marie-Anne from AREVAA. In the meantime, I just wanted to answer quickly the question I didn't know about this morning on the COSI code.

So, I made a couple phone calls at lunchtime, and the COSI code is actually still used at CUA with EDF in France. AREVA NP is the equivalent code, which nearly the same, is called COZAC. And, what this code does is basically everything before what we did and brought here, which is look at the isotope compositions of the fuel that goes into the reactors and comes out. So, it’s also designed to look at different fuel cycle strategies. But, we’re looking at isotopes and not too much the waste. The recycling part of it is not very much detailed.

And, also, COZAC, which is the COSI code, is that AREVA NP is compatible with CESAR and ORIGEN codes. So, that was the quick answer.

ABKOWITZ: Okay, thank you.

On the register here for offering public commentary, we have the following individuals, whom I would ask to come up to the microphone in this order. We have Tim Sippel from the NRC, Greg Love from MITRE Corporation, and Alan Wells representing himself as an independent consultant.

Tim?

SIPPEL: I’ll pass.

ABKOWITZ: You’re going to pass? Okay, that means that you either had all of your questions answered, or you decided to hold off until tomorrow. Is Greg here? Okay, I’m beginning to believe that people might have thought this was an attendee sign-up sheet, although it does say Public Comment at the top.

Alan, you’ve commented some already. Would you like to comment some more?

WELLS: No, I just signed the attendance sheet.

LATANISION: This is like a Red Sox/Yankees Game.

ABKOWITZ: I’m never going to be accused of running a late meeting again, I can tell you that much.

MOTE: Oh, yes, you are.

ABKOWITZ: Is there anyone else that would like to offer commentary, or deliver a final word? Please identify yourself.

GREEVES: You can’t let these meetings end early like this. Anyhow, John Greeves representing myself.

I don’t totally follow what you’re doing here, because I do this part-time, but I’ve got a couple of questions that maybe you would like to address.

My observation is that you’re doing calculations, which there’s a lot of alignment about what goes through the reactor, how does it come out, how does it--it looks like a very simple calculation--what happens with a repository, if there is a repository. Are you headed towards a system which would be able to give you some tools to analyze what the impacts of going to various fuel cycles are, and the consequences of not having a repository, or the consequences of having to develop two repositories? And, Andy asked questions about low-level waste. All of this has a dramatic impact in the low-level waste business, which I’m not sure how many people in this room are following. But, it’s full of political--it’s going to be really good to have some kind of an analytical tool that could fit all of this together at a granularity that is understandable and explainable to politicians.

ABKOWITZ: Okay. I think that’s an excellent question.

GREEVES: Where are you going?

ABKOWITZ: I can speak to where the NUWASTE thought process is at, but I think we should give each of the participants an opportunity to answer your question.

We are a waste management centric, and we have a mission to be prepared to review any type of fuel cycle option that DOE might consider in terms of its impacts on waste management. We see the development of NUWASTE as an incremental process. We are tracking now all the different waste streams, although the exercise that we’re here doing at the workshop is predominantly focused on spent nuclear fuel, commercial spent nuclear fuel. We are tracking all of the waste streams, the high-level waste and the low-level waste, and so forth, and you are quite right, the low-level waste issue, particularly when you’re talking about reprocessing, is a significant issue.

Down the road--well, because the current world is in LWR space and we anticipate that that’s the way it’s going to be, at least for the next few decades, we have chosen to focus our initial development in that arena. Many of the other presenters that are here, and others that are modeling around the world and in the United States, are looking at any number of other fuel cycles, and we would like to get to the point where what we’re showing you in terms of our capabilities and interests in the light water reactor space, we’ll try to do something as well as we can to be able to be in the same position to look at these questions as these other ideas come up.

I think the purpose for this exercise has been to establish some clarity in terms of what the mission of all these tools are, how they’re approaching the problems, and to what extent they’re tracking wastes in ways that the Board is interested.

GREEVES: Just to add to my comment. It’s not just there are other aspects like the regulatory aspect, we’ve got a broken regulatory aspect for addressing reprocessing. It needs to be fixed, and these techniques that you’re developing need to be used and understood by the regulator so that they can, in a timely fashion, develop a regulatory fabric that will work with some new fuel cycle. That’s all got to get done.

ABKOWITZ: Understood. But, a part of that, and I think part of this exercise is to make sure we understand what the basic backbone and assumptions are that each of these tools utilize, so that when the regulator sees results that are run for various scenarios, they can appreciate the extent to which it's being driven by the way the problems is being defined.

But, let's open it up for conversation. It's a very good question.

KADAK: Can I just comment on John's comment?

I think you're absolutely right. There needs to be some strategy that integrates all of these things. We have various elements that if put together, would be a very useful tool to advise people in our area really on waste management. We're not going to get involved in deciding what reactor is the next best reactor for dealing with waste. But, clearly, we should be able to understand the consequences of picking a technology from the beginning to end.

And, the MIT fuel cycle study was an attempt at that, but I think if we are able to blend a lot of the models that you all have developed, I'm not saying into a single model, but there's certain attributes each of you bring to the table that isn't found in any models, any single model, which if there could be an effort to organize around that, maybe DOE, wherever DOE is, might be interested in looking at this, because I think it’s important as advice to the policymakers as to how they try to look forward.

So, I think your points are very well taken.

ABKOWITZ: You’re fine, and I’ll invite anyone else to speak to this.

WORRALL: Andy Worrall again. In my introductory comments this morning, I mentioned about who we are and what we’re trying to do, and I think you’ve hit the nail on the head, when you say our fuel cycle modeling capability and what we do to assist in the decision-making process, okay, we’re not here to make decisions for anybody. We’re here to help in the decision-making process.

Now, whose decision is the next question, because--

GREEVES: Give them a tool that they can understand.

WORRALL: Exactly right. So, how our tools are involved over time is people just say is this fuel cycle more cost effective than the other, economics came into play, so we did an economic assessment. Then, you say, well, hold on, what about the impact on the repository, the heat load and the radiotoxicity, would be another matter. And, somebody comes over the last few years says, oh, my goodness me, what about non-proliferation, so there’s another metric. So, all these decision-makers, and now suddenly the government, regulators, not just the NRC regulators, but the DOE, the IAEA, and then the utilities come into play because of the economics, and suddenly, all these things. So, our tools are all about very much assisting the decision-makers in whatever that decision might be.

So, what we’ve got here is, and we haven’t gone through it in detail, but our tools are very much set up so that they graphically are kind of friendly, to get across that message, look, here’s a fuel cycle, that’s why I showed that picture, it’s a graphic environment where you click and drag and you can see how the flow, very much like Gene showed there, that kind of flow, kind of mass balance thing, so our intention is to try and get that over so people can understand the issues. You can visualize what we’re trying to do and you can score it in some even way.

We’ve just been doing a study, and unfortunately, I’m not at liberty to say at the moment who that study is for, but we’re looking at 42 metrics--42 metrics, of which fuel cycle assessment is an incredibly important part of that. And, so, that’s what this relates, inform the decision-makers, inform the position. We’ve seen this road here for us at least, I’ll just give you the flavor for us, is that this is here--we’re a national lab, as I mentioned, we’re a commercial organization, too, we’re guns for hire. If anybody has a question, we’ll answer it as long as the price is right, and quite seriously, what it means is we’re trying to assist everybody in these things.

But, the important thing for us is just to get across the key information, it’s economics and all the other things. That’s why we’re here. And, we try to learn as we go, and the feedback we’re getting from these organizations helps us improve our tools to help our customers.

GREEVES: That was an excellent answer to my question. I’ve done some systems modeling, and I don’t see it in the US. I saw your charts, and I’m not at all familiar with them, but it looked like it might do what I’m talking about.

So, thanks for the answer.

ROWE: Well, I’d like to, as I mentioned this morning, we spent a great deal of time on the evaluation portion of the modeling, which I’m not going to talk about at all. Okay? The reason that we did that is just for what you’re saying. One of those metrics, and we can evaluate multiple metrics, and we can evaluate multiple scenarios, and the mass balance chart that I showed you, that’s a partial one. Okay? But, again, it’s our attempt at a visualization for people who don’t understand, and we do try to look at what the impacts on natural uranium is, the impact on low-level waste, the impacts on repository size, and those parameters.

And, so, that is part of what we are doing. And, we’re looking at a realistic model, the US fleet and present technology.

PIET: Let me add two or three cents worth. First off, I agree with the premises associated with your question. I've got two slides tomorrow that will try to put some of this in context. But, that's just two slides of a presentation focused on the benchmarks.

We've got a suite of tools that we say can do what you're saying. Now, we have, for example, one of the models, I think I mentioned this morning, that looks at how the fuel cycle is integrated chemically, and it will generate amounts of waste for different waste strategies, different waste streams, subject to two things. One is data. And, when you're talking about anything other than PUREX, then one's--and LWRs, then one's estimate for what type of waste gets generated is educated guess work. We're getting some other. We've got people working on the problem, but I would be very hesitant to believe any of the numbers right now for any of the more exotic option space. People will give you numbers, but they have large uncertainties.

The other caveat, and it goes back to an Oak Ridge report, I believe you were part of, Mr. Croff, some years ago. It's been pointed out, and you might have been the first, that when you get into the legalistics of waste categorization, we have in the US basically 10 CFR 61 that says Class A, B, C, if it's going to be C, then it's this other thing that's not well defined. We know high-level waste is defined as anything that kind of walks and talks like spent fuel, but is written in such a way that it requires lawyers and not engineers to decide if some particular waste stream from some particular process is or is not high-level waste.

So, what’s been discussed at various levels, various places, is moving from a legal mumbo jumbo waste definition scheme to a technical based or characteristic based waste classification scheme. That would not be painless from lots of perspectives. So, a model can be created, as we have, that says oh, I’m going to do waste depending on heat and what not, but that’s not how the law is written today.

So, we, in our documents, in our calculations, we tend to differentiate a two by two matrix is waste particularly hot, heat generating or not, and is it particularly long lived, or not. Well, the repository problem in that language is really how much mass is there remaining in high heat, high longevity. The other three boxes, high heat, low longevity, so forth and so on, there are disposal precedents for three of those four boxes.

So, one of the ways we look at the problem is to say okay, in a given fuel cycle, how much is left in high heat, high longevity, because that is the one for which there is no disposal precedent anywhere today. And, I would argue from some of my American colleagues that might be tempted to point to WIPP, WIPP is longevity, high longevity, but low heat. So, in terms of high heat, high longevity, nobody has it in operation. And, so, I characterize fuel cycles in that two by two matrix.

ARNOLD: Let me just add a footnote, if I may. Arnold, Board.

Several years ago, I served on an academy committee that was studying the exact issue you're talking about. It was chaired by Peter LeRoy and Mike Ryan. And, we were supposed to submit recommendations on making more logical the issue of what's in what category. The problem we ran into, of course, is that these things are set in law, and we pointed all that out and said that really, about the best we can do is some kludges here and there, unless somebody is willing to tackle the whole legal tangle.

GREEVES: Those regulations actually are being modified, too. The NRC is going through Part 61 rewrite which I'm very active on.

As a stretch goal, I think the government in this country needs to come up with a tool, not a series of tools, a tool that is explainable to OMB. That's your target. And, they're not going to understand 13 models. They need to see one that accounts for the front end, the back end, and the consequences of, you know, not developing a repository, among other things.

DUQUETTE: Let me address that, John. Duquette, Board.

The way I explain some of this--Steve, you gave a very nice response, it was very engineering oriented, and I appreciate all of it, because I'm an engineer as well. But, my neighbors don't want to know about heat load. They don't want to know about long life, short life, no life, whatever the case might be. What my neighbors want to know is if I shut off all the reactors tomorrow, what do I have to deal with? If I let them keep running at this same rate, what do I have to deal with? If I bring new ones on board, what do I have to deal with? Where do I put it? Where does it go? How big is it? Can I put my hands around it? That's what government regulators are going to want to know.

Myself as a, putting on my hat as a citizen on this Board, I want to know some of those answers, as well. I mean, I can appreciate all the engineering stuff that's gone into this, but in the final analysis, I want to know how many tons you have. And, what am I going to do with it, where is it going to go, and how dangerous is it if it's out there? And, I think the models we're talking about here will do some of that for those of us who are engineers, but we're going to need an interpreter who is going to interpret what the results are for government, including my Congressman.

ABKOWITZ: Were you saying that as sort of a generic statement, or is it a local statement?

DUQUETTE: I think it goes for 435 of them. I think the models will get us to that. The thing I'm impressed with so far is it looks like the models that have been presented look like they're all about the same results coming out of them. Some minor differences. And, I do think that they will give us tonnage and numbers of things, and I don't think you have to go into all of that. But, again, I think people want to know, we're talking about building new reactors, what's it going to do to what we need. If I don't build a disposal by 2050, where am I going to be and what am I going to do with it?

And, I think some of those questions are being asked now, partly by the Blue Ribbon Commission. Can you store it for that long? If I double the capacity, can I store it for that long? I think those are the kind of answers that John is looking for, and I think your models will do that if we don't do what we too often do as engineers and get into the details and try to explain this to people who don't care.

PIET: I've talked to the public, and I consider myself bilingual, as I've told some of my friends, I can speak nerd or I can try to speak regular English, and I have to say the same thing, but in completely different ways.

ABKOWITZ: And, I'm bilingual at Vanderbilt. I can speak Engineering and Southern. Gene, you've been patient.

SHWAGERAUS: Yes, just to follow up a brief, maybe restating the same thing that was already said.

Obviously, the fuel cycle facilities, repository, reprocessing facilities, and reactors, they're all integral parts, they're all important. And, one can go into more details or less details, depending on what kind of questions people are looking for. And, the real part, I would say, in putting these models together is to balance this high-levels of fidelity, and one word or one sentence answer, I want to know, you know, how much I have to deal with, answers, you know, of this sort.

So, you cannot have both. I mean, it's a balance. They have to be detailed enough to provide specific answers to specific questions, very specific to specific parts of the fuel cycle, and yet they have to be general enough to be understandable and be an effective policy board decision-making tool. That's real hard. That's not easy. And, all these codes are trying to address this to various levels of success.

GREEVES: I would just assert that each country has the responsibility to put together a systems analysis at a top level that accounts for everything. You can't just look at the reactors and the repository. You've got to look at the transportation issues, too. And, this country, my impression is we're all silos, we've all got a piece of the pie, but nobody has the whole pie.

ABKOWITZ: I think everybody is doing some insightful and provoking questions. I would suggest that we keep some of the conversation, the last ten or fifteen minutes in mind, with the anticipation of the last session tomorrow, which is Where Do We Go From Here. I think there's some already, you know, up for consideration, other scenarios, other technologies, ways in which our tools can somehow maybe work in synergy with one another. Any of these things are certainly on the table.

This is an open ended conversation, and I think by tomorrow afternoon, or at least I hope, we'll have sorted through some of this and at least identified the things that make sense to proceed with as a group. Because I think the point is well taken. Ultimately, we're all in the same boat, rowing in the same direction, or at least we're trying.

Any other comments anyone would like to offer? Nigel?

MOTE: I've got one question which I was going to ask earlier and you didn't know if you'd have time, but it appears that we do.

Steve Piet may be the best one to answer this. We know there are other codes around. I don't know the names of them. I do have an e-mail in from the IAEA, which has some in it, and I'll see whether that's something to distill for tomorrow.

I know there's a code called FINESSE, which Argonne has. If it's appropriate, could you tell us how that would fit into the discussion that we had earlier today when each of the participants said what the target was of their code? And, I don't know if you're familiar with it, but I sense that you probably are. I would appreciate a it was designed to do this and it will do these things, and how it would fit in here so the next time we have somebody from Argonne here, we know where that code would fit in.

PIET: It's basically aimed at the same objectives that VISION is.

MOTE: Okay.

PIET: There's some I always call them second level differences. But, it's basically aimed at the same objectives.

MOTE: Within the DOE community, there are other codes. Are there any that you know of, you're familiar with, that you could tell us are ones that we should maybe involve next time, bearing in mind, I think it was Andy's comment, which was we've got several codes here which have a lot of overlap, but they also have their individualities. It might be good to take the best of those and see if we can't splice them together. Are there parts of codes in the DOE community that you know that would be addressed to what we're doing here?

PIET: Not really. I'm in the systems analysis part of the fuel cycle program, and, so, our designated code is the one I've been talking about and using here, VISION. At the time we made the decision to start VISION five years ago, we looked at what was then available and their various structures and limitations, and have put all of our effort, we involve multiple universities and different national labs, it's not just INL. Sandia, for example, is doing the validation and verification on VISION right now.

There is an older model that Los Alamos had called NFCSIM, and it is, in a sense, a fuel cycle variant of the total system model, in intent, not in terms of structure or taking FORTRAN or anything. So, it looks at individual fuel assemblies and individual reactors for the current fleet. It allows only two fuel cycles, which is once through or MOX. And, I wondered in fact whether that's what you guys were using for your calculations. I said, gee, a set of specifications for once through and MOX, that makes me think of the Los Alamos model. So, I was curious about that.

I don't think it's been maintained for several years, and we couldn't use it because it was a black box. They would not give out the source code for it for security reasons. And, so, we said we have to build something from scratch.

Now, if you talk reactor physics models, now there's a whole universe of things, and you've heard many of those acronyms today. But, in terms of total system models, in the fuel cycle sense, it's really VISION and DANESS.

MOTE: I have another question over here.

GIDDEN: My name is Matthew Gidden. I am with the University of Wisconsin at Madison.

We are actually also developing a code called CYCLUS, and we're still on some of the infrastructure stage, which is why we're not presenting--

ABKOWITZ: Could you spell that for us?

GIDDEN: Yes, CYCLUS. C-Y-C-L-U-S. And, the reason I just jumped up is I heard two points in a row that are salient. One is, like I said, the code was hard to get. So, first of all, CYCLUS is open source. This is a point of contention, but the idea that we're trying to foster is to have a basic simulation engine, which is separate from your input. So, if your input is sensitive, if one of your reactor models is sensitive, that's something that you as an entity hold onto, and you would take the engine and then input your model.

Anyway, so I just wanted to say it is being developed--oh, sorry, second point. I think it's important to keep in mind that the codes that we're writing can be separate from the post-processing. So, it was said before that visualization is very important, especially if we're trying to, you know, provide information to policymakers, people who might just not have the same technical background. And, because post-processing, once the data is compiled, other people can work on the post-processing.

So, I just wanted to make that point that you can work on it in two fronts.

ABKOWITZ: Thank you. Anyone else want the last word?

KADAK: You know, as a benchmarking exercise, as we're trying to do today, I think it would be very useful if, Eugene, tomorrow you could just summarize, just take a couple of graphical, so we could have side by side--

SHWAGERAUS: I'm not sure about the power point slice, but yeah, I can say a few words.

KADAK: Okay, just because--

SHWAGERAUS: Steve was also part.

KADAK: Okay, that would be very helpful to see how the system codes, so called, compare to see how close we are, in fact, to reality.

ABKOWITZ: This is for a fast reactor scenario?

KADAK: No, no, this is for all kinds. I mean, they included fast reactors, but--

SHWAGERAUS: Slightly more complex a benchmark.

KADAK: Yes.

ABKOWITZ: Okay. Well, we'll set aside some time tomorrow for that purpose, if you're up to it.

SHWAGERAUS: Yes, sure. I wasn't involved directly with the site.

KADAK: But, as benchmarking goes, that was probably as good as you're going to get; right?

PIET: I would say the IAEA benchmark was probably better in two senses. One is that there were more models involved. The second, there were more iterations where they would say okay, this difference is due to these guys assumed new fuel beginning of the year versus end of the year, or whatever. And, so, it was painful, would be the short form. But, several iterations to try to narrow down more and more details.

And, basically what comes out of these benchmarks is when you give people a highly specified problem and everyone does a highly specified problem, they get the same answer.

SHWAGERAUS: That should be my message also tomorrow.

PIET: Yes, you get some differences in the PU 238, 239, and so forth, and you trace back that to physics. And, so, on the IAEA benchmark, they got around that by saying everybody use this recipe. Well, okay, so all the physics, little differences in physics all disappeared. So, if you specify everything, you get--

KADAK: The reason I ask is not because I worry about the physics. I worry about what do we need to know about these tools to make them useful. And, do we need to worry about Plutonium 241 or Uranium 234 concentrations to be a useful tool. No. Okay? So, where we want to go with our effort, I think, is create a tool that would be useful, but not so micro in detail that we kind of forgot the forest from the trees.

ROWE: Exactly.

ABKOWITZ: Although I think we have to be convinced that the foundation is solid before you start to go in--

ARNOLD: That's the purpose of this get together, is to make sure that the foundation is solid. I think we have the same goals that John Greeves said.

PIET: Let me give you an example of something we try to work with our system--I mean, our separations colleagues on that none of these models can tell you. None of these models are chemistry models. They all do mass balance. They all do a decent approximation of physics. But, we've worked with our separation and fuel fabrication colleagues to try to do essentially a chemistry integration. It's not time dependent, therefore, I can't use it for these sorts of simulations.

But, if you ask well, gee, if I'm recycling fuel, and so I've got these fission product streams, and you say well, what's the waste classification, well, number one, I've got this legal problem that we mentioned before. Okay, so as an engineer, I just ignore that. So, then, I say oh, well, now I can at least look at 10 CFR 61, or look at some of the heat generation numbers or limitations. Then, I go back to the separation guys and say, oh, well, how much transuranic material is going to show up in this waste stream and that waste stream and that waste stream? They will give me a number and then I'll start asking more questions, and say, well, how sure are you of that number, and now, the real secret comes out.

And, so, that's not a model problem. That's not a model question. That ultimately goes back to data, and how well do I understand the chemistry of the system. And, that's not a system model question. That is a data and chemistry problem. We're working on that. That's a different set of tools where you have some real questions, and we talk to the fabrication guys, and say well, what waste comes out of your metal fabrication technique, and the answer is we don't know. Honest answer. I don't like it, but it's an honest answer. I'm seeing a head nod back there.

KADAK: Have you seen--did we publish our new waste report?

ABKOWITZ: Is it out?

HARRISON: It is currently being transported from the printer to this--we should have it either this afternoon--it might be out there tonight.

ABKOWITZ: Is it online?

HARRISON: The latest one is not.

KADAK: Well, I think if it’s somewhere, we might share it with you so you could see how we’ve used and processed--my concern is the low-level waste side. And, Marie-Anne, I would love to see if we could run--can you run your model here online, or not possible?

BRUDIEU: Yes.

KADAK: Yes? Good. Because one thing tomorrow, I’d like to see what you calculate for all your little ICBM missile, whatever you call them.

BRUDIEU: Okay.

ABKOWITZ: Well, what I’m going to suggest, as we’ve got this exercise that you’ve just introduced; we’ve got Stefano working on some things; I’ve taken notes that Gene is committed to giving us some background on the MIT benchmarking study; Steve, whether he knows it or not, has volunteered to tell us about the IAEA benchmarking study, and to fill in these blanks.

So, the organizing committee, i.e. Bruce, Gene, Nigel and myself, will caucus between now and 9 o’clock tomorrow morning, and we reserve the right to modify the agenda to make sure we give everyone an opportunity to discuss these issues.

I just want to make one other comment before we close. The scenarios that we chose for this workshop kind of go under the category of “crawl before you walk, and walk before you run.” We felt that we had to start at the very earliest stages to make sure that if there were any departures from where we started, that we could identify them at the point of departure. And, I think what we’re learning, at least today we’ve learned, and maybe into tomorrow as well, that, you know, we’re still along a single trunk of the tree, more or less, at this point anyhow. But, that’s other grist to discuss in terms of how the scenarios could become more sophisticated if we determine that we’re all on the same page after tomorrow.

At this point, I’m going to call it a day. I want to thank everyone, both for the time and also for the spirit of congeniality, which I think has been extremely constructive today. And, we will reconvene at 9 o’clock tomorrow morning.

(Whereupon, the meeting was adjourned, to resume at 9:00 a.m. on June 7, 2011.)

C E R T I F I C A T E

I certify that the foregoing is a correct transcript of the Nuclear Waste Technical Review Board's Workshop On Evaluation Of Waste Streams Associated With LWR Fuel Cycle Options, held on June 6, 2011 in Arlington, VA, taken from the electronic recording of proceedings in the above-entitled matter.

July 14, 2011

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