Office of Nuclear Energy

FY 2010 Nuclear Energy University Programs Workshop

Final Report & Breakout Session Transcript

August 13-14, 2009
Hilton Salt Lake City Center

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Program Background

A rebirth of interest in nuclear energy is under way in the United States and across the world, driven by concern to secure safe energy supplies and to mitigate consequences of global climate change. Not only government but also private industry and U.S. academic institutions have made substantial investments to support expansion of nuclear power. Recent research activities, however, have not been fully integrated to achieve optimal benefits. In FY 2009, the U.S. Department of Energy Office of Nuclear Energy (DOE-NE) addressed this need by consolidating all its university related work, such as the Nuclear Energy Research Initiative, a national, research-oriented program that has helped to maintain and improve the nuclear research infrastructure in the United States, to create the new Nuclear Energy University Programs (NEUP).

Through NEUP, NE will better integrate university research with technical programs, producing outcomes relevant to the Nation's interests. NEUP's goal is as follows:

> Support outstanding, cutting edge, and innovative research at U.S. universities by
>
> - Attracting the brightest students to the nuclear professions and supporting the Nation's intellectual capital in nuclear engineering and relevant nuclear science, such as Health Physics, Radiochemistry, and Applied Nuclear Physics.
> - Integrating research and development (R&D) at universities, national laboratories, and industry to revitalize nuclear education.
> - Improving university and college infrastructures for conducting R&D and educating students.
> - Facilitating transfer of knowledge from aging nuclear workforce to next generation of workers.

The Center for Advanced Energy Studies (CAES) will provide administrative support to the NEUP to ensure the university program's successful implementation. CAES will facilitate technical integration of NE university programs with NE R&D programs. The office will undertake such activities as administering proposal processes, implementing review and selection processes, and hosting reviews of university R&D.

FY 2010 Nuclear Energy University Programs Workshop

On August 13-14, 2009, CAES hosted the FY 2010 Nuclear Energy University Programs Workshop under the sponsorship of DOE-NE at the Hilton Salt Lake City Center in Salt Lake City, Utah. The workshop provided U.S. universities the opportunity to understand the scope of NEUP for FY 2010 and to become familiar with the current R&D work of the various programs of the DOE-NE. Round-table discussions provided ample opportunity for questions and

constructive dialogue on the research requirements for the Generation IV Nuclear Energy Systems Initiative and the Fuel Cycle Research and Development programs.

FY 2010 Nuclear Energy University Programs Workshop

Hilton Salt Lake City Center

Agenda

Thursday, August 13, 2009

7:00 am *Registration/Continental Breakfast (Alpine Ballroom)*

8:00 am – 12:30 pm Plenary (Grand Ballroom)

8:00 am Welcome Remarks
- Mr. Dennis Miotla – Deputy Assistant Secretary for Nuclear Power Deployment

8:15 am University Engagement and Recommendations/Collaboration Models
- Dr. John Gilligan – Director, CAES-NEUP

8:40 am NE University Program Overview and Process
- Dr. Marsha Lambregts – CAES-NEUP Relationship Manager

9:05 am NEUP Procurement Process Overview
- Mr. Eliot Dye – Contracting Officer, U.S. DOE Idaho Operations Office

9:25 am Peer Review Process
- Ms. Cindie Jensen – CAES-NEUP Review Coordinator

9:45 am NEUP Quality Assurance
- Mr. Darin Jensen – AFCI QA Representative

10:15 am Break (Alpine Ballroom)

10:30 am R&D Program Overview Presentations (one hour each)
- Fuel Cycle R&D – Dr. Kathy McCarthy
- Gen IV – Dr. David Petti

12:30 pm Lunch (Alpine Ballroom)
(Speakers: Survey and Lessons Learned – Dr. Marsha Lambregts/ATR NSUF – Dr. Todd Allen)

1:30 pm – 5:45 pm R&D Area Round Table Discussions

1:30 pm Break-Out Sessions #1 by Topic Area and Presenters

1. Advanced Reactors (Gen IV and FCR&D) – Dan Ingersoll (ORNL), Jack Wheeler (HQ), Tony Hill (INL) *(Grand Ballroom A)*
2. Advanced Fuels (FCR&D and Gen IV) – Kemal Pasamehmetoglu (INL), Dave Petti (INL), Jon Carmack (INL) *(Grand Ballroom B)*
3. Methods and Modeling & Simulation (Gen IV and FCR&D) – Hans Gougar (INL), Xin Sun (PNL) *(Grand Ballroom C)*

4. Materials, Fuels, I&C, and Safety Analysis (Gen IV-LWRS) – Ronaldo Szilard (INL) *(Canyon A/B)*

3:30 pm Break (Alpine Ballroom)

3:45 pm Break-Out Sessions #2 by Topic Area and Presenters

1. Materials (Gen IV) – Mark Carroll (INL), Laura Carroll (INL) *(Grand Ballroom A)*
2. Nuclear Physics/Data and Safeguards (FCR&D) – Brad Williams (HQ), Tony Hill (INL) *(Grand Ballroom B)*
3. Heat Transfer and Energy Conversion (Gen IV) – Paul Pickard (SNL), Mike Patterson (INL) *(Grand Ballroom C)*
4. Spent Nuclear Fuel Disposition, Separations and Waste Forms (FCR&D) – Stephen Kung (HQ), Kevin Felker (ORNL) *(Canyon A/B)*

5:45 pm *Adjourn*

6:00 pm Opportunity for informal one-on-one discussions between University and Program staff (Cash Bar) *(Alpine Ballroom)*

Friday, August 14, 2009

7:30 am Continental Breakfast (Alpine Ballroom)

8:00 am – 12:00 pm Plenary (Grand Ballroom)

8:00 am NEUP Lessons Learned Panel Discussion
- Dr. John Gilligan (Director, CAES-NEUP)
- Michael Corradini (University of Wisconsin)
- Wes Hines (University of Tennessee)

9:00 am Integrated University Program Panel Discussion
- DOE University Programs Overview – Ms. Ingrid Milton
- NRC University Programs Overview – Mr. John Gutteridge
- NNSA University Programs Overview – Mr. Ed Wonder

10:30 am Break (Alpine Ballroom)

11:00 am Closing Remarks
- Senator Robert Bennett (R-UT) – Energy and Natural Resources Committee

12:00 pm Adjourn

Presentations provided during the plenary and breakout sessions have been posted on the NEUP Workshop Registration Workshop website at http://events.energetics.com/UnivWorkshop10/. The following discussion represents participant comments captured during the specific breakout sessions.

Break-Out Session on Advanced Reactors (Gen IV and FCR&D)

Dan Ingersoll's Presentation

Question: Do you think it's conceivable within the next two decades—let's give it sufficient time—that we can amend the Atomic Energy Act so that it does not require approval by the federal government, in a sense, for the sighting of a nuclear plant if you could demonstrate that you don't need that kind of overview of safety and issues associated with it? For example, I don't think China, when they sighted their four AP 1000s, had their appropriate commission. As long as the government decides it's acceptable and it goes ahead without much way of technical review. The nuclear program came under a terrible birth defect. We think that most people in the public think of a nuclear reactor as a tamed atom bomb. If we can finally get away from that over two decades, do you think that's possible? We sight a lot of hazardous things without going through an equivalent NRC, you know, refineries, gas storage facilities and others…

Response: So, you're suggesting plants that wouldn't require NRC licensing?

Response: Or at least, you know, a stamp would allow them if, for example, from the point of view if they meet a certain minimum criteria, you don't have to review safety issues; you don't have to go through this long licensing process of three to five years. The Chinese are going to build their four plants when the party says, "We accept it. Tomorrow you start digging dirt and put the plants in."

Comment: I'm originally from … and there we have this mess where every state has its own agency for licensing and looking at oversight and that would probably be coming up if the federal level would get out of this business here and you would have an even more complicated mess to deal with. I think here in the U.S. we can be happy that there is a federal agency and you only have to deal with that.

Response: I'm too old to even think about charging that hill.

Question: Could you elaborate a little bit on the fuels and materials, specifically if you were going to write a proposal addressing small reactors?

Response: I mean, fuels and materials is just a…you can always improve fuels and materials. The mission of interest there is to have small reactors with very long refueling intervals, meaning up to the full lifetime of the plant. There are concepts out there—most of them tend to be fast spectrum concepts because of the ability to have the conversion ratio near one and sustain that—but today our plants refuel every 18 to 24 months, which means the fuel, the cladding, and the fuel assembly materials come out every 18 months and they're not replaced. The question is, can the fuel cladding and structural materials of a 30-year core survive? I think there'd be a lot of work toward irradiation-resistant materials, fuel performance over a 30-year lifetime, things like that that can be looked at. It's one thing to say you're going to do it; it's another to prove that the materials and fuels can handle it.

Question: Is there a significant change in the design of the operation of the small to medium reactor that warrants the changing regulatory requirement?

Response: I guess I don't really understand the question.

Question: I'm asking, is there significant change in the SMR that will warrant the regulatory requirement?

Response: The kinds of regulatory changes that I'm talking about are to accommodate the lower risk that we think the smaller plants have. You've got smaller source term; you've got effective decay heat removal because of the smaller size. There are a number of aspects in the designs and it varies from design to design as to what those features are, but in general, there are issues that the NRC—in thinking only about large, monolithic plants—doesn't address in their framework. The framework may allow for it but their rulemaking is geared toward the very large plants that just aren't appropriate for the smaller plants. There's not a uniform example across the various designs. Let's say if you want a 50-megawatt unit powering a small community, you don't want to be required to have the same security force size that Watts Bar has, or some large generating plant. You just can't afford that. You've got to be able to take advantage of the lower risk that that small unit imposes. So those are the types of changes I'm referring to.

Question: If I could follow up on this regulatory issue with small/medium reactors. My guess is that the NRC does not have the resources at the moment to do the design review for non-LWR concepts, or especially small reactors. How are we going to get them to allocate some resources? How's that going to change within the regulatory framework?

Response: You're absolutely right. That is a challenge. In fact, they've gone on record as saying they don't have the resources to review these and they're not going to, at least not until 2012 or something, but that is a resource issue and that can be resolved with money. Particularly, the near-term, the LWR designs, the technical skills are virtually the same. It's just, do they have enough bodies to do the review? Of course, we feel that because of the nature of these designs, their simplification, the lower source terms and lower risk, that it ought to be a stream-lined review of those designs…not likely to play out well, but in principle, that ought to be the case.

Question: As these concepts begin to merge into commercial form, or grow into that direction, many aspects of them become proprietary and restricted to the public, especially universities. So, I'm trying to figure out what exactly is it that we can do as universities as the doors begin to close around some of these designs and specific types of designs?

Response: Well, I didn't want to make it easy for you. I wanted to sort of give you the picture of where we're at, and you're absolutely right. Those three that I mentioned—there's a few other commercial, the GE Prism, the Toshiba 4S, there are more out there—there's a lot of proprietary data there and there's probably not a lot we can do, especially on the timeline that they would need it in order to deploy the schedule they want. So, the answer is nothing. A lot of these are just front-running designs. If you talk to the new scale in the Westinghouse and the BMW people—and we have—they say well, they've chosen off-the-shelf technology because they want a rapid deployment timeline. On the other hand you say, "Well, what would you like the next generation SMR to look like?" and then they start talking about these things that "Well, yeah,

we'd like longer fuel cycle times; we'd like reduced maintenance requirements"…the kinds of things I'm describing. While we may not impact that first wave, we ought to start contributing to what they would like those designs to be.

Tony Hill's Presentation

Question: Just a programmatic question: does the fast reactor or the fast spectrum program or R&D have to fall on one side of the fence or the other at the AFCI or the Gen IV?

Response: Well, that would be Pete Miller's call, I think in the end. There's been talk of either/or and a combination, so I'm not sure how this will play out. It is unclear how it will shake out or that it will matter.

Question: There was one slide that said the goal was to have a cost eventually lower than advanced light water reactors and my two questions are a) is it realistic and b) does it matter at all? What I'm saying is the following: people try for a long time to achieve this and it is intended to be achieved from some revolutionary invention. Now possibly revolutionary inventions are possible for ALWRs as well, but then really the main purpose of fast reactors is not to compete in advanced fuel cycle with LWRs. Really, I guess, they would either be used to close the fuel cycle and then there will be a huge +/- delta coming from taking care of the waste that really the cost by itself will not matter or it will come with a, let's say, availability of uranium that again will change the equation. So I'm wondering whether really this part is even necessary to emphasize as one of the main objectives.

Response: That's a good question. It was put up as a grand challenge-type goal to shoot for with regard to helping to focus and name some of the research and development. You can also think of, as you said, given the unique mission and nature that the reactor system can be used for from a fuel cycle standpoint, perhaps there are other innovative ways to look at being able to overcome barriers to potential deployment, maybe through some other innovative approaches—whether it be looking at small reactor-type concepts to reduce capitol cost or whether it be taking advantage of some of the fuel cycle recycle concepts—but looking at what some of those inhibitors are that could be addressed through innovative approaches and research and development. So it's not necessarily to aim everything at that one particular challenge/goal, but to take the reactor system in context of what it can do and maybe some creative thinking of how we can overcome some of these things so they can actually have potential future downstream deployment as part of the fleet.

Comment: I would have some similar responses there. Clearly, the perception is that sodium fast reactors are going to be more expensive and it's probably reasonable when you realize that they cool and ignite in air or water and so you do a lot of things in that design to avoid that, so the question is…let me backtrack a little bit…as Jack said, these grand challenges were just to help the campaign directors in these areas transition from "let's turn dirt tomorrow" to a longer-range type program. We're going to be refining those a lot and thinking about what are the right grand challenges. But I think the cost issue is important for sodium fast reactors because there are reasons why they might be more expensive, and can those be addressed? One option is you use something other than sodium, like the lead-cooled system, but it brings in its own problems, or the things you can do with a sodium system. The advanced heat conversion or power conversion

systems are really important because if you can go to a Brayton cycle on sodium fast reactor then you avoid at least the sodium-water interaction problem on the IE checks. So, encourage people to think about what's unique about a sodium fast reactor, and of those unique aspects, how could you reduce the costs of the impacts of those?

Question: How is this going to be reflected in the call? That is, a lot of these ideas, it kind of goes back to someone else's question about will it be under this category or that category, but I guess going one step higher, is there going to be very detailed sentences and very specific workscopes or is it going to be more general this time? I think, at least myself, did not see the big picture when I saw individual workscopes and not see how it's connected, so my question is are there going to be individual workscopes like, for example, "go out and give us a perk on this," like there was one last time, and yet we don't see how it fits into the bigger picture, we just see the little one-sentence blurb. That kind of leaves a lot of us cold, so is it going to be consolidated to a bigger picture, or how is it going to be reflected this time because that left a lot of us confused on how to attack some of these things?

Response: Well, I think that was the whole point of having the workshop, to get everybody here and to do just that: discuss the big picture in all of this. Now, making this information available could be the next step and I'm not sure how that played out last year but I have seen versions of the next call and it looks very similar to last year. It has very specific, the campaign managers have put up very specific things that they're interested in seeing some R&D carried out, but it doesn't limit you, so the other idea of getting people here and looking at this whole thing is that there are these independent investigator grants as well.

Question: So, if it's going to be similar to last year in terms of structure, last year when it had the table, it did not have individual—and again, it comes a little bit into timing—there were no individuals listed, so if you wanted to get some background information because this is, in some sense, a moving target. Right now, we think we know what's happening but by the time it's delivered, that's four months later. Plans for FY11 will be formulated, things will be changed. So is there a way to get background information so as this moves along there's someone to talk to?

Response: One of the things that I noticed about the current call, at least in its current form, is that there are points of contact in all of these—names, emails, and phone numbers. So, that does give you a chance to actually interact with people on these things. This is a good point and should be brought up. I think tomorrow is the right forum to ask CAES exactly how they're going to compile this information and make it available because it is useful when writing your proposal.

Question: Some of this work is, especially on the high fidelity modeling and simulation, from what I know, there's a fraction that's part of the SHARP effort that's going on and that's, from what I understand, a separate pot of money. So, I guess I'm a little bit confused. I would like to know where's the border between—you know, do we take the modeling and simulation and high-fidelity computing—where's the boundary between what's within this call and then beyond the call that's more M&C area and Office of Science? Where's the boundary there?

Response: Another good question, and I'm not sure how this is going to play out, but again it becomes another organizational and communication issue with DOE. In fact, just two weeks ago,

there was a meeting, a board review, in Germantown and we had a number of campaign leaders and other offices attending the different sections and I think it's been identified that there's going to have to be better communication and close tie-in with the nuclear energy programs. But how this gets implemented, I don't know because it's kind of a tough thing. Some of the things fall easier to nuclear physics, for instance, than to nuclear engineering but there is a clear interphase here. Certainly, there's more academic freedom on one side than potentially on the other.

Comment: I would expect the solicitation to be sharply defined enough that it would be obvious which one you want to submit to. I'm not exactly sure how the breakout will fall but I assume there will be a specific category of modeling and simulation. Money is allocated for that, and then AFCI…if you pay attention to the coating of the various tasks as they were identified last year—and the draft that I've seen for this year is the same—that will kind of tell you, point you back to the R&D organization and who is responsible for those areas.

Response: So, I answered that in a more broad sense. After saying about independent investigator…because it is unclear as an independent investigator, where do you go to get your money to do some of these things? I'm not sure what to tell you.

Question: Is your question looking at individual points of contact? Is that what you're primarily interested in?

Response: ...in what we propose, it would help me to know how far we can go in terms of the high-fidelity modeling and simulation. You know, if you do the multi-physics and multiscale and so forth, is there going to be a boundary where you're going to say, "Okay, this is more nuclear energy- or Gen IV- or AFCI-related and beyond this is more Office of Science or high-fidelity computing area," so I guess that's what I'm asking. Maybe it's not a fair question.

Comment: There's an interesting relationship at the get-go and that is that the Office of Science is actually responsible for the nuclear data library that all of these applications rely on, which is kind of odd to me. I mean, it's a deliverable on the engineering side, but the underlying physics is really what they're after and it transitions at some point and it's kind of gray.

Response: You're right. It's not a fair question. The short answer is that if you show clear relevance to the scope of this program, then that's where it ought to be. If it's just computer science, then go look to ASCR or Office of Science.

Comment: To add to that, there is another break-out session that is going on in parallel with this one on methods and modeling and simulation. The representatives from there are talking about some of the potential program needs, but those are viewed from a more cross-cutting perspective, so rather than saying necessarily more targeted, I'd say, at fast reactors or separations R&D, some things in modeling and simulation area that can be cross-cutting and basically serve purposes for the program from a more fundamental standpoint but are still relevant and are still for mission needs. So, it might be good to converse with some of the representatives from that particular break-out session to get a feel for what, in particular, they are looking for.

Question: You said that transformational concepts, that was really a code word for things that are non-sodium. First of all, I don't share your view that sodium is relegated to that much of an

increase in cost. I don't think we know what they cost. For that matter, I don't think we know what LWRs cost either today. The Japanese worked for ten or twelve years recently on their fast reactor feasibility assessment and they show—and there's plenty of skepticism in the rest of the world—but they show nonetheless that with the innovations that they've come up with for the Japanese sodium fast reactor that by fifth of a kind or so they will be cheaper than LWRs. General Electric Hitachi, when it was General Electric back in the Gen IV days, was on the basis on their super prism effort willing to say that they could be cost competitive with LWRs. Now those are non-trivial efforts. I think most of us still feel that the sodium-cooled reactor, at least in early slog, is likely to be more expensive than LWRs and we ought to be working on that. I would much rather work on features of sodium-cooled fast reactors that attack that problem than to say, "Well, let's go back and instead 'throw the baby out with the bathwater'" and look at lead all over again, look at gas-cooled fast reactors all over again. I mean, those aren't going to cut it and I don't know of any other liquid metal that's going to cut it. I don't know how you get to a fast spectrum machine. We know about sodium. We know it's capable of producing energy in very, very large quantities, enough to make a difference in global warming and I just think it would be more comforting to ask for people to propose things that work within that construct than "Oh, well, sodium is off the table. We already know about it." Well, we don't know enough about it.

Response: Let me retaliate. I absolutely agree with you and if I left that perception, I'd like to correct it. In the early days of the Gen IV, when we said we're not going to fund sodium because we know it, I think that was a huge mistake and we're not going to do that again. It is the most promising technology out there for the mission we want. We encourage innovative ideas to help that technology. The point of this transformational concept is to just open the table to look at a much wider range of possibilities. Those technologies that are viable tend to change with time because of other developments that happen in parallel. I think we always need to relook that and we have the opportunity right now, with the timeline the program is on, to do that. That is all that this is intended to encourage.

Comment: So the other thing that I wanted to point out is if you look at the President's request, it really is looking for more of a broad-based approach across all of these. In fact, the campaigns are actually trying to maintain a focus on the sodium fast reactor despite the language to really look at all the options again because in four years, we could be in a very different position again and somebody may ask you to build something and that's what it's going to be. So, efforts are being made to keep some of the research focused on the sodium fast reactor but the President also wants us to look at transformational ideas, so this whole repainting of the wagon has to do really with language.

Comment: So I think that's a key point. You know, there's a saying: man plans, God laughs. DOE plans, Congress laughs. So, the President submitted a budget that called for a return to look at all of the reactor types, but if you look at the House and Senate committee language, they were questioning right off the bat why did we go from two back to six. They viewed that as being not productive. I think the key, and we're working on a roadmap and we're doing lots of things, but what actually comes out in the 2010 solicitation will, I think, be strongly influenced by the final appropriation we get because obviously, this is going to be a real wordy year. We're going to get a lot of words with the money this year because they're not happy about NGNP. There are issues with sodium fast that make it even more interesting to them that have to do with cooperation

with the Russians. So, there are a lot of things floating around in those two houses, so it would almost be foolish for us to speculate today what exactly will be in the solicitation. And we'll truly be scrambling to react to the Congressional language when it finally comes out. If you really want to see where this is going, you ought to look at the President's request for 2010 and then look at those two sets of house language. They're readily available and you'll then see that there's a lot of differing opinions as to what we ought to be focusing on. These answers aren't being evasive. We're not in a good place, either. I think that in 2011, this is all going to settle out, but the 2010 budget was thrown together as the new administration was just kind of coming in and there wasn't a lot of administration input into what we wrote into the 2010 budget. Now the 2011 budget that's just being written now, it's going to be very reflective of what the administration wants to do. As bad as 2009 was, 2010 is not going to be much better.

Response: I didn't mean to give the wrong impression. I think that money-wise, 2010 is going to be another really good year…a really good year. So what I said about the kind of confusion, it wasn't about the level of research that will be done, it's trying to target exactly what research to be done. Financially, we're looking to be in great shape. One thing that the administration did figure out in 2010 is that if there's no Yucca Mountain, there better be a Plan B. In the eleventh hour, that budget was piled on with dollars to compensate, really, for a Plan B if Yucca Mountain really never materializes. I think you'll have lots of opportunities to write proposals against a fairly large budget again this year.

Question: When we put together last year's workscopes, there was no understanding of budgets at that time, either. Do you think there will be a better understanding of budgets and direction in terms of the total because we worked to a $13 million level and ended up with a $40 million level? That enabled us to change limits on grants, on contract totals and all of this was influx and some people heard about it and some people didn't…there were complaints about that. Any idea about the budgets being a little closer to reality?

Response: Last year, this time of year, we were writing impacts for three-month, six-month, and nine-month continuing resolution. I think this year, they've asked for like a four-week continuing resolution, so they're pretty positive that this budget is going to come out fairly close to on time, which really will give us a lot more time to work on the details of the solicitation. And there's no reason that the community here can't be part of writing the solicitation. We will, I'm sure, be reaching out additionally, maybe we'll resurrect that failed internet discussion. We'll have to have some additional conversations once we actually know what Congress is going to do because they're still battling. They're battling on NGNP. If you looked at the two Houses' marks, they were dramatically different. The Senate wants to, basically, long-term R&D and the House wants to go build something. So, they've got to come to resolution on those but I think that's going to happen fairly quick because you know, Harry Reid is really cracking the whip on this budget, so I think we'll be much better than last year. Last year was chaos because nobody knew when the CR would be over, what the dollar levels would be total. It was pretty much a real mess. This is not so much like that.

Comment: You had on one of your slides nuclear data and instrumentation. I think instrumentation and controls is part of this discussion as well. Just for everybody's information, as part of the old AFCI program which is now gone at the University of Nevada…last week I received three grams of the highest purity depleted uranium in the Nation from Sarov, Russia.

The purpose of purchasing that was to build fission chamber detectors for the safeguards component of AFCI. Unfortunately, our funding is gone, so I have three grams of very pure material, so if anybody has any ideas about using it for safeguards instrumentation, national security instrumentation, anything contributing to Gen IV or high-energy experiments, fast-reactor experiments, safeguards, cross-section measurements, etc., I'm willing to collaborate and to create experiments. I'd love to use it in ATR experiments in the future. So this is something brand new, available. It's six-ninths and an eight percent pure uranium-238 with a tiny, tiny quantity of U-235, about two-tenths of a part per million of U-235 in it. It should make a material that's totally insensitive to thermal neutrons, which we've never had in this country in the past.

Break-Out Session on Advanced Fuels (FCR&D and Gen IV)

Jon Carmack's Presentation

Question: So there should be reports for each month?

Response: So every month we take bullets from—into our campaign—from each of the projects that we have within the laboratory system, so we expect that the universities participate in that exact same way that the laboratories all report a monthly bullet as to what they accomplished that month. It can be simple.

Question: So, bullet points, or it's…

Response: I install my software on the computer that I'm going to be using. I bought equipment for fabrication that I'm going test. I mean, these are simple bullets. On a monthly basis, we ask for reporting, just reporting like that. Now, I think part of the contract is that you provide a quarterly report, which is a different written thing. These are just monthly bullets that report to, by email, someone in the campaign.

Question: The $200K, is it for one year, or the total?

Response: I think that's for one year. So each year would be $200K per year. Ray, do you know anything different? I like $200K a year, but that's just me.

Question: But there is no interest on the bulk properties of the fuel?

Response: During irradiation or after?

Response: During the irradiation.

Response: We'd still be interested in bulk properties during irradiation.

Question: We've got projects looking at nitride fuels, oxide fuels, and TRISO fuels. I can see myself going back to faculty and presenting what you've just presented and trying to steer interest, and they're going to want to know, is there is a higher priority with the oxide and metallic fuels over the TRISO, over the nitride because they're going to want to know what's going to be best…

Response: So we still have the opportunity to look at other alternative fuel forms, so I don't think we'll see a specific priority for metal and oxide fuel. Now, in the program we're still working very largely on metal and oxide fuel because we understand the most about those fuels. We see that they have the opportunity to provide us with this early ability to, at the phase-field sort of stage, model those fuels and put them into the modeling simulation capability early, but there may be opportunities for other fuel forms. You may need the other fuel forms to make our

grand challenges, for instance. So we still have, today we still have—Tony, you may remember—the Future experiment in PHENIX which is a nitride fuel form and a metal fuel form. That experiment is being brought back from PHENIX to the U.S. in the next year, so we'll still be doing work on the nitride fuel system from that experiment. So we would be open to others; that's what I mean by alternative fuel designs. You may propose other fuel forms than metal or oxide.

So, everybody understands that, so I'm doing this presentation for the AFCI and then Dave's going to do a piece for TRISO fuels and NGNP. So those topics are separate in this year's call.

Comment: (Incomprehensible)

Response: I could foresee one of the cross areas as one of these innovative irradiation capabilities, that somebody has an idea to look at TRSIO-based fuel and irradiation and it might cross, that methodology might be able to be used for many different fuel types, so it may cross, actually, the AFCI/TRISO boundary and we'll handle those appropriately.

Question: I was just trying to understand. You talked about this kind of in a framework of supporting phase-field-type models and providing information for those and there was a theory bubble and there was a modeling and simulation bubble, and then that one little experimental bubble. But none of which you actually specifically described here seemed at all modeling-focused.

Response: Exactly.

Question: You don't want modeling proposals here or somewhere else?

Response: Modeling proposals should really show up under the modeling and simulation area for proposal. Now, I think you could propose, sort of a cross-cutting proposal that had a very interesting experiment built into it, maybe of a robust fuel, innovative fuel design that included some modeling and simulation piece. I think that's okay, but you want to be careful, I think, how you realize…we can't always go in and read each individual pre-proposal, so you want to be careful how you title your proposal, depending on where you think your best chance may be for the bulk of your work that you want to do because if you submit a proposal to the modeling and simulation area and it doesn't have modeling and simulation in the title, I could see them as saying, "Aw, this isn't modeling and simulation, it gets a zero" without even reading it because it isn't in the title. Now, that's kind of crass, but that's sometimes what happens because there are so many proposals. So target, I guess, appropriately, as best as you can, but I would say that if the bulk of modeling and simulation efforts should be in the modeling and simulation call, if you've got experimental stuff I would put it in here. Modeling and simulation might fund some experimental work, but I suspect they will rail against that because they're mostly focused on modeling and simulation. In the fuels campaign, specifically in our program, we are working toward developing the data needed to build this phase-field model capability that we can inform back to the overall modeling and simulation capability, but that's because of the huge linkage between doing those base experiments and developing the theory. If you titled something like that, you might have a higher chance than just submitting to one or the other. You see what I mean? I'm not sure I would completely kick it out of the first innovative fuel form design

package. I might say, "Well, it is modeling and simulation, mostly" but we are interested from the experimental point of view and we would work with the modeling and simulation people. So that's a nebulous answer. If I'm going to be interested in it, it's got to have some experimentation in it.

Question: Is there any *in situ* instrumentation now that's literally embedded into the fuels? I mean, I know the thermal couples, flux fires, etc., but is there any…has there ever been a microchip, for example? Microchips don't like high-neutron environments.

Response: No, no we haven't done that. So that's why we'd like you guys to come up with the ideas and develop it for us, so that we can use it. There have been small, *in situ* creep tests designed and built. It's very challenging. I mean, it is a very challenging problem. Holden has some very interesting stuff with creep frames, in-pile. There have been some in-pile pressure measurements. Dave's got an instrument that is very well instrumented with thermocouples, but even thermocouples fail within the life of the experiment, so you put a lot of thermocouples in trying to get at least one of them to read.

Comment: I would think that creep would be the easiest—one of the easiest—to measure.

Response: Some people have done some very rudimentary elongation measurements with just putting a block with a LBDT on top of it or something like that, but there's issues with removing the electronics from the reactor, so that's why I say if you can come up with some way to—I hate to use the word—wirelessly, communicate data from inside the fuel test for some period of time, even a short period of time, on microstructure, we'd even be interested in that because we still find that, I think, very, very, very challenging, but…

Question: You know, I'm not an expert in this area, but can you tell, for example, the microstructure, columnar grains or whatever, by just knowing, let's say, its thermal conductivity or electrical resistance?

Response: Not always.

Response: We were just looking at can you even measure something, temperature—that would be great—a wireless estimate in temperature or a wireless estimate of fission rate? That alone, before you get to something that would tell me about microstructure.

<u>Dave Petti's Presentation</u>

Question: I have a question about the zirconium carbides: so from the last deep burn meeting, I remember the pretty bad properties, mechanical properties at high temperatures, so what is the future of zirconium carbides as the coating material in TRISO?

Response: It may not make it in the long term.

Question: What does it mean long term? Is it a year or three years?

Response: In the next couple of years, we may make a decision to not continue it, but I think there is still interest, for instance, in it in some of these other advanced fuel options where you put zirconium in the kernel or you put it on the kernel, you know, take it out of the classic, where the SiC is. I think there will still be some interest there.

Question: So the studies still—let's say that somebody gets funded—it will still be relevant in the applications?

Response: Yeah, I think so, because even though we might make a recommendation one way or another, you'd still want to gather some of this information. Because obviously, if the program decides to not use zirconium carbide, that's a big, big decision and any information that will support that, I mean, that's what I'd say if I got the smart people in a room and said that we have to decide today; we'd probably decide against it. That goes against the Gen IV roadmap, it goes against a tremendous amount of work that others have said it's the thing to do, but as we've got into it deeper, we don't think it's the right way to go. It's just not needed and it has some negative aspects. It was kind of caught up in the euphoria, shall we say, and some real world look, you know, sort of make that decision, the more information we'd have to deal with, the political blowback we might get would be useful.

Question: I'm looking at your second to last bullet, the mechanistic models of moisture. I assume that there was quite a bit of information learned from Fort St. Vrain on that because of the moisture ingress.

Response: Not in a way that you can plug in a model. You know, what they saw was, they didn't see a lot of enhanced release, but in an integral sense, in that large reactor, I need information that I can show to NRC 'cause they'll say, "Of course it's going to change. It's a chemical state and it's going to move. You got to prove it may only move a little bit or something." So I need more of the fundamental information to put that story together. In fact, there have been no measurements of this. What's been done historically in the program is only fission gas and this is a huge challenge to "let's build a furnace to put moisture in, to measure metallic fission products that the moisture won't screw up the collection system." The moisture will oxidize sort of a surface to collect the fission products that can affect its…I mean, this is not easy. This could add serious, serious dollars to our program. We're throwing around numbers like $50,000,000 to do this. I mean, we've looked at what's been done in the past and we actually have a meeting next week, programmatically to talk about what this could really mean. Put moisture in-pile, we're probably going to do another irradiation, in-pile, with moisture. That's been done in the past but again, all focused on fission gas. NRC doesn't care about the noble gases. They care about iodine, tellurium; those are harder to get to.

Question: (Incomprehensible)

Response: It's very close. When you talk to the end users and the vendors, they're drifting that way. But then there are other end users who still want the others, but it's coalescing, I think.

Question: I just wanted to double-check because this is quite different from the previous…if we're sending in simulation-type proposals, would they be purely for this program, or should they be, should we make an effort to cross list them and ask for a joint review of some kind?

Response: I'll tell you, what Jon said was news to me. What I understood modeling and simulation meant was heat transfer and reactor physics. It's not clear, so for instance, in that session, the guy I sent is the guy who does the physics and the heat transfer. Fuels modeling, we would see still as sitting in our fuel elements, so it's not clear.

Response: So, Dave referred to the 20 percent of funding from each of the programs and all this kind of stuff. Well, in the AFCI program, the modeling and simulation is its own campaign, and they take care of fuels modeling and simulation. So, in the fuels campaign specifically, which there are no representatives of the modeling and simulation campaign in here, we're not focused on modeling and simulation specifically as doing that work. So, there will be two pots of money that kind of get allocated so they'll have so many proposals that they get to fund and we'll have so many proposals that we'll get to fund. On top of that, Dave will have so many proposals that he'll get to fund. I don't know if NGNP has its own specific topics in the call…(incomprehensible remark in the background)…so that's where you would submit a Gen IV TRISO modeling and simulation proposal, to one of Dave's calls. It specifically says that.

Comment: Unless the words get changed between now and the RFP, which they might. Again, I think that is largely because here, it is a very mission-driven for the science, so it's heavily linked in with the experiments and all of that, whereas AFCI is not looking sort of longer-term and so it looks at it sort of the opposite direction.

Question: I have a question about the categorization of the zirconium carbide. So you say CVD, so that means if we propose to categorization of zirconium carbide then we should have the capability to do the CVD or the lab will provide this because…

Response: You could collaborate with Oak Ridge because they're the ones making that. Because you know, you can have a collaborator, and that would be sort of a way to work that out. It's not easy to make. Although, there was a recent proposal, finishing a grant from Travis at, is it South Carolina, and he was doing zirconium carbide, so he has some capabilities, so you could work with him, you could work with Oak Ridge, you know, either way.

Question: So I'm looking at bullet point number three and it says transport, so I was wondering if chemical attack is an issue as well that you are interested in. For example, I don't see plagium on the list.

Response: Yeah, I mean, I think we would. I use the word transport because I don't like to use the word diffusion because that may imply a mechanism, you know, it may be vapor transport, so I tried to pick a generic term that doesn't imply a mechanism one way or the other.

Question: So it does include chemistry?

Response: Yes. It does include chemistry, yes.

Question: I have a question about cesium because you mentioned something there's some evidence that cesium could be chemically attacking

Response: Last year we called for proposals in this area. There's some very old data from Esper that the guys did sort of thermogravimetric stuff, hung some silicon carbide and cesium vapor and "noticed pitting." We see in microstructures of fuel from the old days, from the 80s, an attack, the silicon carbides being eroded, but they didn't have any tools back then and they always just said, "Oh, it was fission products." The whole periodic table? They never did anything, which one…any of that. And so, for us, in terms of high burn-up, accident testing that, if it's cesium and it does attack silicon carbide, that could be life limiting across all of these fuel forms. So we called for proposals last year in that area to get some insight before we start our accident testing that we'll be starting here, and I think we funded a couple of those. Also CO because there's also, carbon monoxide can attack silicon carbide at very low concentrations. So these were some things that we could build if there was some data to build the fundamental models to put in the fuel performance code and to just improve our understanding.

Question: So there were a couple of proposals funded last year on this? Where they experimental?

Response: Yes, experimental. I'm assuming there's a website where all that stuff was posted. Not yet? All the ones that were awarded last year? Yeah, awarded.

Question: (Incomprehensible)

Response: Um, 1,000 degrees, roughly. I'll try to expand that. I got the numbers in a report. I added that last night because I thought it would be useful, but I need to pull some of the numbers. In moisture events, we're not talking about super high temperatures because the reactions are endothermic and so the temperatures tend to be fairly low from all the reactor analysis that was done back in the 80s that I recall. It may go as high as thirteen, if I remember right. But not the sixteen hundred number that we think of with TRISO fuel.

Break-Out Session on Methods and Modeling & Simulation (Gen IV and FCR&D)

Question (broken): …and then molten salt has appeared but we've been talking about other interesting concepts such as molten lead-cooled reactor. Something which to me is still very attractive but not very popular is super-critical water-cooled reactor which disappeared completely from the list. So since we are here to talk about opportunities, could you comment on what would be the criteria if anybody comes up with an interesting idea concerning any novel reactor concept, not just gas-cooled reactor or sodium-fast reactor, how those things would be introverted and how would such a proposal be reviewed? Does it have to speak to the criteria established somehow? This is a very fuzzy area for me and that's why maybe my question is a little bit too general.

Response: And that's a fair question. Let me preface this by saying past performance is not an indicator of future performance but we've had just such a situation arise, a couple different situations arise, like this. Of course the Gen IV program selected these six concepts—and you mentioned most of them. It was by no means exhaustive and in the past few years we've gotten funding, specific congressional funding, through an earmark for research into molten salt-cooled high-temperature reactors and that wasn't one of the six concepts but it had enough attractive features that the Department of Energy picked it up. And of course, many of you might be aware of the things that DOE isn't doing such as…but the new reactor concepts that are out there between new scale and Hyperion power systems and traveling wave reactor and all of these things. Just because it's not a Gen IV reactor, one of the six Gen IV concepts, doesn't mean that it's not a viable future reactor candidate and doesn't mean that it won't get funding. Unsolicited reactor applications will be received by the Department of Energy but the track record is not dismal in that regard, I guess that's my response.

Comment: I wanted to make a comment first on the reactors. I believe, and I'm not positive, but I believe that they are, in the reactor areas, going to be examining some of the different concepts. I know within fuel cycle R&D on the transmutation side we're expanding it to various transmutation systems, not limiting it to the SFR. I believe they're also bringing back some of the small reactor concepts, but I would check that part of the solicitation…

Comment (broken): …fuel interactions and interface issues and how to model them, then we're quite interested in that.

Question: Being one of the ones who is coming in from the basic physics side to measure cross sections because I've been pulled into some particle nuclear physics…got drawn into this through Tony Hill who's one of my students, but we're coming in from the perspective of basic physics. This is the first time I've ever done anything that I see could possibly be applied in my lifetime and so I'm trying to sort out what types…the type of simulations we're used to doing which are large and are very different types that are developed for large systems, very intensive computing side and trying to think, "Well, where can one take the knowledge that one has of doing our type of simulations and moving in to help with stuff that's for Generation IV" because on the other side there's an enormous amount of background on simulation that's done for this

stuff that you scratch your head and go, “Well, gee, I don’t think I can do anything on it because it’s such a different aspect” and so I’m trying to find…there’s got to be a linkage somewhere because I know like, from ours, we use ??? IV for a lot of our stuff and ??? does not do low energy neutrons and by low energy, I mean anything below 100 MeV. So it just doesn’t work well and so we’re trying to figure out where one gets an interface, or is it a place where one could be used because like you mentioned, CFD stuff and I know—I have a former student doing that—and one of the problems is they have engineers running the CFD stuff on the designing wind farms and they don’t know enough physics to understand it. They’re in a very non-linear region and so their models are actually giving them garbage but they don’t have enough knowledge to recognize that it’s wrong and I would sort of be in the same spot looking at something on a reactor that could be giving me garbage and you know, you’d look at it and just start laughing hysterically and run out of the room trying to keep from laughing too loud. Just trying to find a spot with it.

I guess the challenge is how do you, when you have this very traditional, somewhat stovepipe research and development and application regime and you’re sitting on the outside looking and thinking, “This looks interesting. I kind of know about this, but I don’t know where to begin,” the best thing you do is, for example, you take one of these “contact me” and I’m not…I won’t know very much about your area and in fact, my particular area of expertise is one very narrow part of this stuff, but I can try to put you in touch with people who know a little bit more and can speak with you on that and develop dialogue with people at the lab and then develop ideas. You might not be successful first time around, but most people aren’t.

Response: (Incomprehensible)

Question: Again, we are talking about modeling here and you refer to a modeling reactor system and things like system codes, existing codes. You mention that they are more mature for light water reactors than for anything else and obviously this is true but one of the reasons is that the maturity is due to a lot of work done on tuning on comparing whatever we can against experimental data rather than on focusing or understanding. And frankly, system codes were developed when I was a student, and you can imagine it was quite a while ago. It was the past century so I’m trying to say that it’s time to think about moving into the next generation of models, not system codes in the traditional meaning, but advanced models which would involve not only CFD, not only DNS, but a combination. The best tools we can think of and they made it by using 50,000 processors. So what, we are talking not about today, we are talking about 10 years or 20 years from now. Computer codes will become available, they become faster and so on. So I would expect to see, you know, one of the priorities, the development of models—not one category—small models for individual phenomena, which is important, which is great but also modeling reactors. Looking at it from a completely different perspective rather than saying, “Then we’ll improve the existing system codes.” I do not think this is the right approach and I haven’t seen emphasis on this issue.

Response: That leads into our next talk and I agree with you. The future is what you describe, absolutely. My planning horizon and the problems I face and my needs are a little bit closer and they’re more evolutionary but we want to pull, you know, we always want to be looking in that direction and pull bits and pieces that we can use to enhance or validate our older models while we are waiting for these higher resolution tools to come along. I think that’s a very valid point.

Response: That is a good question. Actually, I think sometime in September there is going to be a workshop in D.C. between NE and ASCR on needs and also advanced scientific computing research.

Question (broken): …listed, you limit us, you know, for advancement in the developments of the computation and the modeling. Especially I noticed, for example, for neutronics, you say diffusion of metals, that's about it. So why would you tell us to advance one small method in modeling neutron transport or in modeling reactor cores from that point of view? In the United States, we have computers and electricity at hand. It is still very affordable to everyone…

Response: The types of problems that I encounter in actually designing nuclear reactors require solutions …transport algorithms for these applications, but I know in these types of experiments and designs that I need to construct in the next 10 years, they're not going to get me there. They're a little bit too far off. That's my emphasis is that on the shorter term things evolutionary methods of…and if I didn't mention using transport in here it was my oversight because we are already using neutronic transport for a lot of our analyses, but it's still a little more closer to the more traditional assembly code level types of things and we're breaking out in piece meal ways toward full court transport, which is the goal. The NEAMS program that you'll hear about shortly is really geared up toward your type of research. That is what you want to hear next.

Comment: What you described to me is not just a modeling and simulation program but a complete R&D dream program where everything is included and in order to accomplish such a program, you have to model what we know—and there are very few things that we really know well enough—so modeling also means database experiments and to give you just one example, the other day, we had a project review meeting and there was a presentation, a report, on a project related to experimenting with a type of irradiation on reactor structural materials. A very nice piece work, but it was microscale. When I asked the researchers, "Well, what I would like to get out of it is how we can convert your results into microscale fuel properties, so what I need is thermoconductivity is the strength…when do you think you will have it," well, the response was, "We haven't even thought about it. We are busy with our microscale work and there's so much work to do that it is a completely different game in town." So we have big gaps between various things. So, to be realistic, one has to identify bold goals and also steps to take on how to get there.

Response: Absolutely, this is a bold goal and to be honest with you, on Monday, the program managers said this is like a $50 million program and right now we have to lay out this grand goal. We have to say this is where we're going otherwise it's just going to dwindle, right? This is our goal and then how do we get there and, well, we're trying to lay out that map and I believe we've done that. Each team has already done their requirements, their approach, and like I said, each…university programs, here, we view them as very valuable, like the one you talked about. That microstructure information, irradiated materials microstructure information can be very valuable to us because we could put it in the mezzo scale as validation to our phase field or our weight theory so that we can cross validate between our models and experiments because in NEAMS we're not going to do experiments; it's all about modeling. The validation with experiments will be done through programs and through different campaigns and then they're hoping the NEUP can provide some of that lower length scale validation.

But that's a good question. We realize that this is a very bold goal and this is a grand picture, but that's the way we wanted to do because we don't want to just make a two-year program.

Question: As part of the NEAMS program, you outlined S&M and then there were three others. Those are separate programs, other than S&M?

Response: Yes, they are. They are funded right now at a smaller dollar amount that…no, I take it back. Actually verification/validation and uncertainty qualification has quite a bit. It's funded out of…managed out of Sandia.

Question: So that means that that should include some experiments, right? Or no?

Response: I think it's…linking with experiments; not necessarily doing experiments. They're providing that linkage. Because NEAMS, we decided that we're not going to do experiments inside NEAMS.

Comment: So we have the NEAMS program, which is running parallel to the experimental efforts of AFCI or fuel cycle R&D. So in each of these areas, we have the integrated codes that coincide with each campaign and the efforts they're doing, so the experiments that the modelers need are being done in the campaign and the models are being created that the experimenters need so we're trying to work very closely and make sure the efforts are coupled. But most of the experiments that are needed to support the models are actually done in the experimental portion of the program.

Question: On your last slide you showed that radiation transport computation and whether reactor response computation on MCNP and decided you need to speed up and I wonder studying, if you want people to develop more advanced methodology or algorithm to speed up to calculate a response quickly and more accurately? Is this a general method or you have a special application or you have a special, or specific reactor core configuration?

Response: This is more of a methodology development. Say if you're developing the code for cell cutting, meshing, all of these computational methods for hyper-process computing will be highly desired. The mathematical formulations, say you want to do a coupled thermohydraulic and neutronics simulation. How do you do that coupling? How do you do that computation efficiently with millions or even billions of degrees of freedom? Those are highly desired.

Question: You mentioned MCNP, the Monte Carlo method, are you also trying to explore some atomistic methods or high-burn methods for this similar…?

Response: Definitely. All of the methods, the different lifescales, like I said, we're interested and we will be benchmarking and validating it with the experimental data and try to see, you know, at the end of this…it's not going to be a "one size fits all" approach for each individual phenomena at different scales. We would will take that multiple…method.

Question: Also, you mentioned that MCNP needs 3-D solid model of the material flow in plant. Can you explain, in more detail, what that means? Material flow in plant?

Response: This is just a slide that I took out of the March workshop. They decided to take this activity back into the IPSC, not to leave it in the S&M. So, we're not addressing it here in the fundamental methods and models but it's still part of NEAMS inside of separations and safety and safeguards.

Question: When you say the material flow, you mean the depletion or all material composition changing and…

Response: As a safeguards topic, this would be the fissile material inside of a reprocessing plant or reactor.

Question: You mentioned a workshop for methods and for computational in Washington…

Response: That's in September. It's a joint workshop between NE and ASCR.

Question: And it will have two days? Three days?

Response: I think it's two days. They're going to talk about "how do we use advanced computing in nuclear energy?"

Question: Will it be by invitation? How do we register?

Response: I think right now it's still in the planning stage. I can get you more information if you leave me your information. I think it will definitely be a good thing to go to and to find out what's being funded out of ASCR because ASCR, they're interested in these large-scale calculations as well.

Question: This one deals with point #2 on knowledge extraction/anomaly detection. It's a little bit different than…I see that I'm not thinking simulation because we have a program in computational physics and that's the stuff that we teach…but how far developed in your area is it where you do fuzzy systems to make decisions? When you have information with detectors and such as that…that's what with students…it's what I teach…Bayesian networks and various other things and also fuzzy systems and so on and so forth. How far is that already developed into safeguards?

Response: Honestly, I don't know the answer.

Response: That's an area that we're focusing on. We are involved in some of those activities but it's one of the areas that I'll actually highlight in the next section that we definitely have needs, you know, with the various possibly unknown separations reprocessing techniques we're developing the whole plethora of different detectors and data integration and analysis processes that we want to…we're going to have hundreds, thousands, millions of points of data and we want to find the best—from a very, very fundamental way—the best way to integrate everything. Do we need to evaluate every piece of data? Are there certain patterns that we can focus on certain things? So that's what we're focusing on there but there are definitely needs so I would definitely suggest going to the next section.

Question: That's actually what I was thinking of anyway. It just happened to hit…that's what I spent a lot of time doing, you know, for our own problems, strictly with the fuzzy systems trying to change the way you make decisions because things don't work. Humans can do it but computers don't do it very well.

Comment: I could add a comment on that particular question. I also work in the area of safeguards. Methods like fuzzy logic have been applied only at the very superficial, preliminary level in safeguards with very simplified problems. The challenge that is ahead of us now is to take those methods that do have some promise and to apply them in the sense that Brad was suggesting: to not just simplify a problem with a few data streams, but to very large problems where you might have hundreds or thousands of sensors taking near real-time data in a large plant and do the methods break down and figure out what the challenges are in applying them to these much more complex problems. So, it's not totally a new idea, but the idea is to take it to the next level into where it would become more practical in these large plants in the future, if that helps. The same is true for Bayesian networks and a lot of these other advanced techniques. They've been illustrated on simple examples and the challenge now is to take it more close to practical applications.

Comment: …long enough that we've been getting the IEEE transactions on fuzzy systems since it started which was—what—ten years ago? It's mostly a lot of fun but it's bizarre. You can do this rigorously and it's fun; it's one of these things used to get our students interested in things and it's just an example of an area where I can take something I'm already doing and find ways of…I'm always looking for ways to grow…

Break-Out Session on Materials, Fuels, I&C, and Safety Analysis (Gen IV-LWRS)

Due to a technical problem with the hotel recording system, no discussion was captured from this session.

Break-Out Session on Materials (Gen IV)

Mark Carroll's Presentation

Question: I do mostly modeling-type activities and I was just trying to understand, in terms of the creep mechanisms—I have limited knowledge about graphite and carbon materials but my understanding is that's not true of other people; they have a lot of knowledge about these materials—can you at all narrow down a little bit where there are sort of issues about creep, sub-areas of that general problem that you guys are particularly interested in or where you feel there's really missing information?

Response: I don't want to pull the rug out from anyone that feels like they're in that category where they really have a thorough understanding of it but if we had such a thorough understanding of it, these AGC experiments that we're going to be running probably wouldn't be necessary. We've got these advanced graphite creep or ATR graphite creep or advanced graphite capsule—whatever you want to call it—creep experiments that are going to be run under irradiation because there's a lot of that fundamental information that's missing. I don't know if that really answers your question because how does that help you as a modeler? You really need the raw data first, or you need some sort of trends to start drawing your model from. So I'm not sure where to go with that. There's a very important component to this modeling and that goes all the way from kind of what you're mentioning, which is modeling of the fundamental behavior, the mechanisms behind it, all the way up to your whole core modeling over the expected life. There's room for kind of clarifying those issues and certainly developing those models.

Question: If I come into a problem like this and feel like, "Okay, I suspect I do atomistic level modeling," probably some sort of fundamental insights about mechanisms we don't understand that I might be able to provide. But I suspect there's at least a quite significant and lengthy literature out there and there are people at multiple labs and groups who are doing different kinds of experiments. Is there a way that we could find…is there a group of people we should go talk to and say, "Look, we're thinking about this. We think we might have something to offer"? But I don't have three months to just sit down and read the hundreds and hundreds of papers that might be out there. Can you guys give us some more focus and some subset of the literature areas to go after?

Response: There are a number of activities in this area. You know, my sense is that they would take modeling at any scale. We're that lacking. I think there's a role that we don't completely understand that creep affects reorientation of the crystallites and the graphite, which also changes its properties. We see this in pyrocarbon as well, we think. Really, there's not a lot of expertise here in the United States. I mean, you know, Oak Ridge…INL, the usual suspects at those institutions. The best university is Manchester at the UK because of the graphite reactors in the UK. That's where there's a lot of expertise in the modeling and there is, I believe, an IAEA-coordinated research program that is going to start on creep in particular. There's some work on the IAEA that's starting. The other thing is that there is a graphite specialist meeting that will be in Idaho at the last week of September and there will be some real experts there. It might be worth dropping in and trying to get a sense…might be useful.

Question: How much is known of irradiation growth in graphite? Is it as significant a problem as creep and how much is known about it?

Response: There's actually quite a bit of data on it. It is fairly well-known and the mechanism behind it is also fairly well-known. Probably the group that is the biggest experts on that is the Manchester group.

Question: Is it as significant as creep?

Response: We understand dimensional change in graphite. You know, it shrinks in one direction then eventually it will turn around and start to swell and the real issue here, as I understand it, is the conventional wisdom was that as soon as it bottomed out, it's over as a material. We don't want to use it. Well, that's not where the reactor design community is. They want to see if they can get back to zero on the turn around. But, where that happens, how fast creep will play a role in that, we just don't have data out there and so that's really the lifetime limiting thing: how does creep alter dimensional change at the higher doses?

There is a good IAEA document that just came to my mind. If you go to the HTGR website off the IAEA website, I think it's called "Irradiation Behavior in Graphite" by David Martin from the UK. It's kind of a nice overview and that's probably about 1990. I don't think much has happened since the 1990s. But that's sort of my understanding, that it's really a lifetime issue, this whole creep thing. If you wanted to use graphite to 2 or 3 dpa, that isn't the problem. These guys, particularly the pebble bed where online refuel, they want to button it up and not open it up for twenty years. Those inner reflectors see a heck of a lot of dose. Can you do that? What's going to go on at that high-dose region?

Laura Carroll's Presentation

Question: So, you mentioned new concepts in austenitic alloys, but is there room for new concepts in ferritic-martensitic alloys or ODS alloys instead?

Response: Yeah, the answer is yes.

Question: Could you expand a little bit more on your item that you had on NDE methods to characterize microstructure in ferritic-martensitic steels? What exactly are you looking for? Are you looking to see whether they have been uniformly fabricated?

Response: Did it say ferritic-martensitic? It was, so it's for advanced-pressure steels. So there's a whole host. You have to do the good heat treatments, these thick sections and then you have to monitor them. There's this—what is it—Type IV cracking that we're seeing in fossil systems. I mean, it's been a disaster from what I hear. Wouldn't it be nice to have some measurements? I think the alloys have gotta have some serious issues that maybe NDE can help us see them in advance and that sort of thing.

Question: So what you're looking for are things that you can say, "Okay, I've fabricated this thick component and am I doing it well, uniformly and the way that we specified it?"

Response: Yeah.

Question: The item that you had on the first slide that had to do with strain localization and creep cavitation, can you expand a little bit more and talk about exactly under what conditions would this be a concern and what exact mechanisms you are looking for?

Response: So for example, in Alloy 617, we've seen that you don't see appreciable steady state creep regime. You see a primary and then transition point, then the rest is tertiary creep. The ASME code doesn't really allow for…well, the way it's set up now allows for if you have a steady state creep regime and then you take either some percentage into tertiary creep and that's it. The material is done. But if you look at a high-temperature creep curve for Alloy 617, you realize you're hitting tertiary creep at less than one percent. Does that mean the load carrying capability of the alloy is gone at that point and that you shouldn't be able to go beyond there? Can we understand the mechanism well enough to say that there's a safer limit for…for example, one of the things that Tom Lillo at INL has looked at is how much creep cavitation is actually present at different percentages strain, like two percent strain or three percent strain—how much creep cavitation are you seeing and where are you seeing these cavities? It's kind of trying to understand what's going on and therefore, do we understand it well enough where we can say, "Yes, you can change the ASME rules on this" for this type of alloy?

Question: So this is based on an observation from a creep test that you did not see steady state creep and you related that to microstructural observations that identified the problem as strain localization and creep cavitation? Am I correct in assuming that? So there was a test, and then you looked at the specimens that failed earlier that went into tertiary creep early and you observed these characteristics?

Response: Yeah. There's been a lot of work on this and some of the work that's been done at INL and other places—I know Boise State University has been involved in some of this too—where they've actually, yes, interrupted creep samples at different percentage strains and looked at the amount of cavitation in the alloy and see that you don't have appreciable cavitation until well into tertiary creep. So, in comparison to a stainless steel or something where you can see appreciable strain during the steady state regime, they're trying to look at is there good reason to change those ASME codes? So strain localization and creep cavitation, I think getting at the mechanism and really understanding what's going on so you're not just basing it off of "okay, well we don't see any creep cavities." Well where's the strain localizing to on the granulars?

Break-Out Session on Nuclear Physics/Data and Safeguards (FCR&D)

Brad Williams' Presentation

Question: Are you coordinating your activities with NNSA's activities?

Response: Yes, we're very coordinated actually. Ed Wonder from NA-24 is here and on Monday I had to take the late flight out here because we had a joint roadmapping activity led by NA-22. Frances Keel and Jim Sprinkle from NA-24 were there. We're trying to stay very coordinated and identify joint U.S. needs and then as we move forward from that joint roadmap we will be developing program plans and implementation plans that show how you take that big area of R&D need and how each program is going to work to address them.

Question: So they are involved in the review process, or not?

Response: There may be some reviewers from those offices during the review process. It's slightly tricky to answer because it's the NE University Program. CAES is leading it. Actually, I think there were a few proposals that weren't selected by our office but NNSA…

Comment (broken): …calling both safeguards was causing some confusion. They've come up with a new name that helps clarify their domestic focus. Our focus is international safeguards. Some of the things that will make a difference domestically may not help in the context of international corporation other than timely detection, but then we have to ask the question, "Well, who's going to step in and do something about it?" and there, the world is teaching us a somewhat sobering lesson about how quickly the international community responds. There's coordination among technical experts between NA-24 and NE on what each office is going to do, and what they're laying out here in the domestic context also has relevance to international safeguards because the IEA basically faces the same challenges. If you can really have real-time high, high accuracy detection and the matchment of the inventory, that makes a real difference to the international safeguard. So, what you accomplish on their nickel is relevant to us as well. Then there is this new exercise which is three parties getting together and doing the roadmapping where we're looking at long-term technology needs and R&D gaps. And then NA-22 has a long-standing university R&D process of its own and so we may be working through that. We're waiting for congressional direction on the integrated university program for FY10. It may be a little bit different from FY09. We expect it probably will be, but we also expect Congress to say, "Thou shall work together," so we will and we are already. There is input. The idea of using some NNSA reviewers from the labs—because that's what the technical reviewers on our part would be—and the guys who may be crawling in as reviewers probably support both programs, avoiding conflicts of interest and everything else because there may be lab involvement in some of these proposals. So yeah, we are. We expect this relationship to grow over time. Hopefully I'll have a little bit more to say in the morning.

Response: So yeah, we are staying integrated and discussing proposals as much as possible. I actually got an email this morning about some of the NA-22 university proposals and if we

would be able to assist with those. It's a work in process but we're tying to coordinate, by the joint reviews and sharing information. With our normal program funding for the campaigns, we've been looking at what the joint activities are to make sure we're not double funding something and leaving something else out in the cold. We're trying to make sure we can maximize the efforts of the three programs and leverage each one.

Question: Last year at this same meeting, Kathy talked about a topic that would be funded on looking at the policy issues of closing the fuel cycle. That didn't show up on the FOA and I asked her about it and she said, "Well, we were kind of low on funding this year." Is that ever going to come back?

Response: I'm not sure.

Question: You look like this is the first time you've ever heard of it.

Response: It is!

Response: That's okay!

Response: I'm familiar with several of the activities going on in the program, but not everything.

Question: Well, it was on her slides last year and she talked about it but then it disappeared after that meeting. It was one of those things that, you know, you get a group together who might be interested in that and then it doesn't show.

Response: That's one of the problems we are facing. We've been, you know, everyday we go in, our mission is changing slightly and some of the focus areas are changing, but I think we are getting closer to really getting a solid program and vision in place that we'll be marching forward with a much clearer definition of where we want to go and what we need to get there in the coming months. But I appreciate that it is difficult.

Question: Does she have input on that? Could I ask her?

Response: She would.

Response: Okay, I'll ask her when I see her in the hall or something. Thanks.

Response: For this solicitation, we currently don't have anything identified in the systems analysis area, but that doesn't mean come September it won't be back in, but as it is right now, there isn't anything specifically called out.

Question: What is the size of the proposals that you are expecting to be funded on this and would you be looking favorably to a consortium-type proposal where it transfers our leverage to different universities?

Response: The size of an individual proposal?

Response: Yes.

Question: That's actually a discussion, thank you for reminding me because we need to bring it up in the panel tomorrow. Last year, I forget exactly what the limit was but…$1.5 million…per year…sorry…$1.5 million for the three-year total, $500K per year. One thing that we've been discussing, at least, in the office—and I don't know what's going to happen with it—but was possibly leaving that open. You know, letting the proposer decide how much it required to do what they wanted to do instead of saying, "Tell me what you can do with $500,000 a year." Tell me what you want to do, then tell us how to do it. I don't know if that is an ideal case with unlimited bank, but that's something that's been discussed. It's still undecided right now. On the consortium, I think, personally I think I would like to see both: single PIs and big teams, multiple universities team with…I was also involved, if you guys remember—what was it, last summer—the FOA that went out between universities, labs, and industry through the AFCI program. We encouraged teaming of those three groups. Personally, I like that. Bring in experts from all the different fields. More heads are always better than one when trying to solve a big problem. I think we will welcome both, any of those options.

Response: But in the case of consortiums, probably the budget size would have to be larger.

Response: Right, and that's…again that goes into…and this will be some internal discussions between the different DOE or NE offices and CAES on how we will actually work this out, but I agree, if you are going to have a big team solving a big problem, you need to have a larger budget. That's the reason we didn't want to limit to a specific number, but the results of some of those discussions, I think, are still to be determined.

Question: Nuclear Navy is concerned when they track, you're talking about tracking and keeping up with inventory; they worry about cradle to grave. Tracking stuff…where this piece of metal came from that went into the reactors, everything from the time it was created to when it's destroyed. I got involved in that, once gave a proposal. One guy at the Navy thought man, I walked on water, the other one says, "Well, it's a good proposal," and another one says, "This guy stinks. He doesn't know anything about logistics." How much of your type things that you're talking about would benefit from a good way of tracking it where it's something…pieces…either they're staying in tact or it's a clear point where I take this and break it apart into pieces and you can track it—relatively straight forward and not very expensively—to be able to track it?

Response: I think that's very important to everything we do, from taking spent fuel from the reactor, shipping it to either a storage site or a repository or reprocessing plants and then all the way through the reprocessing plant. We need to account for that material the entire way through the fuel cycle, so I think that is very welcomed and in the fuel fabrication that would come into play too, so I think that's something we do have a need for.

Comment: If you look at, as much as the proliferation debate has tended rightly or wrongly to center on the bad guys, you know, look at what's happening on the front end and if you are looking at what the bad guys are doing very often they are involved in the use of centrifuge enrichment and one of the concerns we have is the knowledge of where UF6, you know, loaded UF6 cylinders are at any point in time. Now from the industry standpoint, it's a property

management issue if it's seen that way. But from a safeguards standpoint, if you had a small cascade, now you can begin to see where small quantities of cylinders become a concern. So if you have some ideas along those lines, we'd like to talk to you.

Response: That's actually a good point. I'd like to add to that another distinction between the programs. Our campaign impact is focusing more on the backend, the reprocessing and the fuel fabrication for transmutation fuels. That is the R&D we're focused on and I think Ed's group and…so anything dealing with the frontend enrichment would fall more into the NA programs. It's much needed but that's their focus, whereas ours is more toward some of the backend issues, just to clarify when you're submitting specific activities between the different solicitations that we have.

Tony Hill's Presentation

Question: (Incomprehensible)

Response: Oh yes, a number of them. In fact, I include that in this processing portion because you can actually…NJOY can produce the grouped data.

Question/Response: (Incomprehensible)

Response: If you're trying to tell me that there are sins in these data and in their processing then you're speaking to the choir.

Comment: (Incomprehensible)

Response: Does everybody understand that? When this stuff gets unpacked, its most usable form is in a flux-weighted form because you're talking about data that come across orders of magnitude and into that neutron energy and in cross sections so to kind of reduce the precision liability, they become flux-weighted and there are sins with that.

Comment: (Incomprehensible)

Response: Yeah, and depending on who you talk to. So I'll have to say that the results that you're going to see from the fast reactor based on extravagant calculations that use seventeen grids. Of course, if you talk to Red Cullen, you can't do a calculation like this without 2200 groups to preserve fidelity and these become part of these sins. But, there's a calculational reality, right? And that's really what gets you.

Question: Don't you need simulation also? You're not saying, at least I didn't see it.

Response: Absolutely. Actually, there are a number of levels of simulation that are involved here. One might be basic nuclear theory simulations and models. The other is the simulation of detectors, which is something that the safeguards folks are actually very good at, very sophisticated tools. Then there is a level of full experiment simulations, which you will have to have as part of your measurement proposal because we're dealing with neutrons here and so everything matters. In fact, when you think about, for instance, elastic scattering, it's at least six

parameters of concern in there and some of them are mutually exclusive. For instance, the mass…you want efficiency for neutron detection but you want as little mass as possible and those two are counter, uh, they're anti-correlated, and so you really do need to have full-blown simulations in order to do a cost benefit against a multi-parameter situation. I think doing it by the "seat of your pants" days is gone. For the types of measurements that are required, we really do have to pin down all the uncertainties and find the best spot in that phase space to get those measurements. So yeah, there are multiple levels of simulation. I don't know if you can actually make a proposal for a measurement without having a simulation component to it. Well, you can, but it might not get past a reviewer.

Question: I wanted to know how you work with the Brookhaven Nuclear Data Center.

Response: So Brookhaven, the National Nuclear Data Center, is primarily funded by the Office of Science, and it's the ENDF/B-7 library along with X4 and Scissors, some of the experimental databases is the responsibility, under the stewardship of the Office of Science. Getting them engaged into creating better nuclear data is something that they're aware of. Of course, there have been high-level talks with Gene Henry and folks and that has been stepped up, so there are funded proposals now on their side of the house for better nuclear theory and whatnot and we've also funded it on our side, but it's been very specific funding. That funding has been for better covariance, not nuclear theory, per se, although if you need better covariance, you need better theory and so it just has to be kind of worded differently. The other thing is evaluations. Again, if you make a better measurement and want to include it, then you're talking about an evaluation. If you want to do it with current tools, we've funded that. Here's "we'd like to fund you to redo an evaluation of linoleum" or whatever and then they go out and do that. Of course, we've also kind of hidden some development in their incremental development on whether it's ? or whatever code that they're using. But at this level, we've always kind of hidden the investment in the basic nuclear theory and we're hoping that there's more synergy and that will actually come through this cross cut. I can't tell you how this will play out but it is certainly one of my goals, to make sure that we have good communication.

Question: What is difficult at a university to sell is the hire of a nuclear theorist because funding has been very low in these areas in the last couple of years, maybe one or two decades, so is there an idea of getting something like a faculty development program with bridge funding for universities who hire or something like that?

Response: Not that I'm aware of. This has always been a problem, right, for theorists. They've always had this moral approach. They basically attach themselves to experiments and sometimes stood on their own if it was appealing enough like super strings. I don't know if we can get any mileage out of super string reactors but I'm not really sure how that…that's really something that Office of Science…that really does fall in…

So, the thing to do is to contact me. I mean, if you have any questions or need any ideas because I'm on the inside. And there's a lot of work to do. I'm more than willing to help to get these in the right shape.

Break-Out Session on Heat Transfer and Energy Conversion (Gen IV)

Mike Patterson's Presentation

Question: Your comments mean there actually will be money for non-NGNP proposals?

Response: I can say maybe. The House and the Senate language this year are considerably different. They're going to go into committee probably in early September and depending on how that language comes out, there could be considerably more money for Gen IV or it could be very specifically NGNP. I think there's going to be more than there has been but it's conjecture on my part.

Question: If it's not legislatively restricted by the appropriation language, will the program allow for money that's non-NGNP…will allow for proposals that are not NGNP-related? You see my question?

Response: I understand your question. Again, I'm a lab employee, not a DOE employee. That's very hard to know because there's going to be a turnover at the top and my guess is probably yes, but that's one guy's opinion.

Question: So just as a follow-on, if anything like this transpires, will it be on the CAES so we're aware and can respond appropriately? In other words, instead of by word of mouth, or by me emailing Hussein and he emailing Andy…but my only point is as long as it's posted somewhere generally so if there is a change in tone we all know about it. That's my point.

Response: Qualified, yes. The appropriations language has to come out before the call but assuming it comes out before the call is finalized, yeah.

Question: In this slide you have one item, industry will design and license. In order for them to decide whether this is the right thing to do or not, they will have to get some encouragement and the funded DOE programs should serve this purpose. My question is, are there any specific criteria or goal what this program is supposed to accomplish in terms of, for example, material research, conceptual design issues, safety analysis…something which would really contribute to the package of information which the industry would have viable when it comes really to deciding whether they want to start doing business?

Response: So, if I understand that question, you're really asking, in a big picture, what is NGNP's final goal and what is it supposed to demonstrate?

Question: I am talking about goals of the DOE-sponsored programs from the viewpoint of the future interest and needs of the industry which obviously affect everyone here because the project will be related to those priorities.

Response: I think I can talk to some of that. NGNP is a pilot. As far as industry goes, it's assumed that there is about a 50/50 split in funding and industry will want an operating reactor as part of their 50/50 split. When I talk about industry, I'm really talking about the end user, not necessarily the designer. There are several end users interested at the moment. Process heat is probably at the head of that list, as well as some interest from a variety of folks who would have some kind of a chemical process and hydrogen production integrated in that. By coming to the table and opening a checkbook, I guess, would be the proof that somebody was interested. It is my understanding that industry would be able to dictate, to some extent, what the goals of the reactor would be. They may be able to dictate a change in outlet temperature and whether or not it would be used for process heat, electricity production, etc., but until somebody actually steps up and puts their name on the line, if you will, that final goal is to demonstrate with a pilot plant. I'll show you a couple of reference configurations, if you will, that are adaptable and will be changed depending on who the final end user is but at this point, I can't definitely say who it's going to be and I'm not party to all of those conversations. Does that help?

Question: It does help and I understand that it is difficult to be very specific. At the same time, the industry perspective is very, very tricky. Sometimes, they get excited to say, "We will do it," and sometimes they realize that there's too much risk or they would have to invest too much. To me, it's maximizing the effects of the DOE-sponsored research to set the ground for the industrial venture whenever it's time for it.

Response: It's a good point and it's an ongoing issue. There's some give and take on who gets to decide what and who gets to pay for what.

Question: It seems as though, at least today, I've been noticing your secondary loop, your process heat, is now steam. As of six months ago or a year ago, it seems like we were talking about a secondary helium loop or a secondary liquid metal loop or something but now it seems to be focused on steam. Is that because of input back from the industry that says, "That's what we really want, steam?"

Response: Yes, that is based on input from industry, not just the end users, but also the designers.

Question: With no IE checks, does that increase the interest in steam ingress in accidents?

Response: Absolutely. I should point something out here. This shows a steam generator as the primary heat removal system. This design actually still has a printed circuit heat exchanger as a shutdown cooling system. So, the need to look at printed circuit heat exchangers doesn't go away. It's just going to be a smaller heat exchanger.

Question: I may have missed the point. To what extent did the design of the heat exchanger has already been advanced? Is it still a black box or has a certain design concept already been suggested?

Response: It's not finalized. It is beyond a black box in terms of heat exchanger design. Some of the designs are still intellectual property and that will be an issue. That intellectual property poses a problem in terms of joining processes because, for example, if you're going to…if we're

going to diffusion bond a printed circuit heat exchanger and we don't know all of the parameters, we can't qualify as part of a primary pressure boundary and we're going to have to be able to demonstrate design rules to the ASME and the NRC will have to accept those design rules, that's not a given, so it is an area that has to be explored but it's not just a black box.

Question: Can you expand a little bit on why the designers wanted to go to a water from a gas power conversion system?

Response: I can expand a little bit.

Response: That's fine because I don't understand it at all.

Response: A lot of it is connected with dropping to 750 degrees from 950. The ranking cycle is considerably more efficient at 950 but not necessarily so at 750, so at 750, the efficiencies out of a ranking cycle are 42 or 43 percent.

Question: I just wanted to go back to the NGNP. The primary side, with the thermohydraulics, there's not interest in any work there, is that right?

Response: No, I would not say that. There is a considerable amount of thermohydraulic interest in terms of research. Thermohydraulic modeling is something that Hans Gougar would have talked about, in all likelihood, today. It's kind of a three-pronged approach to modeling—I'm assuming you mean modeling or do you mean demonstrations?

Question: Both actually.

Response: I think thermohydraulics, there's going to be more of an interest inside the pebble bed. In terms of modeling, the approach is going to be that NRC will develop tools, INL R&D will develop tools, and the vendors will develop tools. The vendors want to, for the most part, develop their own tools and so as far as opportunities for the university researchers, that's NGNP R&D and Hans Gougar, I hope, covered some of that. There will be something in the call. It probably won't be in this area.

As far as demonstrations go, NGNP engineering, the labs have some plans to develop single-effects static tests, once-through tests apparatuses, and probably a high-velocity loop that will include some materials testing capability and chemistry control. To the extent that that can be helped or augmented, yeah, we'd be interested in seeing that. That's on or near critical path for the project. So, I know there were some proposals last year, with regard to different, well, some of the loops or apparatuses that I described—and I imagine that there would be some this year—that would be welcomed. I just don't know how that's going to look in the call. The modeling should be part of the R&D. Does that answer your question?

Question: So in terms of this program, in terms of the NEUP program, there's not an immediate…

Response: In the NEUP program, yes, it will be there. In terms of the part that I'm associated with, probably not. All I'm saying is…different session.

Question: I kind of want to go back to the hydrogen. You said that electrolysis is viewed as the first line process with the other ones as back-up processes. So the steam, or going to a steam cycle or a water-working fluid, is for power production or is it for other processes and applications that may not be hydrogen?

Response: Yes.

Question: So getting back to Rich Denning's point, if I remember correctly, with Fort St. Vrain, their biggest safety problem was glass steel leakage from the circulators and secondly concern about leakage from the steam generators. Has there been any consideration given by the designers as to some sort of an advanced, back-up intermediate loop like a molten salt or is that considered too far out and not mainstream enough given the timeline?

Response: In terms of a 750 degree NGNP back-up molten salt, probably not. In terms of consideration for bearings, they're looking at magnetic bearings, catcher bearings; that type of an approach. Steam generators, I think you can safely conclude they're not going to set the steam generator on top of the core but that is going to be a big topic in terms of leakage and how the NRC is going to view that.

Paul Pickard's Presentation

Question: The split-flow compressor, is that to eliminate your thrust?

Response: No. The split-flow is to take advantage of the heat capacities of the fluids. You cannot take all of the fluid down to the supercritical temperature because you don't need that much heat coming back up. So you pick off the amount you need and just go ahead and recompress it without cooling it and then you take the rest of it down.

Comment: You mentioned on your previous slide thrust balancing...that's for the turbine and there you can do a split-flow. I think it would be very simple.

Response: Let me go to the next slide and show you how we've done this, but thrust is an important issue…

Question: Are you looking to essentially eliminate the needs to use a Heatric black box?

Response: The Heatric black box?

Question: If I understand their system, it's essentially a black box. Is one of the possibilities here looking as a way to essentially eliminate the need for that black box?

Response: The PCHE is still the heat exchanger of choice for these applications. It's very high-pressure; it's still the heat exchanger of choice. We, right now, are just using…we send them the specks and they're trying to design it to those specks. So we're using them as a black box in terms of the specks. It would be highly desirable to have an alternative approach for those things.

Question: There are things in the open literature. There have been a number of open literature alternatives and so I'm just curious if that is an open area.

Response: It is an open area. The heat transfer is not mysterious; it's just limited supplies for practical devices.

Question: You had mentioned the printed circuit heat exchangers. That's not for your recuperator, I assume?

Response: Yes, it is.

Question: Have you considered just a rotating ceramic disc?

Response: You know, I have not at this point. As you'll see on one of the lists of research areas, I think innovation alternatives in those areas are highly…there is high interest in that. One of the things that you do have to keep in mind: this is running at pressures that are pretty high. So you have big ΔP across those units and that's important.

Question: From the viewpoint of the scope of this gathering and all the previous presentations, well the words supercritical have never been mentioned. Tell me what would happen if I were to come up with an idea for a proposal that has to do with novel concepts, let's say, at least heat exchangers for supercritical CO_2, not to mention supercritical CO_2 reactor—I mean in this area—how would such an idea be received from the DOE perspective? Your program is very nice; it's been doing very well but it's sort of unique. The question is how popular the idea would be in the broader sense?

Response: If you're asking what kind of a priority this will have compared to all of the other demands of the program, you're going to have to ask DOE or Mike or somebody else here. On the other hand, you know, I think this is, especially with the new directions going to R&D-oriented, additional reactors are back on the table. You heard this morning several comments that the broader spectrum reactors would be considered. So this cross-cutting kind of energy conversion where you can take credit for that in the overall costing and efficiency of the system, it's on the table. I guess I don't know how to tell you how to quantify that but I think it's on the table. Clearly, when we were just looking at the VHTR, I didn't think it's not the near-term option, so it's a longer term option but with the new model, I think it might be a little more important.

Question: (Incomprehensible)

Response: I think from the DOE standpoint, it has grown for the last three years and we're now starting to talk about how you scale this up. The next stage of scaling has to be something more along the lines of 10 MWe and there are a couple of I-NERIs that are addressing potential near-term, not nuclear, but near-term applications where collaborative means of doing that…I guess that's the bottom bullet. We're looking at collaborative programs, in this case an I-NERI with Canada, to look at a nominal 5 to 10 megawatt system.

Comment: In the session we had before this, the first one in the afternoon in the advanced reactor area, we did talk about the importance of the supercritical power conversion system for the fast spectrum reactor effort. One of the big emphasis areas in the fast spectrum reactor activity will be reducing cost of sodium fast reactor, for instance, and the supercritical work would fit really well in that because of its ability to reduce cost for that system. So there are elements within the program that will be very responsive to that.

Question: What is the power density associated with these small volumes and how would transients respond? For examples, if I'm putting out megawatts over small volumes and I get a slight transient, does it just tear the system apart?

Response: You know, we've done the calculations at both the labs and the turbo machinery manufacturer. They're more severe than maybe the high-pressure turbines on a water system but not very much. So, the conclusion is, well, to give you an example, this turbine wheel, when we first run it, we made it out of aluminum because the temperatures were low enough. We have ruined a couple but the design for this is Inconel and we've made those for the 500°C and the calculations say those will be there. It's a pretty impressive set of densities, even for this little system that we're talking about where the unit is just inches in diameter. You're talking about 5 kilograms a second going through that turbine wheel, so it's a lot of momentum and mass going through that and you do have to worry about those things, but things like root stresses in the turbine and things…Inconels do it, so we're not talking about exotic materials, we're talking about super alloys for the turbine wheels.

Question: I was just thinking, for example, for the fluid passing through, and I get some contaminants or such into the system, what impact might that have, in a sense, on the wheels and the rest? I gotta have a very clean fluid, I guess, moving through the system.

Response: I think you're talking about a materials compatibility, materials corrosion?

Question: Or even entrained in the CO_2 in the working fluid as it's passing through the turbines. Small amounts of lubricants or other things or whatever might come out…

Response: I think there is a compatibility issue, but you'd have to have an awful lot of fluid. When you're pushing 5 kilograms of this per second, you've gotta have more than a minor leak to impact the overall conditions of that fluid.

Question: You remember the workshop that we had with RPI and there were some issues raised concerning heat exchangers—what is wanted and what is not? That the question whether understanding the case of heat transfer is important for designing heat exchangers or is it not a big issue because we'll view in a small scale and we'll test everything and then we'll learn enough to convert into a full-scale device. So what is your perspective because this has to do with research? What research issues are most important?

Response: Obviously at our scale, it's not going to be a driver. We can design with some margin and it's a minor…but it's a highly recuperated cycle. Heat exchangers are going to be a big part of the cost this cycle and that's why we're starting to do at least token work on validating the heat transfer and I think innovative approaches or ways to refine our model

accuracy fidelity are important. I think moving forward, they get more important; the bigger we get, the more important they get.

Break-Out Sessions on Spent Nuclear Fuel Disposition, Separations and Waste Forms (FCR&D)

Question: To what extent are the former technology developments for the transformation technology area reviewed or investigated? There is a concern that the gates to reinvestigation of many processes that are probably not worthy of the time/effort will be opened.

Responses: The intent was to look briefly at these technologies to determine if one or more may be viable with changes in the program focus to simplify the processing, look for ways to reduce waste generation, and reduce processing cost. Some of the technologies that were developed may have been discarded/terminated due to political or programmatic decisions rather than technical decisions. This would be an opportunity to give these a second look.

Question: To what extent will the program follow the recommendations of the Nuclear Energy Advisory Committee (NEAC) on program direction and program focus?

Response: This is a good question but one that should probably be answered by the overall program management rather than by this specific area. It is believed that the recommendations of the committee are given due consideration by the program directors and DOE management, and that the committee recommendations will be included in future program direction to the various campaigns.