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TECHNICAL SESSION - TH26

MISSION RELATED RESEARCH PROJECTS: PREPARING FOR FUTURE CHALLENGES

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THURSDAY,

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The Technical Session met via Video-Teleconference, at 10:30 a.m. EST, Ray Furstenau, Office Director, Office of Research, Nuclear Regulatory Commission, presiding.

PRESENT:

RAY FURSTENAU, Session Chair, Office Director, Office of Research, Nuclear Regulatory Commission

MARIA AVRAMOVA, Professor, North Carolina State University

JOSH McLEOD, Undergraduate Research Assistant, Auburn University

DAVID MEDICH, Associate Professor, Worcester Polytechnic Institute

KADIR SENER, Assistant Professor, Auburn University

P R O C E E D I N G S

(10:30 a.m.)

MR. FURSTENAU: Welcome to Technical Session TH26, Mission-Related Research Projects: Preparing for Future Challenges. I am Ray Furstenau, the director of the Office of Nuclear Regulatory Research, and it's certainly my pleasure to share this session and moderate the question and answers. I want to especially thank Nancy Hebron-Isreal and Jinsuo Nie who helped coordinate this and put this session together. And I know it's a lot of work. And, of course, thanks the presenters and the PIs that are part of this session, as well.

I want to just make a few introductory remarks about mission-related R&D here at the grant program here at the NRC. The mission-related R&D grants are part of the University Nuclear Leadership Program. Prior to fiscal year 20, it was called the Intergrade University Program. And then it's about a $16 million grant program. And, traditionally, the NRC used this for fellowships, scholarships, and faculty development grants, which are all good, of course. But in fiscal year 20, we expanded that program or broadened it to support research projects that are problematic mission of the agency.

So in that year, we published a funding opportunity announcement, now it's called a notice of funding opportunity, specifically for mission-related RND projects. And we did that in FY 20 and FY 21 and there's an announcement out now for FY 22. And it turns out these grants, we have overwhelming response to them. We were really pleased with that. They're highly competitive. The first two years, 20 and 21, we received over 200 proposals and were able toward 26.

And these projects are supported under this program really do compliment the research in development that we're doing here at the NRC in our programs. A reminder that the fiscal year 22 funding opportunity is out there right now and it closes on April 5th. So I hope everybody out there, if your universities are listening in, please apply for these grants.

As I mentioned before, the grants compliment out research portfolio, but I think the added benefit to these grants is it directly engages students, university professors, and university programs. And to yield control of it to the agency, that's helpful to us. We really value these projects. And it really also is there to help

develop the next generation of engineers.

The only area where I know we could improve in the grant program is participation of minority-serving institutions. And to encourage greater participation this year, in our notice, we encourage institutions to develop partnerships with MSIs. We continue to evolve our UNLP partnership with DOE and the NNSA to ensure our programs are complimentary and provide coverage for the various technical areas we're all interested in.

All right. With that, next, I'd like to just briefly introduce all of the speakers today, and then we'll get into the presentations and Q's and A's. So the format is I'll introduce the speakers. We'll have presentations from each one of those. After each individual presentation, we'll have a Q and A session. So please submit your questions throughout the session. And then, at the end, we'll all come together with a brief panel discussion.

So, first of all, I just briefly introduce the presenters. Maria Avramova, professor at North Carolina State University. Kadir Sener, an assistant professor from Auburn University. And he'll be accompanied by graduate student Joshua McLeod. And then David Medich. He's associate

professor at Worcester Polytechnic Institute.

So thank you, again, for all the panelists. And we're going to start with you, Maria. Dr. Avramova is a professor of nuclear engineering and university facility scholar at North Carolina State University. She's founder and director of the NCSU consortium for nuclear power and a founder and coordinator of the International User Group of the NCSU advanced nuclear thermal hydraulic code CFD.

Dr. Avramova holds a BS diploma in engineering physics from Sofia University, a St. Clement in Sofia, Bulgaria, and an MS and PhD in nuclear engineering from Penn State. Dr. Avramova has led several high visibility international programs supported by the Nuclear Energy Agency and the Organization for Economic Cooperation and Development, the IAEA, the US NRC, and the OE. Currently, she's co-chair of the NEA OECD expert group on core thermal-hydraulics and mechanics under the working party on scientific issues and uncertainty analysis of the reactor systems of the Nuclear Science Committee.

And so the topic of her presentation's going to be the development of liquid metal fast reactor core thermal-hydraulic benchmarking for

verification validation on certain quantification for a subchannel and CFD codes. So, Maria, I'll turn it over to you. Thank you.

MS. AVRAMOVA: Thank you very much for the nice introduction. First of all, I'd like to let the -- look at my -- sorry. I don't know why you can't see my slides. But I will open --

MR. FURSTENAU: Maria, your slides are up. And, if you just ask, they'll change your slides for you.

MS. AVRAMOVA: That's fine. Sorry about that. So but I would like to thank or acknowledge the work of the team. This is not just a work done by a single person. It's a joint work between North Carolina State University and Texas A&M University. We have Dr. Holler and Mr. Takasugi from NC state; and Dr. Vaghetto and Prof. Yassin Hassan from Texas A&m. Please advance. Next slide, please.

Okay. So this presentation will focus on the research and development project with the work name, as you already heard about it, it's Liquid Metal Fast Reactor Core Thermal-hydraulics Benchmark for the and -- computation of Dynamic Pods. It's funded through the US and university leadership program grant, and is in line with NRC strategy and plan for

advance of non-white worker reactor research. It's intended to help benefit to prepare for upcoming challenges related to validation that calls for new non-white worker reactor pod. And we also hope that will provide the nuclear industry with well-defined international standard problem based on high fidelity resolution data, full validation of such costs.

So we hope to contribute to establishing modeling and simulation tools for licensing and operation of liquid metal fast reactors. Please advance. Next slide, please.

So that's, briefly, the outline of my talk. I will give you an overview of the benchmark. We'll talk about the uncertainty quantification, started electro beam at UNC and then a brief discussion on the importance of the benchmark to further end this manipulation. And then end with conclusions. Let's go to the next slide, please.

So, again, that's a benchmark which will employ a series of poorly-defined problems with complete set of input specifications and the referenced experimental data. It's interesting that we have here data from two different facilities. So we have sixteen around in this facility, Liquid Metal Fast Reactor Core Test Facility of Texas A&M. This

is very recent data, high resolution, high fidelity, very good quality data. And then we will be using another data, legacy data, from past experiments performed a long time ago at Oak Ridge National Lab for thermal-hydraulics reactor safety experiments.

So the first set of data, the Texas A&M data, we have pressure and velosity distribution in a very fine resolution. And for total data, what we have is the data is temperature measurements and pressure drop as well. Next slide, please.

Briefly, again about the benchmark team at Texas A&M and North Carolina State University. It's sponsored by the USNRC, so thank you very much for that. But it's important to mention that it's also endorsed by Nuclear Energy Agency, and they provide supporting activities in terms of establishing benchmark website, email distribution mailing list, coordinating the benchmarks, the workshops, which are outdated benchmark activity, distribution of materials, preparing reports, and so on. We have a website to see the evidence there.

Our benchmarks is also linked to an ongoing benchmark within NEA. That's the Soto Fast Reactor on Uncertainty Analysis in Modeling Benchmark. And it's, I guess, also monitored within

expert in proton reactor thermal-hydraulics and mechanics for NEA. OPICH will help us for the second phase. And you'll see we have our three years. We are just in the beginning of the second year in our update. Next slide, please.

So I'll spend a little bit more time here on this one. And it's a busy one. But I think it's important because the benchmark, as we envision to have it, it's slightly different than the traditional benchmarks that we are used to see. So our goal is not only to just predict the measured value and compare and say, well, look at that. That's just the beginning of the task. But let me first talk about the two phases and the objectives of each phase.

So we have phase 1, which is focused on Texas A&M data, a set of numerical predictions that Texas A&M said were effective. There are three main objectives here. The first one is to provide the high resolution experimental data of isothermal and full and pressure drop. And isothermal is underlined because it's very important meaning one, first to target the fundamentals before moving to hit the conditions and so on. So that's the first objective. And we will use that to assess the performance of numerical schemes and different program modules

currently implemented in CD pods, computational thermodynamic pods.

Commonly, we want to establish best practices for uncertainty pontification of model geometry, we show boundary conditions and their associated uncertainties in this. The calculation in this is the first link to the sodium fast reactor uncertain analysis of modeling benchmark, which is ongoing.

So, now, you probably have noticed that phase 1 is mostly targeting COD pods but general pods can be applied here as well. Then moving target to the second phase. This is on the total data. It's more like integral effective. And we'll have here with our targets of objectives start to provide us certain problem for our sub data base. Now for validation of pods received in subchannel pods. Emphasis on the importance of the uncertainty analysis in this simulation. And, again, we want to establish best practices for quantification of uncertainties propagation. Another link to the ongoing benchmark. Develop guidance for the safety model validation for the start-up reactors and the beta current page model for pressure drop and thermal-dynamics for each pod like subchannel pods.

Finally, develop a hybrid experimental simulation database needed to establish and calibrate the low fidelity core resolution with high resolution, high fidelity data.

So, again, I just want to underline again what are the differences between traditional benchmarks. We are used in two different facilities lots of times, and there may be some issues and without some inconsistency. But we really want to go back in order to try to derive some lessons; how you can use your old legacy data, good data but maybe not well-documented, missing uncertainties, bounds and so on, and compliment it, in some way, with new data, even with numerical data if you wish.

That's the first one. And we are targeting differential investigative pods, POD versus subchannel system can use this benchmark as well. And, the next important part, the subject is really propagation of the uncertainties. It's a very hard topic in the simulations. But they are very little work. There is very little work done on estimating the uncertainties in the models. But they are all based on the data from high fidelity pods being propagated for the low fidelity. And this is something that we want to address. Okay. Let me

move if we are done and go to the next slide because the time is running. Next slide, please.

So I'll start with phase one, then cover the benchmark phases. That's, again, the Texas A&M data. We have sixteen of them. I'm seeing a lot of them bundle, completely isothermal, room temperature. You see the seventh material, it's acrylic plastic, and then you have the cement after working for it. It's in the data that the facility's still in operation. That's very important as well. Next slide, please.

Can you move the next slide very briefly. I'm not spending time here. It's a lot of information and just I want to show it to you to give you an overview of what we have. Most of the dimensions of the main things in this section in nominal conditions. Again, you see it's six to nine bundles. It's almost two meters total length. A very representative geometric proposition for the liquid metal fast reactor bundles. Again, system pressure around, slightly above hundred kilopascals at room temperature. Next slide, please.

What do we have as experimental data for comparison for the benchmark. So we have a pressure drop and high resolution velocity measurements. As

you see the very first slide representation. So the measurement techniques are practical image samples. So we go through the benchmark exercises. So you have the pressure drop on at least one axial and practical image for measurements for vertical and axial plane. And you see a focus on the facility there. So with that, let's move to the next slide, where you'll see all kinds of data we are requesting from the participants.

So, starting from the pressure drop comparison. So you see the dramatical details here and we have similar, or a few, pressure drops with the measurements available. Now I really want to spend more time and focus on the requested data. So, again, look here. We are not requesting only the predicted value of the pressure drop. We also want the participants to provide the uncertainties. They have to put estimates what are the uncertainties coming from that predicted value in order to compare it to measured values with its uncertainties. And then, similarly, for the velocity. Please move to the next slide.

Similarly, for the velocities. Again, we have, again, a very good, high resolution velocity measurements here for different Reynolds number.

Velocity data measuring fully developed region between the pressure drops. And, again, what we all request is velocity prediction plus uncertainties. I will talk about what types of uncertainties are being propagated, or you ask participants to propagate when providing the applicants uncertainties of their created velocity solution. So let's move forward to the next slide where we have the model where we moved to the second phase.

This is the integral effect comparison to internal effect. So, we have a different story here. It's a legacy data. As you can see, the experiments were performed in 1970s, '80s. On the next slide, we will see the whole set of available data. And there are no targeting through the whole database here. It's not needed. Our range, we selected part of the database, those are bundles 6, 8, and 9. You will see the specification on the next slide.

The good things about 3C and 6A, those are public. The data is publically available. 3C involves state to state reactor, sorry, and transient conditions. 6A is national circulation and boiling, it's really interesting. And then 9 is the one, which, bundle 9 is the one which -- it corresponds almost to the Texas A&M data. And above there, we

have state to state and transient data available. Let's look at the table on the next slide.

So lots of data is, of course, experimental. Something given here. Again, we have a different number of pills in the bundles, brokerage, configurations simulated and so on. We, once again, we are perfecting the last three, six days, 3C, 8 and 9, for all of our benchmark exercises. Let's move to the next one.

So total data is, again, and all data, it's not digitalized. The first thing that the benchmark is facing that is a challenge is data recovery. We have to put it in a nice, digitalized format for the benchmark. Again, most of the reporters still export control. But, again, we won't need everything out from the data for good benchmark activities. And we are working within the Gateway of Advanced Innovation and Nuclear Office. They are assisting us with, to address a part of the bundle 9, which will be with us in the benchmark exercise. Again for bundles 6A and 3C data, the data is publically available. Okay. I think I'm maybe running out of time, so let's move to the next slide, please.

Our total uncertainty quantifications.

So, again, we want the participants to propagate the uncertainties. They can propagate input uncertainties and provide the output predicted value without the consultants. So the effect is to depropagate it and put boundary conditions may attach intolerances. For the Texas A&M data we have defined pressure drop in the most measurement uncertainties for comparison. And we have the temperature uncertainties for the first data.

So we are giving the participants the freedom to choose their own variable based on uncertain participation methods. Copy the tools and the purpose is encouraged and possible. And this is what the benchmark is actually doing to get the proper report to propagate the uncertainties. Next slide, please.

Very quickly, where we are. So, I will not go through this slide. The benchmark is open-minded somehow. So we are replacing output for a measured data plus uncertainties. But, as we see need for adding additional information back in, that can be done as well. So we do not want to limit ourselves to a particular output format. And also we are being kind of independent reference calculations in both CTF subchannel and CID SAC, we

are the participant like that. Next slide, please.

I have my final slides to kind of conclude on the benchmarks. So also the contributions again, to summarize briefly. It will provide records for database for high resolution model validation, emphasis on uncertainties propagation, how to address these issues. We want to develop variance for high profile propagation and even moderate validation inputting the uncertainties as well. And we really aim to develop a high-quality experimental simulation database necessary for the validation. Next slide, please.

And where we are with the status very briefly. So the specification for phase 1 is already released. By the end of this month, they will release specification on phase 2. That's done for the NEA and agency. We had our third benchmark workshop this past June. It was virtual. The next one is coming end of May, beginning of June, and it's going to be hosted by CA France. And also deliverable, we've had, of course, some benchmark specification results, reports, and so on. And I really want to conclude with the last slide, just briefly, to summarize what the benchmark is. So if you go to the last slides, it's the conclusion. Next slide, please.

So, again, the benchmark intention is to serve and address the modeling challenges by assembling teams of expert research. It's very important to not be isolated from the rest of the world. We have to work with experts from around the world. So right now, for example, we have participants from Europe, US, and Asia in that benchmark.

But, again, the focus is not on comparison to experimental data but addressing issues of the propagation of uncertainties and uncertainties in the predictions as well and developing address guidelines. We hope that we will be able to assist USNRC, our sponsor, and industry for upcoming challenges, especially related to modeling, design, and licensing of new reactor, particularly liquid metal fast reactors. The very last slide that I have in the presentation are just the references.

Thank you very much for your attention. And I am open for questions.

MR. FURSTENAU: Thank you, Maria. This was really, very interesting. It looks like you and your team's made a lot of progress since the award was made. Yours was in the first group of awards. So I really enjoyed that. And I really like how

you've brought in a lot of participants in this. I imagine it's a logistical nightmare to get everybody together. And I also wanted to comment on the data recovery that you're doing with Department of Energy through GAIN. I really encourage that. There's a lot of data out there. Don't give up on trying to get it. It's there. It just may take some time.

MS. AVRAMOVA: Thanks.

MR. FURSTENAU: Yeah. Good. Good. You did mention, on the benchmark, participants are, they're encouraged to use the best uncertainty quantification methods that are available to them. When you have multiple participants like this that contribute their results to the benchmark system you're developing, obviously there'll be differences between the results. Could you comment on how you plan to treat those differences in the overall understanding of uncertainties in the current capabilities of modeling the thermal-hydraulics phenomenon in the LMFR cores?

MS. AVRAMOVA: Yeah. That's actually a very good question. And we do have some experience here because I personally was involved in other benchmarks from the pressurized water reactor, various water reactors. But, important part is when,

in my understanding, is when asked for participants to submit the results, you have to ask them to submit answers to questionnaires where it's a really detailed questionnaire. It's where the participants should describe what are the numerical methods, totalization, assumptions, everything to go to the simulations because at the end, we will be comparing different pods, different ability, different resolutions.

You may have user effects when you ask different users to use the same pod but apply different assumptions. You have different modeling fidelity pods, pods here, or even using different models to predict the same phenomena. So asking for uncertainty of the predictions and compare those to uncertainties in the measurement. That's one thing. But we want to somehow, systematically define different cross steps of predictive data and see how to address the uncertainty in that.

And let's say the -- one cost could be that, a subchannel pods using subchannel costs using that normalization. Or one subchannel thought based by different participants with different assumptions. And so on. That's very important, just to see where the problems could be coming, what are the dots we

have to have a systematic basis for comparison of the predicted result and uncertainties. When I say predicted results, I include the uncertainties there as well.

So, of course, within each cluster or predication available, for every participant, you can regulate the common things like through mean error and standard deviation based on the difference between the mean calculated conversion and surround that. It is important to compare apples to apples. Let's put it in this way. So this is why we are asking for the very detailed questionnaire and supplying that questionnaire and asking for participants to submit that. I don't know if I answered your question.

MR. FURSTENAU: Yeah. Yeah. That did. That was very good, Maria. I'm sorry we don't have any more time for questions right now. But thank you very much, Maria. We very appreciate it. Thanks for what you're doing on this NRC-sponsored project.

Next, we'll go to a presentation by Auburn University, Dr. Kadir Sener. He's an assistant professor in the civil engineering department at Auburn since 2019. Dr. Sener has been actively involved in numerous research projects

pertaining to nuclear structural engineering that were funded by both public and private agencies.

Prior to joining Auburn University, he devoted much of his time into research on testing analysis and development of design specifications for steel plate concrete composite structures for use in Gen 3+ nuclear power plants such as the AP 1000 and the US APWR. He subsequently was the lead research engineer in a project funded by the US DOE to investigate the in-plane and out-of-plane sheer behavior of both steel plate concrete and reinforced concrete structures.

These projects involved large-scale experimental investigations and advanced computational studies of RC and SC structures to understand their fundamental behavior under extreme loading conditions, such as seismic events, that involved operational and accidental thermal conditions. The outcomes of these research projects have been incorporated into the code specifications that govern the design and construction of steel concrete composite structures for safety-related nuclear facilities and used extensively around the world by engineers, consultants, and regulators.

Dr. Sener has also participated in a

research project funded through the US DOE through the ARPA-E program where the project focused on investigating different concrete technologies for deployment and stable salts. His current research interests include investigating topics that will enable the widespread implementation of next-generation nuclear power plants and small modular reactors, including seismic, thermal, and soil structure interaction behavior.

And, with Dr. Sener is Joshua McLeod, who is also working on this project. So I believe you guys will be tag-teaming on the presentation. And the topic is development of a soil-structure interaction framework in support, to enhance regulatory oversight of small modular reactors. So, Dr. Sener, I'll turn it over to you.

MR. SENER: Thank you very much, Ray. Despite being the least experienced among the speakers today, I seem to have the longest introduction. I should have cut that short.

But greetings to all the attendees. Again, this is Kadir Sener, System Professor at Auburn. And I'm going to talk about a research project that we recently started working on, that was funded in FY 21.

And again, the title is same as our project, as development of a Soil Structure Interaction Framework in Support to Enhance Regulatory Oversight for Small Modular Reactors.

And I should mention that during my talk I will interchangeably use acronyms. Mainly use SSI for Soil Structure Interaction, and SMR for referring to Small Modular Reactors, which most of the audience will be familiar with that.

So, since we recently began working on this research, in this presentation I'll just give a broad overview of the project, and highlight some of the important aspects. But hopefully next year we'll show some research results.

So, the project team include myself and Dr. Jack Montgomery at Auburn University. And we have Professor Amit Varma at Purdue University as a Co-PI. As mentioned and also shown on the slide we have two students working on this project, Brian Hurley and Josh McLeod.

And Josh, again, will actually present a couple of slides during this presentation. So, you'll soon hear from him. Go to next slide, please.

So, I'll start with highlighting some important structural attributes of SMI designs that

are currently under development. And when we do the survey of general structure layouts of SMR from publicly available documents we notice that a common feature of these structures was the partial embedment of critical compartments below ground level. And this was regardless of the vendor.

You'll see some examples on the slide where we have various SMR designs from several different vendors. And it's a common feature to have partial buriance, a partially buried structure, by typically placing the reactor compartment below ground level.

And this partial burial feature of SMRs is desirable because it adds an additional layer of safety against natural or manmade external hazards. And also potentially minimizes the effects of internal hazards, by limiting the exposure of contaminants or extreme heat during an accident scenario, due to these critical compartments not directly, not being directly exposed to the environment. Next slide, please.

So, the partial burial of these compartments is advantageous. But at the same time this burial leads to uncertainties in the seismic behavior of SMRs, as the dynamic response will

largely depend on the soil structure interaction behavior.

So, understanding the rocking, gapping, sliding behavior, and accurately incorporating these into our models to assess the dynamic response becomes even more critical for these structures.

Since SSI effects are less critical for survey sectors, most modeling evaluations of these evolve around strategies, typically disregard the nonlinear, so contact and interface behavior.

And obviously there's a lack of large scale experimental data for validating these models. And therefore, our main motivation is to fill this gap through conducting large scale experimental studies, and developing advanced numerical simulations that are validating, validated against reliable test data. Next slide, please.

So, our overarching goal is to support regulators in assessing new generation power plants with the specific objective of our research all developing a framework to analyze and evaluate the seismic response of SMRs while accounting for the unique structural attributes and nonlinear soil structure interaction.

So, we identified two major research

trusts to accomplish the objective. First addressing the need for large scale experimental research to clearly understand and characterize the SSI behavior.

And secondly, developing numerical modeling methodologies, validating against the physical data generated during the experiments, which can then be used for modeling and evaluating SMRs for nuclear facilities with similar structural attribute. Next slide, please.

To accomplish these objectives we have three major phases in our research. So, the first phase we will conduct large scale SSI experiments on partially buried caissons to generate reliable test data for validation.

Once we have the experimental results, in the second phase we will develop experimentally validated numerical finite element models. These models will be based on time domain rather than frequency domain methods, since we know that the frequency domain modeling tool, despite being the industry standard for SSI evaluations, they have several limitations in terms of accounting for nonlinear interface behavior. And also requiring separate models than structural models, which is an additional effort.

And then in the last and third phase we plan to validate the small developed modeling approach against actual field data from past events. And also perform comparative studies against frequency domain analysis methods to highlight the differences.

So, next we'll give more detail about the phase. And now Josh will take over the talk about the, to talk about what we plan to do in the experimental phase. And then, Josh is obviously a future engineer that we're training through this research program. So, please go ahead, Josh.

MR. MCLEOD: Thank you, Dr. Sener. Next slide, please. So, as mentioned the first phase of this project we'll be conducting a large scale SSI test, generate some experimental data to validate our numerical simulations.

The test will be conducted in our newly opened advanced structural engineering laboratory. And we use a very unique feature of our lab. As you see in the pictures on the slide we have a geotechnical testing chamber that is built into our strong floor that is 20 foot in depth, and 24 by 10 foot in plan, which will allow us to conduct these soil structure interaction tests.

Having the geotechnical chamber built into our strong floor allows us to apply large loads as well as dynamic loads. The structures that are inside the chamber when it's filled with soil.

With this unique feature of the laboratory we can conduct tests where we closely control the physical property of the soil, particularly the density and saturation levels. Large scale tests will allow our results to be more representative of realistic field conditions. Next slide, please.

We plan to have several testing parameters in our experimental program. On this slide you can see a schematic of our planned SSI experiment layout, where we're going to apply loading on a caisson located in the center of our geotechnical testing chamber.

We're planning on the caisson to be as large as possible, while still maintaining enough distance from the boundaries to allow potential failure modes to occur.

Some of the parameters we'll examine in these experiments are caisson shape, including circular and cuboid shapes, different surface material such as steel, concrete, or a geosynthetic

liner, and different caisson burial depths.

In terms of soil properties we'll be using a granular backfill. We're planning to look at two different levels to examine soil density and different saturation levels.

The loading types we look at initially are quasi-static loads. The plan with increasing amplitudes at low frequencies. Of all these low frequency cycles we plan to apply sinusoidal harmonic motions of gradually increasing amplitudes and frequencies until we reach the limits of the hydraulics in our laboratory.

The following loading phases we plan to move towards more realistic loading speeds that will represent the response of structures to ground motion expected in eastern and western United States.

We also plan to repeat some of these tests at different surcharge load in the soil to account for different levels of overburdened pressure that would be applied by the main structure. Next slide, please.

During these tests we plan to record and monitor response to soil and the structure using various sensors, including displacement, rotation, acceleration, and pressure sensors.

Displacement sensors and inclinometers will be placed on the caisson to obtain the force displacement and the moment rocking angle response of the caisson.

Vertical displacement sensors will report transient and permanent settlements of the caisson in the soil surface.

Accelerometers will be placed in the soil and on the caisson to measure accelerations. And core pressure sensors in the soil and at the interface will monitor fluid pressures in the saturated tests.

Surface pressure sensors on the caisson will be used to measure dynamic pressure and to report gap formation. We're also going to take samples of the soil near the caisson after testing to evaluate any particle crushing at the interface that may occur.

Entering these results will allow us to determine the dynamic capacity of soil structure systems, which can be compared with static interface strings and existing analytical models for SSI behavior of caissons.

Next, Dr. Sener will take over again to discuss the numerical phase of the project.

MR. SENER: That was great. Thank you

very much, Josh. Can you proceed with the next slide, please?

Great. So, as Josh talked about, Phase 1, which is the experimental phase, and I'll continue talking about the upcoming phases, or the following Phases 2 and 3. And for Phase 1 the experimental phase is completed.

We'll at once start working on developing benchmark numerical models using time domain finite element software, and validate them against the test data.

So, the models will use nonlinear constitute material models, and nonlinear interfacial models. The experiment again will incorporate several plasticity parameters for detailed definition. And interfaced models will have features to capture the behavior in both, in normal and tangential directions.

We plan to use one or more of the software listed in the slide. And depending on the finite elements and material model capabilities, as we have seen similar studies performed by other researcher have indicated that either Abaqus, or LS-Dyna, or MASTODON is capable of capturing the behavior that will be observed during our tests.

So, finite element models will include significant detail regarding the tests at caisson. Test chamber boundaries, and incorporate measures and dynamic properties of the soil.

Comparisons will be made against the hysteretic and backbone curve of the measured mode displacement or normal rotation responses. And we will do qualitative and quantitative comparisons using the various pressure measurements that we obtained during the test against the analysis results. Next slide, please.

So, once we complete that we're in the final phase of our project where we plan to use our developed benchmark numerical modeling approach. And from that a comparative numerical study of a real seismic event on a large scale structure.

For this study we chose to conduct an exploratory study on the Fukushima Daiichi Nuclear Power Plant using the available soil profile and ground motion recorded during the major event that took place in 2011.

The developed modeling methodologies will be implemented to build models and compare against the structural response measures on the plant. Comparative studies against frequency based,

frequency domain based linear analysis again are the current industry standard for the analysis type used in SSI evaluations.

We'll do comparisons against that, and point out the key differences in the performance of each approach, and highlight any shortcomings or limitations of each SSI approach. Next slide, please.

So, here's a timeline of our project. We expect that the experimental phase will take the longest by about a year and a half, and be the most critical test in our belt.

We plan to start the benchmarking FE model development as soon as we start having some experimental results, and continue with the following computations phases.

We're obviously in the experimental phase, and hoping to provide results at the next regulatory conference. Next slide, please.

So with that, that's all we wanted to present in this session. And again, we're grateful for the generous support of the NRC. And looking forward to presenting our results in the upcoming conferences. So, thank you very much for your attention.

MR. FURSTENAU: Thank you very much to both of you, Kadir and Josh. We do have time for some questions. So, let me get started.

First of all, the geotechnical chamber I think, Josh, that you talked about. That's, it's really pretty impressive, the size of that. I guess, I think it was like 24 by 10 by 20. So, I don't know how you're going to unload it once you get the soil in there. But anyway, that's for you guys to figure it out.

But how would you, how do you plan to apply the insights from your experiments to real constructions, where the structures are embedded, and buried in soils that don't have the finite boundary?

Is it part of your, you talk about the sensitivity studies on the finite element models. Where do you compensate for that from the limitations of a, even though it's a large structure, a large experimental structure, how do you compensate for the, for predicting the real life situation?

MR. SENER: That's an excellent question. And that's one thing we also have been considering when we were trying to come up with the caisson size. As we're currently targeting a meter, so which is three to four feet in plan.

And when we were trying to come up with that size we were looking at the distance from the boundaries, so that the boundary does not really suppress any of the failure modes that we might incur with, when doing the testing.

So, although we're trying to have, come up with a caisson as large as possible, so it's a best representative of a actual structure, obviously we have limitations and we don't want to be too close to the boundaries.

So, we have about twice the size of the caisson on either side so that it has minimal effect on the results. And then in these sensitivity studies we'll obviously take into account both the boundaries of the chamber, and really observe just what kind of effect the boundaries will have on the results.

But so, at the same time you want to minimize it we still want a large caisson as possible. And then look at the influence of the boundaries to, in our numerical models. And hopefully they'll be minimal.

MR. FURSTENAU: Okay. Thank you very much. Okay, the next question. In your large scale testing, how do you consider the scaling effects in

the cyclic clone testing, such as the density of the materials?

MR. SENER: Scale effects in the sense that we will use just regular soil in it. So, there is no scaling in the soil size. And like I mentioned, these are not really simulating a full scale structure, right.

So, our main intention actually through these tests is to obtain that interfacial response between whatever method you'll be using, whether it's steel caisson, concrete caisson, or some geosynthetic. And then look at the pressure in the large scale test.

So, it's not like these will be directly used for an actual structure. But in a sense that will, these will become the properties that we use in the interface.

So hopefully with the, you know, large sizes that we have, we hope to have minimal scaling effect between what we measured in the test versus what's done, what we would use in the models for the large scale test.

Because the alternator for these tests was centrifuged tests, which are significantly scaled when doing these type of experiments exercise

studies. So, at least we're getting much closer to reality, as opposed to those very small scale centrifuge tests that are commonly done in research.

MR. FURSTENAU: Okay. Thank you. One last question, Kadir. A substantial amount of excavation soil replacement and soil compaction were done for the Vogtle 2 and 4 project to address liquefaction. How applicable is that information for the work that you're doing in this project?

MR. SENER: So, part of the specimen test matrix that Josh mentioned had a parameter in saturation. Although, though we can control the water level in our soil. But we will most likely not consider liquefaction as a main parameter.

As mentioned, you know, these structures when, and be aware when they're built they'll be, large excavations will take place. And then the soil will be compacted, the granular backfill.

So, the density levels we expect are in the high range, sort of in the 80 to 90 percent relative densities. So, that's what we're mainly going to target.

And maybe that's a great follow-up project, to look at liquefaction effects. But currently we're going to address more of the common

cases. And then for special cases I'm sure that would be a good next project.

MR. FURSTENAU: Well, that's all the time we have for questions. Thanks to you, Dr. Sener and Josh. Now we will look forward to updates as this project gets going. So, thank you very much.

MR. SENER: Thank you.

MR. FURSTENAU: Our next discussion will be from David Medich. He's Associate Professor at Worcester Polytechnic Institute. And Dr. Medich received his PhD in physics, studying nuclear and radiological sciences at the University of Massachusetts Lowell, 1997.

During this time he was a senior reactor operator, and then the chief reactor operator for the UMass Lowell 1 megawatt research reactor. After receiving his PhD, Dr. Medich spent an additional year as acting director of the UML Research Reactor.

And he says he's still tickled pink about thinking about the time he ordered and received a shipment of new HEU fuel. And supposedly there's a picture of you holding one of the fuel elements. So, we'll have to see that sometime.

So, Dr. Medich then became a post-doctoral researcher at University of Virginia. He

was a senior scientist at Implant Sciences Corporation, the director of the University of Massachusetts Lowell Radiation Safety and Materials program, and was ultimately appointed as an assistant professor at WPI in 2012, where he helped develop a new nuclear science and engineering program. He was promoted to an associate professor and granted tenure in 2016.

Dr. Medich has been a qualified expert consultant for the IAEA, and is presently the Vice Chair of the ISO Radiation Protection Committee, on the Editorial Board of the Health Physics Journal, and is the Chair of the Operational and Medical Health Physics section of ANSI N13.

He also is on the Executive Board of the American Board of Health Physics, and the author of more than 30 published journal articles. His personal mantra is that it is all about the neutrons. That's a good personal mantra. I like that.

So with that, I'll turn it over to you, David. Thanks.

MR. MEDICH: Thank you very much. And it's a pleasure being here. The purpose of my research is to adopt a Gen 4 microreactor, which is something right now that's being developed for use as

a next generation source of university research reactor.

And being that it's a next source university research reactor we're also looking at kind of advancing what research reactors do, and operating this reactor as more of a hybrid model, where it's not only producing neutrons for research, but it's also going to produce electricity for the campus. And I'll talk about how we can envision that. Next slide, please.

So, based on what I've seen for the topics given at this conference it seems, you know, everyone here probably has a very broad understanding of power reactors, probably much better than I do from my physics background. But maybe not as much for research reactors, since I didn't see too many topics here.

So, I just wanted to kind of remind you, or just go through the basics of the status of nuclear research reactors in the United States right now. So, nuclear reactors are non-power reactors. And they're purpose is to be used for training and development purposes. Next slide.

When we look at these U.S. university research reactors we see that they operate between

about zero to ten megawatts thermal. They were developed initially primarily to study reactor operations, and provide greater insight into nuclear physics and engineering, you know, especially things like cross sectional tables, which we now pretty much take for granted or, you know, half of them were probably obtained from research reactors.

Now, as these research reactors started becoming more mature then they really started to be noticed that their neutrons were a very, very good tool for research in other fields, such as chemistry, biology, engineering, medicine, geology, et cetera.

But here's the thing. These fields, these research fields often times need high intensity neutron sources. And when I talk about neutron intensity, I'll talk about either engineering flux or science fluence rate, which is neutrons per square centimeter per second.

And you're going to get these high intensity neutron sources from research reactors that all say operate at about 5 megawatts thermal or more. Next slide, please.

Okay. So, to date the university, the U.S. has built 59 research reactors. Of those 59 research reactors 25 remain in operation. The

question is why? What are the limits of university research reactors? And this is what I want to focus on.

All university research reactors are based on designs made in the '50s, and maybe into the '60s. They all began operating between the period of 1955 to 1975.

And just because I want to make sure I keep my time commitment I'm going just going to kind of gloss over this, these next two areas, and say that now that university research reactors are becoming more and more of a source of neutrons for research.

I will say that there's only two university research reactors right now that actually can meet all current research needs. And that's the MIT reactor and MURR. MIT runs at about 6 megawatts. MURR runs about 10 megawatts.

And really what this causes is a huge limit to scientific research, a huge bottleneck. There are plenty of examples. But for example, one of my areas of research that I've recently gotten into is neutron radiography of plant roots, potted plant roots.

And when I first got into that area of

research, you know, I did my due diligence. And I was looking at what is the state of the art, you know, through all these review articles?

And half of the review articles I looked at would talk about, you know, in one sentence they would say, we have neutrons that they actually have a higher contrast between the different tissues. And they have higher resolution. But it's impossible to get neutron beam time.

So, and it's true. I mean, you're often times making beam time six months in advance. So, you know, because of that they said, this is not a great opportunity.

The other half of those review papers didn't even mention neutrons at all, just because so few people could use them, because they're not easy to use. Next slide, please.

So, what does it mean? Our reactors, our research reactors are roughly 50 to 60 years old. And the vast majority, I would say 23 out of 25 U.S. research reactors can be considered under powered.

I did work at the UMass Lowell reactor. And I know all the different things that our 1 megawatt reactor, when I was working there, what our 1 megawatt reactor couldn't do in terms of research,

brachytherapy, nuclear medicine, small angle neutron scattering, the list goes on. So, next slide, please.

Okay. Concurrent with that problem is another issue that's going around in the United States right now. And that is universities are really pushing to become more sustainable and reduce their carbon emissions. And it's all about, you know, can a university become carbon neutral?

This was the easiest slide to make in my whole slide deck. Because it took me all of about two minutes to get these topics. On the left it's, my screen is a little blurry in terms of the slide.

But on the left I just did a symbol Bing search, where I looked at university sustainability. And I got page, after page, after page of all the different universities and their sustainability programs.

And on the middle and on the right I looked at the news. And I was able to get from pretty high profile university websites talking about university actions and the like, all talking about how campuses are going green, or should go green, or et cetera, et cetera. So, next slide, please.

So, you take those issues, and you bring

them together. And what I think is that a nuclear microreactor might be the best option for replacing these research reactors originally designed in the '50s. And I'll quickly remind, or I'll quickly summarize some of these things about a nuclear microreactor.

So, a nuclear microreactor is a type of Gen IV reactor currently being developed. They aren't being built right now. But they are in the development stage.

And the idea of a microreactor is they're small. So, when we talk about their power, you know, we've talked about in previous talks small modular research, or excuse me, small modular reactors. Microreactors have a lower power than these SMRs, typically around 20 megawatts or less. Next slide, please.

Okay. So specifically, what is a microreactor? First, it's output is going to be low. So, this slide, which is nice and citable, and it has nice graphics. I decided to keep it. It says that an output is usually less than 50 megawatts electric.

Often times you do a search on the internet, you look at publications, they'll talk about 20 megawatts electric. So, you know, you can

go somewhere between that, and you can compare that to a current power plant, which is on the order of 1,000 megawatts electric.

So, you know, again, you're looking at something that's maybe 50 to 100 times, even 1,000 times if they're operating a megawatt lower in power than current power reactors. Next slide.

They're also designed to be modular. And of course as, you know, we've seen with TVs the whole goal of a modular design is that, yes, in the beginning --

First off, it's actually safer to produce a modular design, rather than having a completely new structure every time you go to a different facility. But, and easier to construct. But over time you see modular designs have marked decrease in prices.

And again, if you look at your TVs you can talk about what happened when HDR, yes, HDR TVs came out. They were very expensive. Then as the science became, and the engineering became standard then the prices went down, and yada yada.

So, you know, modular, these modular designs really can have longer term effects for the viability of all these next gen reactors. Next slide.

The thing that really got me going, and this was really the first, my first introduction to a microreactor, is that these microreactors not only be small in power, but these microreactors were being designed for use in places like, you know, places that are off the grid essentially, they're remote.

Or they could be used for military deployment sites. Or they could be used, you know, the thoughts, they could be used to help out regions that are overcoming a natural disaster.

So, they have to be transportable. And with a microreactor the idea is, the microreactor has to fit on the bed of a truck. All right. So, within a truck.

And that includes the part of the microreactor that generates electricity. So, the entire system can fit on a truck bed, which is amazing. Next slide, please.

The other thing about these Gen IV reactors are that they have to be inherently safer than the Gen 2 reactors of the past that are currently being run.

And so, what happens is, you know, you'll have your, for example, negative temperature co-efficient where, you know, you'll inhibit the reactor

from having a positive temperature co-efficient.

As it gets hotter it gets more efficient to producing neutrons, which makes it hotter, et cetera, et cetera. You lead to a Chernobyl incident. Okay. You won't get that with current Gen 2 reactors in the United States. So, that's the safety, a passive safety system.

But one active safety system with current reactors is you have to have someone there to ensure that, for example if the reactor is shut down that the reactor is being cooled, right, that there's water in the reactor vessel to make sure that you can remove that decayed heat.

Now, and of course that was the issue with Three Mile Island, right. So, with these next generation reactors the idea is to keep all of these safety systems passive, including the need for having someone intervene to ensure that there is appropriate decayed heat removal during a shut down.

And so, they do that in many ways. There's new types of fuel that has much higher melting point. Like for example, tri-cell fuel. And a lot of place are looking at things, like for example nuclear grade graphite as a moderator.

So, what it means is these huge reactor

control rooms of the past, let's go to the next slide, will not be needed. And so, when I talk to, for example our colleagues, we're working with Westinghouse, their eVinci reactor, as I'll mention slowly, shortly.

Really these microreactors are meant to be, you know, seeing, being that they're supposed to be employed in these places that may not have a lot of people that can take the time to constantly be ensuring that the reactor is operating safely. Because they have these passive safety systems you don't need these huge control rooms.

And, you know, when I talk to the people at Westinghouse the comment was, yes, you know, these reactors can be run off of a laptop. So, it's kind of of an interesting and different paradigm. Next slide, please.

Okay. So, putting all these things together, what are the advantages of using a microreactor as the basis of a next gen university research reactor?

First off, these microreactors are going to be operating at equivalent thermal powers to a lot of these high demand university research reactors. So, for example if you're talking about a reactor,

the one we're working on is a 5 megawatt electric.

So, 5 megawatt electric means you're probably going to be producing about 5 megawatts thermal power. And that puts that reactor, or at least the one we're investigating, that puts it a little above the MURR reactor, the 10 megawatt MURR reactor, and a little below the 20 megawatt NIST reactor, both of them research reactors.

So, that's really good. You now have a way to inexpensively hopefully and quickly be able to perform a lot of this research which is now bottlenecked.

So, next interestingly enough, these microreactors can meet most university's power needs, as we're going to show, at least in the case of WPI. And of course meet those university carbon reduction goals.

And so, you know, where universities now are giving these 50 year plans for being carbon neutral, which quite honestly if you can't do it in three I'm not sure, you know, what they're assuming to, you know, become carbon neutral in 53, 50 years from now, other than making some really difficult and possibly not very accurate assumptions on what they think the world is going to be 50 years from now.

Now, you know, you can have an immediate huge impact on university carbon reduction goals. Of course, because they're modular they can be stationed at a university fairly quickly and economically.

And last, and this is just a side thing. We've had university research reactors operating in the United States for over 50 years. And these research reactors, there haven't been any major safety issues that we can point to, you know, such as with power reactors.

And they're in major cities, Cambridge, you know, and all sorts of other big cities. And so, really right off the back this is a good way to promote public support for next gen reactors.

Because we're going to say, okay, well, you know, here we have these research reactors that already have been operated safely. But now we're having this next generation research reactors. And, you know, now we want to use them to not only be built, but also to enhance fields like --

You know, no one could argue that you can't be doing a good thing if you're making medicine that's used to treat cancer or, you know, diagnostic equipment that's used to detect disease, you know. These things are like, oh, that's really great. So,

next slide.

So, you take these four items, next slide, you add them together, and you get happy graduate students. And actually, you really get a happy public. But for me, as long as I have happy graduate students my life is easier. When my graduate students are happy that's, you know, kind of a miserable time for me. So, next slide, please.

All right. So, as I mentioned we're using the Westinghouse eVinci microreactor as our basis for our advanced or next gen research reactor. The eVinci is a very high temperature reactor. It's designs were just finalized.

We are also a second generation recipient of the research proposal, of the NRC research grant. So, we're still kind of in the early phases of our project.

And not only that, but as I mentioned Westinghouse just designed and finalized their design in the fall. So now we're kind of really up and going, and trying to start development on our project.

It uses a solid core and advanced heat pipe technology. And this is another advantage. Because you want a compact microreactor what's going

to happen is, when we developed these original reactors the whole idea was, you know, we're not going to be worrying about anything like optimizing neutron flux. You just wanted to get to see, you wanted to see how reactors operate.

So, long story short, because these microreactors are being built with more compact cores, you know, because you really want them easily transportable, then what's going to happen is, at the same power level as let's say a current research reactor that may be more distributed, you'll be producing the same number of neutrons roughly between the two reactors.

But because the microreactor has a more compact core that will mean a more intense neutron source. So, right off the bat you're operating at the same energy, let's say, and you're getting an enhancement in terms of your neutron intensity, which is the key to all these research projects. So, it will really help with research.

Power output of the eVinci is up to 5 megawatts. It's planned for a 40 year design life, with three year refueling. Targeting less than 30 day onsite installation. And that's typical for all these microreactors.

So that means, you know, everything from soup to nuts. Once the reactor goes on site that within 30 days it's producing electricity and sending out electricity to the region.

It is, as other microreactors being designed, to be operated autonomously. And it, as a very high temperature reactor it's also able to provide heated water for building heating, and super-heated water for desalinization and hydrogen generation.

And with the hydrogen generation I can see this as another advantage for universities that might need hydrogen for their research. Next slide.

Okay. So, the question is, can eVinci meet WPI's energy needs? In 2020 WPI produced about 25 million kilowatt hours, or used 25 million kilowatt hours of electricity.

So, if you do the math that turns out to an average amount of electricity at any point in time during the year of 2.8 megawatts, which is well within eVinci's 5 megawatt power capabilities.

And according to our facilities director during that year our peak electrical energy was 4.1 megawatts electric. So actually, the eVinci seems to be able to meet all of the power requirements for

WPI, based on our 2020 numbers.

And I will say, based on our 2020 numbers because we did do, we just built a new building on site. So, they're going to change a little bit. Next slide, please.

Now, from all our campus activities in 2020 again we generated about 15,000 metric tons of greenhouse gasses. Next slide, please. And those greenhouse gasses the EPA can divide them into two types, Scope 1 and Scope 2 emissions.

Scope 1 emissions are due to things that happen on site that produced greenhouse gasses. Scope 2 emissions are due to us using electricity, which further away causes the power source to generate carbon gasses. So actually, if you look --

First off, as I've already mentioned, we cannot only meet the electrical needs, the Scope 2 needs for electricity on campus, we can probably exceed them, which would put us in kind of a Scope, or in, you know, potential for a negative carbon impact.

And this is unfortunately blue. I pulled it off a report from WPI. Our Scope 1 emissions, 90 percent of it if not more is all from burning natural gas to heat water.

So, you know, also being able to use water to heat some of the buildings at WPI will have a big impact on those emissions. So yes, this could really impact greatly the amount of carbon that we produce per year on campus. Next slide.

So, the main aspect of our research, and again, we really haven't been able to advance too far on this because we're still in the version of designing a Monte Carlo model for the eVinci reactor.

But we will be designing an MCMP model for the eVinci reactor. We're right in the middle of it. And then once we do that we're going to use the model to determine the shielding needs of the reactor. And that's going to be our base for generating our research reactor.

And once we do that we're going to compare it against Westinghouse's scale model. And we're going to use that to validate the two models, their model and our model, to make sure that everything looks reasonable.

Now, once we do that, and as we're hoping that, you know, we do like to call this a next generation research facility, we're also looking at advancing some of the facilities that have been used as research reactors for, you know, 50, 60, 70 years.

First off being thermal columns. And in our plan we're looking at using a micro column array to image at higher resolution and fluence rate, rather than the single long collimators currently used.

And we're also looking at the prospect of using fast scattering materials in, you know, surrounding the ex-core neutron activation ports that we're planning on building.

And we want to look at the costs, not only the costs, but also the increase to neutron intensity to see if you can do this, and which would be an interesting thing.

Research, modular reactors as they are, you know, being modular they're built in a certain way. And so, it might be an issue that you probably will not have in certain models the ability to have a center flux trap.

And the difference between irradiating something in the center of a reactor versus, let's say immediately outside a reactor vessel, could be a loss of intensity on the order of a factor of ten or more.

And again, let's not view that with these microreactors. Because one, because they have a

smaller core. You really won't have such a decrease in power, in intensity. Because of, again, you know, you're going to be creating a more intense beam to begin with.

Westinghouse has other very high temperature reactors. They're using graphite in their system to, as a way or removing heat, and other piping technologies. But there is a center flux trap, or a center area that's filled with graphite that they would like to create into a flux trap.

And they're talking about using two models, a research model and a pure energy model. So, they might be able to get a center flux trap. And we'll be looking into that.

But in addition to that we'll be looking at beam ports, cold neutron sources, et cetera. And we will be doing a structural analysis for facility shielding. Next slide, please.

I'm going to go just very quickly. We had, a few years ago we wanted to, when we started learning about small modular reactors in this case, we wanted to see if indeed these more compact cores would increase the flux at a given power.

We did a simple, these were our capstone, our senior thesis students. We did a simple project

for them where they simulated an SMR reactor at the minimum level of power needed to get a given k-effective, and compare that just against a few other reactors. And we did see that increase. Next slide, please.

And this is work that just recently came about with our microcollimator arrays. And so the key is, currently when you want to make an imaging source for neutrons you have these collimators, which, you know, to get a really high resolution collimator you're talking about something that's three to four meters long.

And of course through those three and four meters long you're suffering a significant one over r squared reduction in intensity. And then of course you also have to, in the collimator if you don't vacuum out the tube, if it's not evacuated you'll also get attenuation of the neutrons just from the air present.

So, you tend to get a big loss in signal. And when people do a lot of imaging at high resolution it takes a long time. So, what we're trying to do is replace it with an array of microcollimators. These microcollimators that we're testing we actually have some experimental data that I didn't throw in

yet.

These microcollimators have a ten inch diameter holes. And they're separated by like 12 micrometers center to center. I think they have like a 60 to 70 percent opacity for transmission for neutrons.

And the key is that these holes and their separations are so small that they wouldn't be noticed as a grid structure if you make the image. Because, you know, in our case we were looking at trying to get a resolution, a system resolution of about 30 microns.

And looking at the thickness of the microcollimator versus the whole diameter size, I used to use L over D for anyone who's familiar with that. But I wanted to stay away from it here just not to confuse you. Because this is a different application. Typically a C over D is 75 was able to hit our target of 30 microns. Next slide, please.

One of the biggest interesting things I've been dealing with was when I deal with colleagues of mine who are like, well, how are you going to license this reactor? And, you know, they talk about their questions.

And so, you know, in our, actually this

is in our application to the NRC. Our original thoughts was, what we want to do is we want to initially license this reactor as a research reactor. Because it's a very, I shouldn't say simple, but a very more streamlined application.

So, we wouldn't initially use the reactor, we don't envision using the reactor as a power reactor, originally. So, we use it as a research reactor. We collect data for a couple of years. And then after that if there's enough data to justify it we'd apply for a power reactor license.

Now, that said, if everything goes right we'd analyze data for another couple of years. And what we'd then like to do is see if there's really any difference between operating as a power hybrid reactor versus just a research reactor.

And it's very doubtful that it would be, since, you know, it's just turning on power, so essentially flipping a switch. So, you know, what we would like to do is at least see if we can make the recommendation of having all these microreactors at least at a certain power range to be licensed equivalent to our research reactor. Next slide.

Okay. With that I want to give my thanks to all my students who have been helping out. I have

two PhD students who are working on this project, and two senior students who are doing their, we call them an MQP. But they're senior capstone project. And they're all happy, which all makes me happy. Next slide.

I also have five junior students. WPI is a project based university. So, we do, we require junior theses also. And so we have five students looking at the energy portion of this research. And I'd like to thank them. This was captured during a Zoom interview. Next slide.

And of course the students that worked previously to give us the preliminary data that we used in our application. Next slide.

So, with that I would like to sincerely thank the USNRC. We had two of their research awards that have been used to support this work, their Research and Development Grant, and their Fellowship Grant.

Darren Rosbach is the CoPI for the research award. And my follow CoPIs are Izabel Stroe, Germano Iannacchione, and Snehalata Kadam. Next slide. And with that I'll take any questions. Thank you very much. I appreciate it.

MR. FURSTENAU: Thanks, Dave. I know

we're short on time. So, I just wanted to make a comment. We don't have time for questions. Because I want to bring the panel back on.

But I think, I know it's early in the stage. And you talk about the attributes of a test reactor, flux traps, the ports, that sort of thing. But it's going to be interesting how you weigh getting an all in one reactor.

What do you have to compromise with respect to operating cycles, and flux, and external capabilities, up time and down time, that sort of thing? That's, I'm going to be anxious to hear about that. So, I'm sure we'll be visiting with you about this.

MR. MEDICH: Yes.

MR. FURSTENAU: Yes.

MR. MEDICH: That's a very good question. Because, you know, the idea is, this is probably operating more as a research reactor. I guess it depends on the facility.

If it operates more on a research reactor, where it could have up and down times, you know, it would be operated similar to how solar cells are placed on a house.

Meaning that, you know, if you produce

excess energy it can go into the grid. And you could use that as credits for times when, you know, you're not producing energy.

So all in all, you know, it looks like on average we should, even with down times, we should be able to meet the full energy needs. But even if it, you know, meets half, or anything, it's an added benefit. Because the true benefit really is the research that we've been, you know, inhibiting.

MR. FURSTENAU: Well, thanks, David. I'd like to bring the other presenters back in. And I know we're running short on time. I think we can run a little bit over, because there's no sessions after this.

But I did want to pose a question to all of you. Maybe give you each a quick minute to answer. And this is more of a pitch for this program. As you know, we just started it in Fiscal Year '20, made two rounds of awards. And obviously you folks were successful in that.

But I'd like to know, as we try to look ahead and improve the program, what attributes of the FOA or the grant program as you've experienced it were, you know, attracted you to apply for it? And what should we do, be doing differently that could

improve the program and the outcomes? So, who'd like to start with that? Maria, how about you?

MS. AVRAMOVA: Okay, I can start. So, I'll be very short.

MR. FURSTENAU: Okay.

MS. AVRAMOVA: So, what I like is focus on the advanced reactor. Because that makes our students happy. Yes, it's about making, most of the time, yes. And that's really good, the focus on new technologies.

And what could be helpful in my opinion is the continuation as put it in this way. So, sometimes it's not really enough to completely finish one, you know, development.

And maybe it's good to have a continuation on the subject. I know that probably means more funding, but this is off the record.

MR. FURSTENAU: Okay. Well, thanks. Thanks for that input. Kadir, how about you? How about from your standpoint?

MR. SENER: Yes. So obviously we're, so my team is more composed of junior professors. And so we have a little less experience with grants overall, but we're learning them as we go. So, in this case it will be similar. We'll learn as we go.

But so far it's been great. Well, in our field, especially in civil engineering, related work, or work related to nuclear there's few alleys. And having NRC fund our research is first of all, you know, that's the main thing.

What we see, and obviously since we're new, whatever opportunity that's out there we go for it. So, that's, grateful for it.

And then I think one aspect would be, especially for juniors like us, would be to have more feedback, and more communication with the NRC staff, for example. Maybe next year this conference will be in person. And we'll get to meet the NRC staff, and have conversations with them, and get feedback.

Because obviously there's many new vendors that are trying to get licensed. And they have their issues which, you know, it's hard for us to know if we're not directly working with them. And talking to NRC staff and engineers we can get an insight, all those.

And then make our work more relevant, and be more applicable eventually, by getting some of those inputs from them, which I think it would be very beneficial.

MR. FURSTENAU: That's good feedback. I

know we have been conducting some internal seminars that, where PIs are presenting their projects internally in NRC.

So, you might want to think about doing that. We'd be more than open to any of you to do that as you progress. And we'll set up seminars for you as well within the NRC.

So, I'm glad, Josh, I'm glad you're here. Because I wanted to get from a student's perspective what it helps you, besides surviving. How does it, how, what do you see with the program? How is it helpful for you?

MR. MCLEOD: I see it probably as a way for me to get direction of where I want to go following completion of my PhD. I'd really like to stay involved in research. And it gives me a opportunity to get my foot in the door, learn how the grant process works to continue this after my education is done.

MR. FURSTENAU: Great. Thanks. And you have the last word on this, Dave. How about you?

MR. MEDICH: Oh I --

MR. FURSTENAU: From your perspective?

MR. MEDICH: I think that this is an outstanding program honestly. Because I remember

that period of time, maybe there was ten years where there was no real support for the nuclear field.

And during that time, I mean, these universities, that's when you really started to see a lot of universities losing health physics and nuclear engineering programs. So, this has done a huge service to these fields in propping them up.

And the research program in specifically I think is now giving a way of allowing a lot of these new tenure track faculty to show research that they're doing to get tenure.

So, you know, there's been a lot of support with students. There's been a lot of support with, you know, hiring faculty. But I think that this research program is truly a great avenue to help support the faculty on all levels at these universities.

MR. FURSTENAU: Well, great. I thank you all for that feedback. And I appreciate you coming to the RIC and presenting your projects. I'm really excited about this. And I hope I can hear, get updates from all of you in the future as the projects progress. So, thank you again.

And with that I'd like to close the session. I know we ran a little over. But it was

very, very enjoyable to me. And here's some contacts if you have any questions after we close. So, thanks, everybody.

(Whereupon, the above-entitled matter went off the record at 12:05 p.m.)