Introducing new Plant Systems Design (PSD) Code
Prof. Nawal Prinja, Jacobs, UK

Berta Oates
Hello, welcome everyone next Gen IV International Forum webinar presentation. Today's presentation on 'Introducing New Plant Systems Design Code' will be presented by Professor Prinja.

Doing today's introduction is Dr. Patricia Pavia. Dr. Paviet is the Group Leader of the Radiological Materials Group at Pacific Northwest National Laboratory. She is also the Chair of the Gen IV International Forum Education and Training Working Group.

Patricia?

Patricia Paviet
Good morning, everyone. It's a pleasure to have Professor Nawal Prinja with us today. He has 40 years of academic and industrial experience in the nuclear sector. He is the Technology Director of Jacobs Clean Energy and holds the position of Honorary Professor at four British universities. Currently, he is working with the World Nuclear Association on Harmonization of Nuclear Codes. He has been on IAEA missions to China, South Africa, the United Arab Emirates, Spain, and Poland. He was appointed as an advisor to the UK Government to help formulate their long-term R&D strategy for nuclear industry and continues to advise as a member of the Fusion Advisory Board of UK Research Innovation and the Nuclear Propulsion Science and Technology Advisory Group of Ministry of Defense. He participates in a number of international committees, notably the ASME code committee for developing new Plan System Design code and represents the UK at the Senior Industry Advisory Panel of the Gen IV International Forum. So, without any further delay, I give you the floor Professor Prinja. Thank you so much for volunteering to give this webinar. Thank you.

Nawal Prinja
Thank you, Berta and thank you, Patricia for your introduction. And I also thank Generation IV International Forum for giving me an opportunity to share my experience and my views on this very important topic that I believe will impact the way we design the next generation of nuclear power plants.

We all know that Generation IV International Forum is to address the next generation of nuclear reactors. The big question is how are they going to be designed? There is a need to change the design methodology. So, in today's talk I will, first of all, talk about the need for this new standard and then show you the kind of solution that is being offered and the objectives of this particular standard. And at the same time, I will also mention the other initiators which are being taken by the nuclear industry and explain to you the ASME PSD code committee structure and the charter. And then finally, address a very important topic of integrating safety and design.

So, a quick word about myself. I am here to share my experience as I span across industry and academics. I sit on a number of code committees and I work with the regulators. And that's the kind of information and the knowledge and the experience on which my talk is based.

So, back to the topic of today. We know how the nuclear reactors have developed from Generation I to now Generation III, III plus, and in near future on to Generation IV. But what we see is that during this time the cost of nuclear power has been going up. Typically, technologies become cheaper with time, but not in case of nuclear. I mean, I remember buying my first digital camera and now of course digital cameras are so cheap. I mean, they are in mobile phones. But the cost for nuclear has not come down and the reason that is given for it is that there is increasing demand to keep on improving safety. Of course, safety is absolutely paramount. It is number one priority and this is where lies the challenge, how to improve safety, yet decrease the cost.

Governments right across the world are putting this challenge across to the nuclear sector. In the UK, where I work and live, back in 2018 the UK government issued the nuclear sector deal and it called for 30% reduction in the cost of new build by 2020. We really need to address this challenge, and of course need to understand why safety is being increased.

So, let us look at this issue. Typically, when we design a nuclear power plant, you consider operating basis events. These are typically a return period of 1 in 100 years, and often the operating environmental conditions are moderate to severe. And then comes the design basis. This is the basis of the design, that your design must be able to withstand external hazards in the UK set at 1 in 10,000 year frequency and manmade hazards set at 1 in 10 million frequency.

And extreme events which then go beyond this design basis, in the past we called them the 'beyond design basis' and these are really very extreme event. However, after the Fukushima event, the IAEA reviewed their safety codes and they came up – they actually extended the current design conditions and included some very severe hazards. These are multiple hazards impacting multiple sites and so on, very extreme events, which were not previously in the design basis but they are now covered under what is known as Design Extension Conditions A and DEC B. This is the sort of major reason why the safety is going to be costing us more.

So, the solution now is to have this new plant system design code. The focus of this design code is to reduce cost of new build and increase safety. That is its first prime objective. It has essentially four main objectives shown here. The second one is to conduct the plant process hazard evaluation and analysis early in the design stages, and then sort of improve them as the design matures. And I will talk more about it in the later slides. The third objective is to integrate systems engineering design processes. This is something which is very important. Because typically, in the nuclear industry we design components and then we kind of put them together to create a system and a plant and then we check on the safety aspects unlike other industry like aerospace where they actually design a whole system first and then they get down to the components, and we will again talk about it in the in the later slides.

And in order to do that, the fourth objective is there, to help us integrate risk informed probabilistic design processes with traditional deterministic design methods because we are aware that a lot of experience has been gained in nuclear sector where designs have been based on deterministic design methods.

So, just to remind ourselves, what we mean when we say systems engineering. This is the definition given by INCOSE the International Council on Systems Engineering. It is a transdisciplinary and integrated approach to enable successful realization, use, and retirement of engineering systems, using systems principles and concepts, and scientific, technological, and management methods.

So, here is the big change that I've been talking about. Currently, if you look at the typical practice in nuclear sector, we set down the requirements, then we do the design, then we look at the safety and write the safety cases, and then we seek the regulatory approval. This is the so-called waterfall approach. And you can well imagine if something goes wrong in later stages, it will be very difficult, expensive, and time consuming to correct it. Whereas, the new approach, which is the spiral approach, is where you start with a concept, but as you grow, as the design matures, you are continuously at the same time looking at the requirements, the design, its safety, and of course the regulations and spiral out towards a mature design.

So, let us see how the new PSD code is meeting it. Again, it has six objectives. So, the first one is to provide safer and more efficient system design and design alternatives, but with quantified safety levels. Believe me, there are many current design codes used in the nuclear sector, they do not tell you the reliability. They will say, yes, if you have designed it to this code, your component system structure is safe, but how much? What is the quantified number? It is just not available. The new design code will give you that.

Then the second one is of course, provide you with more effective requirements management. The third will be that it will be cost-effective and timely strategy for any resolution of any issue by offering alternative analysis, design modification, and through early formulation of safety function and any additional research or lab testing or scale testing that may be needed. And the fourth objective is a very important one, to combine risk informed probabilistic design methodologies with the traditional deterministic approaches which are already taking place. There is a Joint Committee on Nuclear Risk Management, it is the American Nuclear Society and ASME joint committee who are putting together some reliability and availability targets.

The fifth objective is to cover the entire lifecycle: design, construction, operation, decontamination, and decommissioning. So, it isn't just the design part, but the whole cycle. And then of course it will be a system-based approach rather than the component-based approach that I mentioned earlier on. And therefore, it will cover multiple disciplines: mechanical, electrical, control and instrumentation, HVAC, etcetera.

So, here are some other initiatives which are being taken by other bodies, ANS 30.1. There is EPRI Book of Knowledge, there is ASME Section XI Division 2, talking about Reliability and Integrity Management, in short, called the RIM.

So, let me explain to you how the plant system design committee is structured. So, at the top we have the executive committee, the Standards Committee, and I'm a member of that. This committee is chaired by Mr. Ralph Hill, who used to be Chair of ASME. And then we have a specialist working group to look at the interfacing with the regulators and I am a member of that. And below are the subcommittees which actually are producing the real design work that will be needed to start off with. There is the subcommittee PRE which is The Probabilistic Hazard and Risk Analysis Evaluation. So, I will be talking about each individual subcommittee. The next one is the Systems Engineering Design Development Integration, the SEDI. And the third one is the Probabilistic Design Methods subcommittee, and then the Conformity Assessment subcommittee. And I am a member of the Probabilistic Design Method and act as their vice chair.

So, very quickly take you through the charter. The PRE subcommittee is responsible for probabilistic hazard assessment and risk assessment, but their main focus is to provide requirements and guidance for system development and design integration processes, methodologies and tools that will provide safer and more efficient system and component integrated designs, but all with quantified reliability levels.

The next one, the SEDI is responsible for systems engineering design development integration, and their focus will be again on systems engineering.

The third subcommittee is on probabilistic design methods. And once again, their focus will be on offering the design methodologies and tools to provide safer and more efficient systems. Again, they will be incorporating risk informed probabilistic design methodologies with the traditional one. This is actually quite a big challenge. Because traditionally deterministic design codes are used. Now, when ASME working with the World Nuclear Association was looking at harmonization of nuclear design codes and mechanical codes, they found that there were many, many reasons for different codes. And one of the main reasons was that the scope was different, and this is where the committee needs to look at and the methodologies.

Now, typically, there are three types of design methods which are used, one is deterministic based on just a rule to say if you meet the requirements you are safe, then there are semi probabilistic codes where a partial safety factor is used. They do not rely on the old factor of safety approach, but these partial safety factors are probabilistically calibrated. So, one big example of these codes are the Eurocodes. And some of them, not all but some of them are used in [Unclear].

And then, of course, the third approach is fully probabilistic like Monte Carlo, but it is very, very difficult and expensive to use, or competitionally [ph] expensive to use. So the challenge here will be how to mix and match deterministic codes with semi-probabilistic or the probabilistic design methods.

And for that, one needs to take risk-informed performance-based approach. And this approach, of course, involves risk-informed approach and the performance-based approach. And let me just very quickly talk about it. The risk-informed approach in very simple terms means what can go wrong. Are you informed about? Do you have the knowledge about the risks? And the performance based approach in simple language is, can your design survive the demand that is being put on? And in here, you can have various levels of performance. For example, if the demand or the load is put, will it recover from it? In other words, is it elastic? Then the second performance could be, okay, some kind of a damage or plastic deformation can happen but it can be repaired.

The third level could be, oh, it collapses or fails, but the damage is limited to itself. And the fourth could be catastrophic failure which could cause damage to others. So, these different performance levels can be agreed and designed to.

So, in risk-informed performance based, the risk informed and the performance-based approaches, elements are brought together. So focus, the attention is on most important activities where the highest risk is coming from, the objective criteria for evaluating performances which I was talking about, and then have measurable calculable parameters for monitoring the system and of course the licensee performance and provide flexibility to determine how to meet the established performance criteria. And the focus will be on the results because they are the primary basis for safety decision making.

So, let us see how this risk informed performance based approach can work. So, in this picture, there is a risk domain being shown in two dimensions. So, on the Y axis you have the frequency of occurrence of an event and on the horizontal X axis you have the consequences or impact. This can be broken down into plant states. You can say, oh, these are anticipated operational occurrences and then design basis or the design extension conditions, the extreme event, and then of course things which are almost practically eliminated, but they are there.

Or you could actually relate the X axis to defense in depth level, level 2, 3a, 3b and so on. So, this is the picture where different plant states can be mapped on and you would have noticed that there is a safe zone and the unsafe zone, the dark zone. The shaded zone is the safe zone, but the boundary between the two is not very precise. It cannot be very precise.

So, if you have a safety critical system, structure, or component, it better be deep inside the safe zone. If there is a situation where a plant system or a structure could foresee an event, and this is what is shown here, which lies in an unsafe area, then we have three options to bring it back into the safe. First is, work on its performance, improve the design such that it does not fail and recovers from that condition. The second option is, to improve – reduce the frequency of that event happening, improve the reliability. And the third one is, of course, the combination of the two. So, this is typically how at the high level the approach can work.

So, how is it being applied in the plant system design code? So, here is a picture that actually shows the design influence – the influence diagram of the various committees. So, to start off with, it is a complex picture but if you focus on the boxes going diagonally down, they basically reflect the design maturity. You start with pre concept design, establish the functional baseline, and then of course, the system, the structures, and the components baseline, and then the whole product, which then gets constructed and commissioned and started up. So, superimposed on that once the concept is established, there comes the whole idea of hazards identification. Now, this is the PRE subcommittee. They will be producing similar to the curve that is shown here is the hazard curve. What can go wrong and how often? So, these typical hazard curves will show the sloping line because, of course, frequent events will generate small demands and very infrequent severe event could generate very, very large load. So this is the typical sort of hazard curve that will be generated. And then as the system structure baseline is established, the design matures, the Probabilistic Design Committee will start to play its role. This is where the system structures are being designed and their fragility is being established. Fragility is conditional probability of failure.

If the event generates the load or a demand, what will be the probability of failure? So, of course, if the load is very, very low, probability of failure is zero. But as the load increases, the probability of failure reaches one. So this is the fragility curve. And these two curves, the hazard curve and the fragility curve can be mathematically combined to work out the risk which is shown in the next slide.

There are two ways mathematically to combine it, the first one is where 'H' is the hazard curve, and 'a' is the demand that is being put on. So, you can actually look at the rate of change of hazard with the load multiplied with the probability of failure from the fragility curve. Or you could do the reverse, you could actually have the rate of change of probability of failure with the load times the hazard. Both ways are okay, they will give you the same result. Only thing is the hazard curve, because it has a negative slope you'll see the negative sign in front of the integration. I have given one example where Bob Kennedy had looked at the hazard of seismic hazard curves and combined them in a very simple way. It is published in this SMiRT 19 paper that is given in the slide and you can obtain more information from there.

So, this is the slide where I just wanted to show the PSD taxonomy. Typically, you should be able to, once the code is ready, to work out the risk at system level, at structural level, or at site level. And this whole taxonomy is also shown in terms of the three baselines that I was talking about, the functional baseline, system structure baseline and the final product baseline.

The next slide shows you the design maturity matrix. So, the three baselines: functional, system/structure, and the product. So, once the project design stage has completed its conceptual stage, the functional baseline can be approved, and then the preliminary stages will be where the system and the structure baseline is approved. And of course, the final is where the product itself is approved.

Now, you must be wondering that there are so many subcommittees carrying out so many different activities, it must be very complex. So ASME is actually making use of a tool called Inoscillate [ph], which actually stores various tasks. Each task as shown over here, or activity diagram, has its start and end, the inputs, and the outputs. And they are all linked together.

And here is next slide shows you a table of the input, the actions that are being taken and the output. Here of course, FBL stands for the Functional Baseline, SS is the System Structure, and PD is the Probabilistic Design. But it basically has this numbering system which is used for various inputs and outputs and activities and all of that is actually connected.

This design code is actually following recommendations made by other international bodies like the IAEA and ACME. [ph] I am sharing with you the IAEA TECDOC 1851. This TECDOC was written for fusion components. It was felt and in fact many people in the fusion sector tend to use nuclear codes which were written for the fission. And please remember that fission codes, their prime objective is of course to prevent core meltdown or radiation leakage and safe shutdown and so on.

But in case of fusion, as you all know that the core itself exists in a molten well, in fact in a plasma state and it is very difficult to actually maintain it in that state. So, the decay heat removal and core meltdown issues don't really matter in fusion. So why then use the fission codes which were actually designed for that? So, those were the issues that the committee here discussed, but look at the approach. The system safety analysis is split between inductive and deductive – because deductive is later on to do the fault tree analysis or event tree analysis. Here we are talking about design, so we will remain on the inductive side. And there again there is hardware and procedural which are mostly human factors.

So, if we against stay on the side of the hardware, there is a quantitative approach, the reliability analysis total probabilistic work or a semi-quantitative. This is where failure mode effect analysis or failure mode effects and criticality analysis is done, where you try to identify mode of failure, what mode it is, what causes it, what frequency, the kind that we were talking about earlier on, what its impact is? Can it be detected, the probability of detection and the severity or the impact level. And then, if there is any corrective action.

So, this is the approach that they took. And in case of structures, yes, the failure could be plastic collapse, buckling, fracture, fatigue, creep and so on. And on the other hand, once the design is there, the material and geometry is known, the loads are known, therefore one could do the stress analysis and then agree what the damage allowable limits are and compare them to establish the design substantiation. So, this is how very cleverly the safety and the design is being integrated.

And the same thing is being done recommended in the report, which is mentioned here on the slide. In October 2019, they issued this report. So, you start with the pre-conceptual design and then do the 'what if' analysis and then do the source term estimate and bounding release, and carry on as the design evolves to the conceptual design where the HAZOPs is done, event tree analysis, fault tree analysis is done to reach the preliminary design and so on. So, once again you can see how a spiral approach can be done to include hazard identification, consequences analysis, frequency analysis, and so on. This is again another sort of a trend that the nuclear industry is following.

So, finally, regarding the timeline for this new PSD code, the intention is that it will be approved for publication in March 2023. The good news as far as I can see is that the time line of PSD design code suits very well the Generation IV initiatives.

So finally, in conclusion, I want to say that safer but more cost-effective designs are needed. Many governments are asking for reduction in cost, yet the regulators are asking for increased safety. For that, new design approach is required in nuclear industry. If we keep on designing using the same approach that we have been following, there is no way we can achieve higher safety and lower cost.

The third is to include hazard analysis in early stages of design, okay, and then advance as the design matures. This provides a structure to the initial development of probabilistic risk assessment and we must incorporate systems engineering design processes. We should move away from this idea of designing components to put them together to see what system or a plant we get. We have to take systems approach and incorporate risk informed probabilistic design methodologies along with the traditional deterministic design methods because a lot of experience and a lot of investment has gone into it. And we can do that by looking at the reliability and availability targets. And finally, integrate them all into the existing design processes and procedures to produce a new plant system design.

With that slide, I will end my talk. And thank you all for listening to me. I do want to acknowledge Mr. Ralph Hill, who is the Chair of the Plant Systems Design Standards Committee at ASME. Thank you.

Berta Oates
Thank you, Dr. Prinja. As questions are coming in, we have a special event to talk to you about. Patricia?

Patricia Paviet
Yes, thank you, Berta. I would love to bring your attention to our special GIF webinar, which is going to celebrate the 20th anniversary of GIF. We have, as you can see, a prestigious panel where current and former chairs of the GIF International Forum will provide their perspective on the progress Gen IV has made and the prospects of the deployment of Gen IV systems. So, the webinar will take place in almost a month, April 20 at 8:30 Eastern Time. Thank you.

Berta Oates
Thank you. We look forward to that presentation. The other upcoming webinar presentations in the GIF webinar series. In April, we also expect a presentation on Experience of HTTR Licensing for Japan’s Nuclear Regulation; in May, Advanced Manufacturing for Gen IV Reactors; and in June, In service Inspection and Repair Developments for SFRs and Extension to other Gen IV Systems.

Excuse me. There are some questions. Give me just one moment, I am going to. Okay. Is the screen still showing?

Patricia Paviet
No Berta.

Berta Oates
That did not work, hold place. I apologize for that. I have run into a technical difficulty. Dr. Prinja, can we still have you on the line?

Nawal Prinja
I am online and I can see there are questions in the question window.

Berta Oates
I think we can go ahead and field those questions in spite of the fact that I seem to have lost the slide presentation on the screen.

Patricia Paviet
So written waiting to view Dr. Nawal Prinja’s screen. We can go ahead, we see the title of the presentation. So, let’s go ahead with the question.

Berta Oates
Here we go.

Nawal Prinja
There are questions in the question box.

Berta Oates
Okay. So, I apologize for that. The first question I see is reducing costs is directly related to production rates. When production rate goes up,

costs go down and nuclear production is very low therefore unit cost cannot be reproduced. Do you agree? Please comment.

Nawal Prinja
Yes. Thank you. I think this question is from Washid.

Berta Oates
That's correct.

Nawal Prinja
Yeah. I do agree that cost is of course related to production rate. But please remember, nuclear power stations are not a production line. The kind of costing rule will not apply them. There is of course a trend where they are talking about doing small modular reactors which can be factory produced and therefore take advantage of what you are proposing. But for the big gigawatt reactors which are probably made on site, I don't think that this issue will apply. But whatever is done, whether it is the big gigawatt reactors or multiple units being produced in factory, the issue of designing and constructing will keep on costing us more because of the safety issues that I had talked about. So, while I agree with you that multiple production can reduce the rate, but that is only possible with small modular reactors, which are again going to be, I guess, part of the Generation IV Reactors. But they will all suffer the same issue. So, I think the proposal to use plant systems design to save cost will apply whether it is a big gigawatt reactor or the multiple small modular reactors.

Berta, there was a question beforehand by Giles, how often and when would you recommend to hold a hazard method during the design progress? Again, it depends on the spiral diagram that I was talking about. Of course, there is the first one that you will do after you have got your concept design already. And you have established, done your system and structure design that will, I guess, will be the first time you will do it. But if there is a need to repeat it, then you can repeat it. It's difficult to say how often because it depends on the situation, the particular design of the events that you have come across.

Berta Oates
Thank you.

Nawal Prinja
Then there is another question I can read from Robert Pase.

Berta Oates
Sure. He's given you some accolades.

Nawal Prinja
That's a comment. Thank you. Thank you, Robert, for that comment.

Berta Oates
There are some more questions coming in.

Nawal Prinja
Sure. This is about what is your opinion between the technical economy of SMRs? When do you see for them a time for large deployment and feedback for the virtuous economical philosophy? Work is going on. We know that in the UK, the UK Government has sanctioned funding for UK SMR. There is a consortium of British nuclear industry working away on it. There are three other advanced modular reactors being looked at. So, in fact, there are four designs being looked at just in UK alone and there are many more around the world. So, the work is still going on. I do believe it makes sense, economic sense to actually have these components which could be factory produced and then taken to site. I mean, it just makes sense that mass production is more economical. But the timescale again depends and the large deployment of them will very much depend on the progress that is being made on the design right now. Once again, I would recommend that the plant system design codes are used to help reduce the cost and improve the safety.

Berta Oates
Thank you. I am not sure what that background noise was.

Nawal Prinja
I think it was the phone call which went up.

Berta Oates
Is there any point in the process where risk levelizing of safety features is reviewed. That is a point where the deployed safety features are examined to ensure an acceptable risk is reached but also to check that the deployed safety features due to the results were overly conservative risk reduction from which reduction and the safety systems could be applied.

Nawal Prinja
So, my quick answer to that will be in the spider approach, safety is being reviewed continuously. This is where the big differences between the spiral approach and what I call the waterfall down or the consequential approach, where you did the requirements, the design, and the hazard analysis, and then you assess the safety, and then you went to the regulator, whereas in the spiral approach, it is more of a continuous approach. So it is not that we have now come to this particular stage, no. It will be done frequently and it is done, most importantly, right at the beginning of the design. That is that is the beauty of it.

Berta Oates

Thank you. Also the questions that have come in so far, do we have more questions for Dr. Prinja? The spiral mode on slide nine implies a phased approach to regulatory approvals. How do we address that different regulators have their own different removal process?

Nawal Prinja
True. This is one of the big challenges. So, nuclear sector can only change if the regulators also change their view. In the past, regulators, it depends. Regulators in the world are of two kinds, prescriptive and non-prescriptive and very many of them stand aloof, they do not want to influence the design and they say you do everything else and then come to us. But I think the times have to change. And this is why if you notice in the PSD committee, we have a special working group for regulatory interface. We appreciate this challenge is there. There is, I would put it down more on to the cultural aspect as well of the way the nuclear sector has evolved over the years. I think we need to work with the regulators right from the beginning and have them agree with us on our design approach, the way we are integrating safety earlier on in the design and how our design is evolving. It is a continuous approach. Again. And we should not wait right to the end of the waterfall and then go to the regulator to say, oh, please approve my design. That is actually not very good because if they pick some issue, then it will be very – I mean, it has happened, it has happened historically where then the designers have to go back and make changes. And I think it is far better to have these discussions earlier on and address those concerns right at the beginning. So yes, I appreciate the challenge. But as you can see in the structure, we have got a special working group on regulatory interface.

Berta Oates
Thank you. The follow up question to the risk levelizing, I've seen designs with more safety systems added, but never removed. Is there a removal process?

Nawal Prinja
Yes, I mean, this is the continuous process. Please remember that we are talking about PSD not just for the design, it is for the whole plant life. So, there are some systems which are perhaps needed during construction, some systems needed during operation, and of course some needed during the commissioning. So systems, safety systems can come and go.

Berta Oates
Thank you. I really like the approach to risk informed design from the start. For new generation advanced reactors where we do not have good performance or data, how do we do PRA PSA calculations?

Nawal Prinja

Yeah. This is where the probabilistic methods come in. There is a lot of research being done and it's a very good question. Many times, particularly in nuclear industry where we are having to deal with such remote events that there is no data. So if there is no data, how do you design against that? This is a big challenge for the probabilistic methods, but there are methodologies which are being developed to work out the risk basically based on what is known to try to then guess what is unknown. So, I do appreciate, but more emphasis will be put. Having said that, I am also very hopeful that the new data science, particularly artificial intelligence, which is data-centric, looking at all the past data, which was not sometimes possible, but now it is, to establish the trends. So please remember, in the past, the design approach was very much based on experience. And currently, it is very much based on mechanistic approach where we try to understand the physics. We perform tests. We try to work out what is causing the failure, which parameters, which equation, and then come up with the design rules. But I think the future could be very much data centric because we cannot – and you're absolutely right, for such remote things sometimes the physics may not even be clear or the data may not be there. So you have to look at the past experience and rely on a data-centric approach. But I believe that the experience, the mechanistic understanding and aided by the data-centric approach, all three will help us. That that's my view.

Berta Oates
Thank you. Will the PSD code include a suggested standard regulatory model to work with the design and safety assessment approaches therein?

Nawal Prinja
It will not include a suggested sort of standard regulatory model because please remember, the design codes do not write regulations. Regulators are quite independent and free. However, it should take account of the expectations of the regulator. That is the job of this special working group. So yes, it will account for regulatory practices, but I don't think that we will be proposing a standard regulatory model.

Berta Oates
Thank you. Are there user requirements for Gen IV Reactors as was prepared by EPRI for ALWR?

Nawal Prinja
Sorry, can you repeat it. EPRI did prepare the user requirement. So, what's the question?

Berta Oates
Are there user requirements for Gen IV Reactors as was prepared by EPRI for ALWR. Are there also user requirements?

Nawal Prinja
There are user requirements set up by many bodies, EPRI is one example that you have quoted. Thank you. But then there is also in Europe the utilities have come up with certain requirements. But the job of the plant systems design committee is not to write the requirements, okay. It actually shows that if a utility or somebody writes the requirements, how to then design to meet those requirements.

Berta Oates
Thank you. Do you foresee any changes to this process with the advent of 10 CFR 53? And if so, what changes would you like to see? I am not sure you are going to know what the US codes are.

Nawal Prinja
No, I would like to know what 10 CFR.

Berta Oates
Yeah, that's the code of – that's a US regulatory. So I don't know that you are going to know the details of that.

Nawal Prinja
Exactly. But I guess my colleagues in the special working group of regulators who are from US, they will know about it. I can definitely take the question to them.

Berta Oates
Do you believe the possibility to address a homogenized view of reactor licensing between different countries? How can we progress in that frame?

Nawal Prinja
Very, very good question. I work with World Nuclear Association whose purpose of life is exactly that, to achieve international design licensing. So, there are basically three stages. The first stage, which I think is doable, is exchange of information. If a reactor has been approved in one particular country by their regulator, then that information can be exchanged. The next stage will be not only exchange the information but accept it. So, if there is an acceptance of one particular aspect, then yes, and then of course, the final, it's our dream that we start to behave like the aerospace industry where an aircraft is licensed to fly all over the world or a pilot is licensed to fly all over the world, that we could have a reactor design that is licensed to build anywhere in the world.

But that is a third stage which still looks remote, because there are many, many challenges. But the first and the second phases can start to happen. I know that regulators from different countries work together. There was MDEP, Multinational Design Evaluation Program, and also the Committee of Nuclear Regulatory Activities. I think regulators from 30 countries work in that in the NEA headquarters based in Paris. And we are in touch with them. They all know about what PSD is trying to do and achieve. They are aware of the desire of nuclear sector to have some sort of an international agreement, the international licensing desire. Yes.

Berta Oates
Thank you. Traditionally, PRA calculated core damage or meltdown frequency. Some advanced designs exclude this by design or by its characteristics. Do you have any comments on what the measure should be for these reactors and how can we define it?

Nawal Prinja
Measures in terms of core damage frequency, I find it difficult because please remember, the PSD code is technology neutral. I think I've already alluded to it during my presentation that there are certain reactor technologies where core damage frequency may not be a parameter at all. So, it depends on which reactor technology that you are basing your design on. For example, in fusion, there is no such thing. But again, I would go back to the fundamental point that the design code itself is technology neutral. It will encourage the PRA people to look at what kind of risks are there. And yes, if there is a core which is likely to get damaged and release radioactivity, it becomes an issue. And then you have to then decide what kind of risk is acceptable. And this is where then comes this whole idea of risk-informed performance-based and so on. The old idea of this where you had no connection between safety integrating with design, that is where this typical question arose. But it should not really be arising in the new approach because you will be looking at the risk from core damage right from the beginning.

Berta Oates
Thank you. Performing safety assessments are perceived to be expensive, requiring multi-discipline teams. How do you counter this argument and how do you control these costs over the life design stage of a project?

Nawal Prinja
Exactly, it is expensive because the people who actually traditionally – I am just talking about most commonly, that the people who do the safety or not the designs. There is a design team who do the work, the construction team is of course different, and then that safety team comes along and it says, okay, what can go wrong? The risk people will tell you that. Then where is the argument against it? Where is the evidence and then they try to put together the safety kit. Everything is done in pigeon holes; every team is different. There is not a clear flow of knowledge. There is lot of repetition and that is why the whole thing becomes very expensive. So I do agree with you that doing or writing safety cases for systems which have been designed for somebody else becomes a very expensive exercise. However, it needs to be done. It's paramount, it's

very important. But if the approach is taken in a more integrated way with the design team, so there is a team where the designer and the safety people, the regulatory people, are all integrated, you will find that when you come to write the safety case, it is much easier because the arguments are already known. The evidence is already known.

Berta Oates
Thank you. Thank you. That's all the questions that have come into the question box. Again, thank you, Dr. Prinja for sharing your time and your expertise. It's been a wonderful presentation, very engaging, as you can tell from the number of questions that we fielded this morning.

Nawal Prinja
Thank you. Thank you for the questions as well. Very, very good. Very informative questions.

Berta Oates
Indeed. Well, we look forward to seeing people join us again in April for the presentation and the upcoming celebration of the GIF anniversary as well. With that, I think we'll end today's webinar presentation and thank you again.

Patricia Paviet
Thank you, Professor Prinja. Thank you, Berta.

Berta Oates
Thank you. Bye.

Patricia Paviet
Bye. Bye-bye.

END