I'd like to introduce our first speaker. Commissioner George Apostolakis from the Nuclear Regulatory Commission. He was sworn in as commissioner of the NRC in 2010 and his term ends in June 2014. He is internationally recognized for his contributions to the science of risk assessment for complex systems. Before joining the NRC he was a professor of nuclear science and engineering and a professor of engineering systems at the Massachusetts Institute of Technology. Mr. Apostolakis served as a member of the NRC statutory advisory committee on reactor safeguards from 1995 to 2010 and served as its chair in 2001 and 2002.

In 2007 Mr. Apostolakis was elected to the National Academy of Engineering for innovations in the theory and practice of probabilistic risk assessment and risk management. He founded the international conference on probabilistic safety assessment and management. He has served as editor in chief of the international journal, Reliability Engineering and Systems Safety. He received the American National Society Tommy Thompson Award for contributions to improvement of reactor safety in 1999, and the ANS Arthur Holly Compton Award in Education in 2005. He is a fellow of the ANS and the Society for Risk Analysis. Please join me in welcoming Commissioner George Apostolakis.

George Apostolakis.
Good morning. Thank you for having me here. I will talk in the next 15-20 minutes about risk information and how we use it at the Nuclear Regulatory Commission.

My background is nuclear reactors so maybe there will be a strong flavor for reactors here.

From the early days of the development of nuclear power, people realized that there were a lot of uncertainties in the estimation of the frequency of accidents and the consequences of accidents. So they had to develop methods to manage this uncertainty when in fact they could not quantify it. We're talking now about way back in the 60s and early 70s. They came up with this very clever idea in my opinion of defense in depth, which is a term that is not used uniformly everywhere. But it means to employ multiple layers of protection so if one fails another one hopefully will save you.

The concept of defense in depth became embedded in the regulations especially for reactors. A problem with defense in depth is there is no guidance as to how much defense in depth is sufficient. We're always relying on the judgment of experts. For example, it would be ridiculous to propose to have two containments in the reactor.

However, as we found out after risk assessment came and it was used in the regulatory activities, a lot of the regulatory requirements had been imposed in the name of defense in depth. Which by the way it has many meanings. The basic definition is the employment of multiple layers, but people have

expanded this and quality assurance is part of defense in depth and periodic testing and so on is part of defense in depth. In other words, everything we do to make sure we have a safe facility is part of defense in depth. So that's another broader definition.

But what we have found is that a lot of these requirements did not contribute significantly to safety or they were really not contributing to risk. They constituted what we call unnecessary regulatory burden. The licensees had to spend resources meeting those requirements that turned out not to be risk significant.

The first risk assessment was issued 38 years ago by the active safety study. What I show on the slide here is three questions that people have found very convenient to remember and it tells them what risk assessment is. So you have a system and the first question you ask is, what can go wrong? And that leads you to developing accident sequences. But that's not enough.

The next question is, how likely is it the thing that will go wrong? These scenarios. And then the final one is, what are the consequences if something goes wrong?

Many times people pay a lot of attention to the probability, the likelihood of the scenarios, and this is very important because it allows you to prioritize the scenarios so if you want to reduce risk obviously you will have to spend resources

on the top four or five or ten scenarios. But in my opinion the most useful insight from risk assessments is the delineation of the accident scenarios. You really understand the system when you understand how it can fail.

The words risk-informed regulation are used routinely now at the NRC and this is the definition of the term from a commission white paper back issued back in 1999. Basically what it says is that in regulatory decision-making you can use risk insights together with defense in depth and safety margins, the traditional methods to better focus the agency's attention but also the licensee's attention on issues that are commensurate with their importance to public health and safety. So it's really the prioritization issue again.

Pictorially now I want to show you what risk-informed means. You have here the traditional deterministic, it's not quite deterministic, it's one way of managing uncertainties by being conservative. Putting upper bounds and so on. So in the traditional deterministic approach defense in depth and safety margins of the guiding principles and the downside is that you may pose unnecessary regulatory burden on the licensees.

In a purely risk based approach you would look at the scenarios, the accident sequences that I mentioned and their probabilities and so on, frequencies, and you would be making decisions based strictly on risk results which is something

we don't want. So we have come up with this risk-informed approach which tries to combine the best attributes of both the deterministic and the risk based approach. And how do we do that? Well, basically we use the judgment of experience managers at the agency and the industry.

The reason I'm showing this is just to point out something important. The reactor safety study was the first risk assessment that was done for nuclear power plants. It was issued in draft form in 1974 and the final form in 1975. I don't have to get into the details here but there is one point that I want to make. If you asked people before the 1974 timeframe what in their opinion was the frequency of core damage events. First they would tell you they couldn't tell you because nobody could quantify the frequency, but then if you pressed according to old-timers they would tell you that the frequency of core damage was an incredibly improbable event down to once every one hundred million years or once every 10 million reactor years. But then at the same time the perception was that if indeed there was such an event the consequences would be catastrophic. Thousands of people would die, land would not be usable for a long time and so on.

The safety study showed that the frequency of core damage events as significantly higher than what people had thought it was. Instead of talking about once every hundred million years, they talked about once every 20,000

years without certainties, once every 3300 years or there's some magnitude higher than the earlier perception. At the same time the safety study showed the consequences would be significantly smaller, they would not be as catastrophic as people thought before the study came out. So this is a good example of how perceptions may be misleading if you don't try to understand the system better in the sense of asking yourself what can go wrong and then trying to put probabilities on the scenarios that you develop.

In 1995 the Commission issued a policy statement that very cautiously directed the staff to use PRA, probability risk assessment, in their daily activities and decision-making, but you see how cautious the Commission is. It says the use of PRA should be increased to the extent supported by the state of the art. That's 18 years ago. And in a manner that complements the defense in depth philosophy. So the Commission at that time placed defense in depth and safety margins at the higher level than risk insights.

However, they also added the second bullet that says that these risk insights should be used to reduce unnecessary conservatisms. They are necessary regulatory burden that I mentioned earlier. These conservatisms are associated with current regulatory requirements and I might say the industry, reactors in this case, was cooled to the PRA from 1975 on until this time and the reason was that the NRC staff was very eager to impose new regulations based on insights

from risk assessments but not remove any regulations using the same insights. So the industry naturally viewed this new methodology as being another excuse for the NRC staff to impose additional regulations.

By having the Commission state in the policy statement that risk insights can be used to remove or reduce unnecessary conservatisms, that was a major step forward and the industry started looking at this methodology with a different eye.

The very first regulatory document that explicitly discussed this approach to risk-informed regulation was Regulatory Guide 1.174 issued back in 1998. I don't need to go into the details here but I just want to point out that at the top you have the three traditional elements, well, first of all, you have to comply with the regulations before and after if you get the request approved. But you have to maintain the defense in depth philosophy and the safety margin philosophy. In other words, if a licensee comes and proposes some change in the regulations that change should not be significant enough as to affect defense in depth to a significant level. Because defense in depth is still a philosophy that the Commission believes is the foundation of our regulations. And the same with safety margins.

The bottom two ask the applicant to calculate the change in risk from the proposed change. This is a risk informed decision-making regarding licensing basis changes. So if a licensee wants to change something in the licensing basis, maybe perform periodic tests less frequently, they will have to do a risk assessment before and after the request. If the request is approved risk, whatever that means, would be increased by a certain amount or decreased by a certain amount and so on. And that's an important input to the integrated decision-making process and then of course if the request is approved the licensee is required to monitor the performance of the particular system to make sure that no unexpected consequences occur. So how is the decision being made here? In the center box the experienced people are putting together all the information and make a decision. In other words, the decision is the result of the deliberative process, it's not the result of some numbers that are calculated. And most safety decisions are that way.

What is the benefit of having a risk-informed regulatory system? Well, the system becomes more rational in the sense that you don't have unnecessary regulatory burden so you have the respect of the licensees. It's easier to include operating experience in the regulations because you have the frequency and the magnitude in the regulations of accidents. It encourages performance based regulation because you can now use risk metrics as performance measures and the licensee then is required to demonstrate that they meet those performance

measures any way they wish. The problem with this approach is you need quantitative health objectives or safety goals. In reactors we do have those so we are risk-informed. I'm not sure in your field of transportation you have those objectives that are approved by the Commission.

A major obstacle we have found when we try to promote this approach is we need to educate a lot of people. Most engineers I would say are not really trained in probabilistic thinking and there is always a resistance. People are used to the deterministic framework, maybe they've been doing it for 10, 15, 20 years and then all of a sudden you tell them to use probabilities and that's not something that's very welcome. So it is a problem.

I headed a task force at the agency about a year ago where the then chairman asked me to work with a task force to develop a risk-informed performance based regulatory system that would be applicable to everything the agency does. We realize that the reactor side was way ahead of other offices at the NRC except perhaps the high level waste repository people. The idea was to see how risk information can be used by all the offices and how performance based regulation can be implemented. So we started with, this is new reg 2150, and we started with the mission of the agency as given to us by Congress which is to ensure adequate protection of public health and safety, promote the common defense and security and protect the environment.

Then we set as the objective of the agency is to manage the risks from the use of radioactive materials. We started with the words manage the risks because we wanted everybody to use the word risk, and especially to send a message that even when you are conservative you are managing risk, even though you may not have quantified the probability of some particular event, by being conservative in your regulations you are managing risk. One objective was to make sure that a common language is used across the agency in all the offices.

Then in the risk management goal, this is the issue of defense in depth again. There are two sub-bullets there, the first one says that you have to put defense in depth barriers and these can be physical barriers or controls or qualified personnel. But those will be commensurate to the hazard present. In other words, you use more for a nuclear reactor than a transportation package. And also they would have to reflect the uncertainties that we have about the potential accidents. But after you do that and this is now where risk information comes into the concept of defense in depth, you start failing some or all of the protections and you calculate the probability of such a sequence. In other words, the accident sequences coming into the picture and then you compare that frequency or probability to some standard. And that's why you need quantitative objectives. Because those have to come from the Commission. And as I said, the reactors have and the other parts of the agency do or do not.

And the last box deals with something that we do every day at the NRC, making decisions. It starts from the left with an issue that needs to be resolved, and the next box says identify options for resolving the issue. And much to my surprise when I presented this to a senior member of our staff he said this is where we're not doing a very good job. I was surprised to hear that. He said well, when we have an issue we get together a couple of people or a few people depending on the issue, and maybe there will be one or two ideas as to how to resolve the issue and we take them and run with them without spending serious time trying to develop a more complete list of what the options are. Then each option is analyzed which means the appropriate physical sciences are used to analyze the issue and risk information as appropriate. And all these results are input to a deliberative process. It's integrated, the decision making process I showed you earlier where again experienced people are making the decision and this is in recognition of the fact that that's how regulatory decisions are made. And then it goes to the implementation and monitoring.

I wanted to emphasize deliberation. This part here where the group that makes the decision, that it's not just the analytical results that are driving the decision. There are many other things depending on the decision of course, how high level it is and so on. But there are other things that that group, the decision makers have to take into account. For example, there may be legal

requirements that are important in this particular case. They may want to take various stakeholder views into account. The need for extra resources and so on. So it is something that is very important to appreciate that this is how decisions are made. And again, it depends on the significance of the decision. Maybe you don't do these to this extent for every decision, but it's important to bear in mind that that's how decisions are made.

Regarding transportation the task force in reg 2150 makes accommodations for every office at the agency. It turns out that in transportation you are risk-informed to some degree and performance based, so there is nothing revolutionary that the task force is recommending. We have to comply with IAEA standards, but when these standards are being revised maybe one can bring some risk insights into those revisions. And also risk-informed implementation of the regulations through guidance where I understand we have more freedom.

Finally, risk information should be developed for other radioactive materials than spent nuclear fuel. And that completes my presentation.

Rick Boyle.

We have a few moments for questions and we have two microphones set up.

Question.

Kenny Pledger with Weapons Complex Monitor. I was hoping you could comment on the court decision last week regarding Yucca Mountain. Maybe you could tell a little bit about if the agency is preparing right now to restart the licensing process or what the current situation is. And also how much could be accomplished with the funding that the agency has on hand currently.

George Apostolakis.

I've been dealing with probabilities for a long time and the probability was won before I walked into the room that I would get the question like that. Yes, we received the court decision. The Office of General Counsel is preparing recommendations for the Commission. We should be receiving those in the next few days or maybe a week. I can't say anything more than that, I'm sorry. But the recommendations are coming up.

Question.

David Blee, U.S. Nuclear Infrastructure Council. Waste confidence. Could you status us on the waste confidence. Obviously you're aware that the draft rule was approved by the Commission. It will be ready for publication. But specifically when do you think the process might be complete? Earlier this year one of your colleagues was quoted as saying that they believe that the waste confidence rule would be finalized by August 2014. Obviously for those of us

who are focused on nuclear competitiveness of the industry, the resolution of this issue is paramount given the current moratorium.

George Apostolakis.

Well, originally we gave it two years I believe to the staff. But that presumes that things go smoothly as one plans. I don't know if you have seen the votes for the publication but several Commissioners raised some issues that have not been settled yet. I appreciated some of the issues that were raised but I wanted to see the public input also, the comments on these issues. So the public comment period is I believe 75 days. After that the staff will have to work on the comments and present them to the Commission. I expect it will take some time for the Commission to reach consensus or at least a majority. So I would be reluctant to say that it will be ready in August or September or before that. Because I don't know how long that deliberation among the Commissioners will take. Some of them are raising some pretty serious issues. I myself have some questions about the assumptions regarding institutional controls and so on. I don't know. We'll try to do it in two years from whenever, but the most important thing in my mind is actually do a good job. That if challenged it will not be again rejected by the court.

Rick Boyle.

Further questions? Sitting through working for the IAEA we do our risk based new documents. The transportation regulations are very stable and they're very accepted and they have a great transport safety record. But as we go toward risk-informing them, how do you address provisions of the regulations that would have to be removed because they aren't risk based, they were defense in depth and maybe they've gold plated the regulations. How do you propose taking them out where that would appear like you're decreasing safety?

George Apostolakis.

Well, one way of stating it is that you're decreasing safety, another way of stating is that you have imposed unnecessary burden. So what is necessary or what is unnecessary? That's where the goals come in. You really need some agency to say these are the quantitative objectives of this particular activity. Then you do your risk assessment and if you avoid the law then obviously you have overdone it and maybe you remove one piece of the regulation and you do the calculation again to see by how much you are affecting the thing. So the critical thing is to have these objectives because otherwise what is necessary or unnecessary doesn't make sense. And by the way there was a lot of concern when the regulatory guide was issued.

In fact I was not on the Commission then but I remember the Commission was taking an unusually long time to approve the proposal. The word came down

that exactly that was the concern. Some Commissioners were concerned that maybe the media would pick up on it and say, the Nuclear Regulatory Commission is relaxing its regulations. And I just remembered, I was talking to a colleague from Germany at that time and he was very frank. He said are you Americans crazy? What are you trying to do? I said well, maybe it's an unnecessary burden. He didn't want to hear anything about that. He said the perception will be, at least in his country, that safety was relaxed and that was politically not acceptable. Well, the regulatory came out, the Washington Post didn't say anything, the New York Times didn't say anything. So, it was just an internal issue and the NRC staff didn't trust the industry, the industry didn't trust the staff and remember I showed you the defense in depth philosophy should be maintained. So the industry guys felt that in the name of that, the staff will reject everything. Our staff also had concerns that the industry would manipulate the risk numbers to their benefit. None of this has happened. Everybody is very happy. Fifteen, 18 years later the thing has worked beautifully. Thank you.