**Remarks of The Honorable Joyce L. Connery**
**Chair of the Defense Nuclear Facilities Safety Board**
**At the Workshop on Education and Workforce Development**
**August 1, 2024, Vanderbilt University**

Good evening, I am very happy to be here tonight. I want to thank Sue Magidson and Connie Flohr for inviting me, and all of you who have worked so hard to make this workshop a success.

As many of you know, my agency oversees nuclear safety within the Department of Energy's defense nuclear facilities. By government standards, that is a small jurisdiction, and I will only talk a little about my agency tonight.

However, my personal and professional interests go well beyond those defense facilities. I am strongly committed to encouraging and supporting the continuing development and advancement of safe and reliable commercial nuclear power in the United States. It's important for our environment, our economy, our infrastructure, our national security, and our workforce.

And this is certainly an exciting time for nuclear power. There are new designs on the drawing boards and new commitments from utilities; and with the new smaller reactor designs major corporations are looking at buying their own reactors. All these changes will introduce new safety issues and concerns, and the need for a new generation of safety professionals trained and able to manage those concerns. There is a bright future for nuclear, but only if we can build the workforce necessary to support it.

I think the biggest problem we face now is the same one we have recognized for the past 10 years or more. A decade ago, we worried about the aging nuclear workforce, and we recognized that we needed to revitalize the educational pipelines.

Well, now the bow wave of the retirees is upon us, and we are feeling the pain, so let's talk about how we are progressing on the educational pipelines. But to start, let me ask you all a couple questions. First, please raise your hand if you completed your main collegiate education before the end of 1994. [Pause for a minute.] Thank you, now please lower your hands; okay, now please raise your hands if you finished your main collegiate education during or after 1995 and keep them raised. Now, please look around and ask yourself the question, have we done enough work on improving the pipelines?

I'm sure you are wondering, why did I pick the end of 1994 as the line in the sand? I'm not sure exactly why, maybe it was the solar eclipse in May of 1994, but that year appears to be a pivotal year for the current and future nuclear industry.

Let's consider some data from surveys conducted by the Oak Ridge Institute for Science and Education or ORISE. It has been conducting these surveys since 1972. Specifically, I'm going to use four metrics in this discussion, the **total enrollment** and the **graduation rates** for **nuclear engineering** and **health physics** students per year in American collegiate programs. These metrics include students at the junior, senior, and graduate levels.

Total enrollment in **nuclear engineering** programs peaked in the late 1970s and drifted downward until 1994, but then it nosedived by more than 50 percent in the next five years. Total enrollment in nuclear engineering programs did not return to 1994 levels until 2010 and was fairly stable until 2015.

Total enrollment in **health physics** programs stayed reasonably steady between 1973 and 1994, but it nosedived by more than 60 percent in the next five years. Unfortunately, total enrollment in health physics programs had not recovered before 2015.

So that was 2015, what about now?

In 2015, the total enrollment in **nuclear engineering** programs was at 3,450 students in 35 programs. By 2022, total enrollment had dropped to 3,060 students, and **three schools** had phased out their nuclear engineering programs. In 2022, a total of 929 students graduated from all degree levels. The overall graduation rate for nuclear engineering students averages around 32% of the total enrollment per year.

Also, in 2015 the total enrollment in **health physics** programs was about 400 students in 22 programs. By 2022 the total enrollment was stable at about 410, but **nine schools** had phased out their health physics programs. In 2022, a total of 79 students graduated from all degree levels, yielding a graduation rate of about 20% of total enrollment per year. The lower graduation rate for health physicists appears to be because most students tend to enter health physics programs at the graduate level.

To be clear, let me repeat that. We are currently graduating *maybe* 1000 nuclear engineers a year, and *if we are very lucky, maybe* 100 health physicists a year.

Now, I absolutely do not intend to inundate you with data all evening, but I want to give you two more numbers. First, in the opening speech to the recent International Conference on Nuclear Knowledge Management and Human Resources Development in Vienna, International Atomic Energy Agency Director General Rafael Grossi announced that his agency forecasts that more than <u>one million new professionals</u> will be needed to meet the needs of the international nuclear industry by 2050.

Second, in its 2023 report, *Pathways to Commercial Liftoff: Advanced Nuclear*, DOE predicted that, and I quote, "*the U.S. would need an additional ~375,000 people with technical and non-technical backgrounds to support the deployment and operation of 200 GW* [gigawatts] *of new nuclear by 2050; today it has ~100,000.*" End quote. That is 15,000 people a year that we need to add to the nuclear workforce!

**YIKES! THESE NUMBERS ARE FRIGHTENING!** Our total enrollment is dropping and the number of schools phasing out programs is climbing. If we are going to contribute our share to those 15,000 new professionals and workers per year in the U.S., shouldn't these trends be going in the opposite direction? And we dare not sacrifice training in nuclear safety to bolster training in design and development. As the Chernobyl and Fukushima Dai-ichi experiences have shown us, nothing will stop the resurgence of nuclear quicker than a major accident involving an "advanced" reactor design, particularly an accident that takes the nuclear field by surprise.

**FROM MY PERSPECTIVE, SOMEHOW, SOMEWHERE, WE ARE FAILING TO ENCOURAGE STUDENTS TO ENTER THESE FIELDS THAT ARE SO VITALLY IMPORTANT TO THE FUTURE OF THE NUCLEAR INDUSTRY. NOT ONLY ARE WE FAILING THE STUDENTS, BUT WE ARE ALSO FAILING THE NUCLEAR INDUSTRY THAT WE SUPPORT.**

Okay, as I shift back from panic mode to speaker mode, I'd like to spend the rest of this time talking with you about what I think we need to do about this.

First, we need to recognize that our traditional approaches to attracting students need drastic updating. When a four-year college education can cost up to 200,000 dollars, students are going to be darn sure that they pick a program they can relate to, one they believe will support their lifestyle and needs, and one they are confident they can complete without difficulty.

But we are not here tonight to solve that problem, so we will leave that to the next workshop. Tonight, we are talking about how to redesign our curriculums to successfully educate, support, and retain those students that do decide to join our favorite industry.

At a conference this past March, I spoke about the value of including non-STEM trained professionals in a STEM-dominated workforce. I am one of those non-STEM trained professionals in a STEM-dominated workforce, so I can speak from experience.

In the past, non-STEM educated individuals were often viewed as lacking skills needed to compete in a STEM workplace. That is not, and never was true. So, what does differentiate a STEM-educated professional from a non-STEM educated professional? It isn't the skills the individual possesses; **it is their interests and where and what those interests led them study.**

For example, I am an accidental nuke. I've worked in this field since 1999, but my educational background was in international relations, conflict resolution, and Russian studies. I remember watching The Day After in 1983 and was influenced by the nuclear arms race and subsequent focus on arms control. I first visited Russia—then the Soviet Union— in 1987 as a high school student. I studied "physics" from the standpoint of the geopolitical implications of widespread nuclearization. Fear of math didn't sway me from a STEM education, an intense interest in the world's geopolitical situation did.

Why do I recommend more non-STEM workers in STEM-dominated workforces and enriching STEM curricula with more training in humanities and liberal arts? Let's look at key skills that a few non-STEM educational programs have in common; namely, let's consider journalism, public policy, law, and liberal arts. All those programs teach their students the ability to conduct research, organize material effectively, and communicate effectively both orally and in writing. Those students become proficient in critical and reflective reading and thinking skills, and the ability to pose meaningful questions that advance understanding and knowledge. Finally, the students all learn the vital importance of independent judgment and ethical decision-making.

These skills align exactly with the skills needed for a STEM education; only specialized expertise and advanced knowledge unique to each field differ. Professionals with a non-STEM education bring to a STEM-dominated industry the same skills but different perspectives and analytical tools. Those different perspectives and tools are essential for all aspects of a STEM-dominated industry, particularly research, analysis, design, and risk assessment. And most important, decision making, and risk communications.

So why do I mention this now? Because tonight I am going to take this to the next logical step. To both address the needs of the future and to promote nuclear sciences and engineering, and nuclear safety as exciting, broad topics to prospective students, I believe that we need to redesign our nuclear-centric curricula to build bridges between professions and professional skill sets. Let's teach science students to also be artists; let's teach budding engineers about environmental law and social ethics; and let's teach humanities and social studies to health and safety students.

And by this, I do not mean for us to build those bridges by simply adding a few more electives to the core curricula. I mean that we need to build those bridges directly into the curricula. And to do that, I am proposing four essential principles upon which our curricula should be built.

And by the way, you will recognize these principles from other important social areas. I believe you will understand why when I finish presenting them.

First is the principle of ***diversity***. By this I mean that we must broaden students' perspectives by exposing them to much more diverse technical, cultural, ethnic, and social views and relevant problems within their core curricula, seminars, and social interactions. I believe that this will help expand the students' capabilities related to critical thinking, problem-solving, identifying hazards, and understanding risks. And more importantly, it will teach students to appreciate diversity rather than tolerate it.

Hands-on experiences are important here. We need work with industry, labs, and international centers, etc., to increase the students' exposure to a range of situations and challenge their newfound skills in meaningful ways.

Let me give you a simple example here of why we want to enhance diversity in nuclear sciences and engineering. One thing I sometimes struggle with in my agency, and I don't think any of you will argue with me, is that nuclear engineers have a terrible record for communicating risk to the public. We need to stop trying to have them lecture "the public" and instead educate them about the diverse "publics" they face.

Second is the principle of ***inclusion***. We need to include a much wider spectrum of technical skills in the students' curricula than just the specific field they are studying. Modern science and engineering projects, particularly in the nuclear field, are highly dependent on large teams of highly specialized professionals. And that dependency will only get more intense as technology continues its rapid advance into the future.

However, each discipline has its own jargon, its own perception of risk, its own set of tools, and its own approach to problem-solving. Providing more cross-training between disciplines within the core curricula will help students develop the teaming skills they will need in the workplace of the future.

To use my agency as an example, I must say that all our technical staff are top-notch in their areas and serious contributors to our mission. However, I find that the staff members that provide the most insightful observations tend to be those with the most diverse range of educational, professional, and personal experiences.

Third is the principle of ***adaptation***. This principle applies as much to the educators themselves as it does to the curricula they teach. We must recognize that climate, technology, generational, and post-COVID social changes have fundamentally altered how people learn and how they view the workplace. These global changes, along with world-wide social unrest and terrorism, have also introduced a whole new set of emerging threats and challenges to both individuals and global society. Educators must adapt their core curricula to address these emerging threats and challenges, and they must help students develop the adaptation and coping skills needed to deal with an ever-changing world.

And the examples of the emerging challenges are not just extreme weather, cyberwarfare, and terrorism. Even within the technical fields, new tools like digital twins, gene mapping, artificial intelligence, machine learning, 3-dimensional printing, and additive manufacturing not only introduce significant new opportunities to advance society, but they also represent serious risks to society if used maliciously or without proper caution.

In my own agency, we have already begun to consider the impact that more frequent and more extreme weather conditions may have on the nuclear safety analyses of the facilities we oversee. And while we are not responsible for any aspect of DOE's nuclear security, we are just beginning to ask ourselves whether there is a collateral linkage between cyberattacks and defense nuclear facility safety. All in all, we all have got a lot of adapting … and a lot of learning and UNLEARNING… to do!

But we also need to ask ourselves a parallel question: What are we losing that we don't want to lose? In recent years, we've seen a steep decline in university ownership and use of test reactors, radiation sources, and radiation monitoring and counting equipment. All these losses impoverish the training of a new generation of nuclear professionals.

Fourth is the principle of ***integration***. All the first three principles—diversity, inclusion, and adaptation — need to be integrated into the core curricula like a fine, hand-woven tapestry. The core curriculum needs to embrace all these principles at all educational levels and in all activities. And this integration needs to become deeper and more sophisticated as students progress in their educational careers.

This integration of the principles should not be just within the coursework and activities, educational staff should be examples of the principles for the students. Leaders must lead by example.

We need to look at nuclear education more holistically in the context of education as a whole. The people who will be best prepared to tackle the challenges of new reactor designs, new technologies, and new safety concerns will be those who have a firm grounding in critical thinking and continuous learning that began long before they entered college.

New research into neurodiversity and different human thinking patterns offer many opportunities for nuclear science and engineering to maximize the talent those fields attract. Dr. Temple Grandin, in her book, Visual Thinking, discusses in detail people whose natural thinking patterns give them a high-level of skills in areas such as accident investigation and systems thinking. The nuclear field needs to understand and take advantage of those skills.

Given today's massive news coverage of artificial intelligence, we must ask ourselves, can artificial intelligence substitute for basic educational programs? My answer is a resounding "NO." Artificial intelligence is basically built on the concept of pattern matching, and as our society builds bigger and more detailed databases, artificial intelligence systems can discern more and more discrete empirical patterns and the interconnections between those patterns. But what artificial intelligence cannot provide for us are the answers about why those patterns exist, and how we might change them. For reasonably simple applications like generating market trends or fake news, artificial intelligence works great. But would I want to place my health and safety in the hands of an artificial intelligence-trained safety professional? Probably not. Let us remember, AI is a tool, AI is not a solution.

In conclusion, perhaps you haven't recognized it yet, but I am not just talking about curriculum change, I am talking about culture change.

Students learn far more about life from their collegiate experiences than they learn in any area of study. Those experiences instill a cultural perspective in students that lasts their lifetime. We need to do both them and us a huge favor; if we can instill in the students a culture that appreciates the principles of educational diversity, inclusion, adaptation, and integration, I believe the future society will benefit both from their value as scientists and engineers and their value as world citizens.

Thank you for this opportunity to speak with you tonight. This has been a great honor for me. I will now be happy to answer any questions you may have.