The world's first small module reactor control room simulator in Corvallis, OR.

Test Facility Ushers in Small Modular Reactor Revolution

by Eric Williams for DOE's Nuclear Energy University Program

When Jose Reyes looks back to the genesis of the NuScale nuclear reactor, it's something of a time warp.

"In some respects, it seems like a long time ago, yet it also seems like yesterday," Reyes says, remembering the progress made possible 20 years ago by a novel thermal hydraulics facility at Oregon State University. "It was one of the first Nuclear Energy Research Initiative awards. The Department of Energy was looking to rejuvenate the nuclear program. Bill Richardson was Secretary of Energy. At Oregon State, we were finishing up our work on the AP600 and the AP1000."

Reyes is more enthusiastic than ever, as the efforts and investments of the Department of Energy (DOE) and private companies like Fluor move the United States ever closer to the next generation of nuclear power.

Citing numerous studies, including those from the Massachusetts Institute of Technology (MIT), Energy and Environmental Economics (E3), and others, Reyes notes "If you want to go to clean energy, you need to include nuclear."

Indeed, carbon reduction has been a pillar of NERI and related programs since the beginning. NERI was the U.S. DOE Nuclear Energy Research Initiative program that began in 1999 to foster innovative public research, with specific focus on what were termed ultra-small and ultra-safe reactors. NERI was one of the key programs consolidated in 2009 into DOE's Nuclear Energy University Program (NEUP), which is managed by the Office of Nuclear Energy.

At the heart of developing the next generation of nuclear power is that novel test facility Reyes and others have used to advance several projects. Known as the MASLWR, or Multi-Application Small Light Water Reactor, it is located on the campus of Oregon State University (OSU) in Corvallis. The MASLWR is but one of numerous initialisms interwoven in the fabric of OSU's School of Nuclear Science, housed in the College of Engineering. The AP600 and AP1000 Reyes mentioned, of course, are the Westinghouse-branded reactors.

Qiao Wu, Professor of Nuclear Science & Engineering at Oregon State, points to a 2003 report that notes the fundamental objectives of the MASLWR project were to "develop the

Undergraduate student Harrison Liu (left), Qiao Wu (center), professor of nuclear engineering, and unknown (right) make adjustments to the NuScale Integral System Test facility at Oregon State University. Wu leads Oregon State's NuScale-related research and testing.

conceptual design for a safe and economic small, natural circulation light water reactor, to address the economic and safety attributes of the concept, and to demonstrate the technical feasibility by testing in an integral test facility."

Also in 2003, while the original work done on the MASLWR test facility was concluded, the OSU team continued working on the design. Then, in 2007, NuScale Power was founded by Reyes and others. OSU conferred exclusive rights to the design to the newly formed company, and the MASLWR facility was repurposed to represent the NuScale design.

Today, as NuScale nears the finish line of the arduous licensing process, OSU's objectives become ever-more real. In December 2019, the Nuclear Regulatory Commission (NRC) completed the fourth phase of review of the design certification application (DCA) of the NuScale Power Module. Soon after, in January 2020, the company submitted its pre-licensing vendor design review to the Canadian Nuclear Safety Commission.

The first deployment of the NuScale, 60-MW power module is planned in the United States later this decade. Like every previous step in the development of the NuScale plants, this is a multi-participant collaboration: a dozen modules will be planted at the Idaho National Laboratory, with the Utah Associated Municipal Power Systems (UAMPS) as the utility and Energy Northwest, which runs the Columbia Generating Station in Washington, as the operator.

Oregon State is just one example of how the transition from NERI to NEUP exhibits DOE's commitment to both continuity and steady progress; though the names have changed and organizational charts tweaked, DOE and its university partners have kept their mutual focus on "investing in the next generation of nuclear energy leaders and advancing university-led nuclear innovation" while maximizing the use of taxpayer dollars.

"That program was really innovative," says Reyes, "allowing universities to team up with industry and government in productive ways."

It's been that way from the start. In May of 1999, Charles A. Thompson of the Office of Nuclear Energy, Science and Technology made a presentation to a committee of the International Atomic Energy Agency (IAEA). Thompson's report explained how NERI was in no small part initiated as a result of the work of the President's Council of Advisors on Science and Technology (PCAST), under President Bill Clinton.

Thompson's presentation noted the observations made by PCAST, which today seem almost prescient:

- Potential benefits of expanded contribution from fission in helping address CO_2 challenges warrant the modest research initiative.
- "To write off fission now as some have suggested ... would be imprudent in energy terms and would risk losing much U.S. influence over the safety and proliferation resistance of energy activities in other countries."
- Fission belongs in the R&D portfolio.

Building on those observations, the PCAST recommendations were:

- Foster innovation and new ideas through investigator-initiated R&D proposals.
- Enhance cooperation among universities, DOE laboratories, and industry.
- Establish a new program to address the key issues affecting the future of fission energy, including:
  - Proliferation-resistant reactors and fuel cycles
  - New reactor designs with higher efficiency, lower cost, and improved safety to compete in the global market
  - Lower-output reactors for use in settings where large reactors are not attractive
  - New techniques for on-site and surface storage and for permanent disposal of nuclear waste
- Establish an R&D program to address continued operation of existing reactors to assist the U.S. in meeting greenhouse gas emission goals.

Also important, Reyes says, is the DOE support for first-of-a-kind tools. "When doing something for a first-of-a-kind design, for first-of-a-kind test programs, there's always an extra expense," he says. "The role of government is key because it reduces that risk."

In the mid-2000s, there was a great team with "lots of ideas on how to move the MSLWR design to the NuScale design," according to Reyes. Also, during that time, they not only took critical steps in the design of the NuScale reactor, but also began to make the business case. "There were three basic patents, which became the IP (intellectual property) for the company," he said. Today, NuScale has more than 400 patents granted or pending in 19 countries.

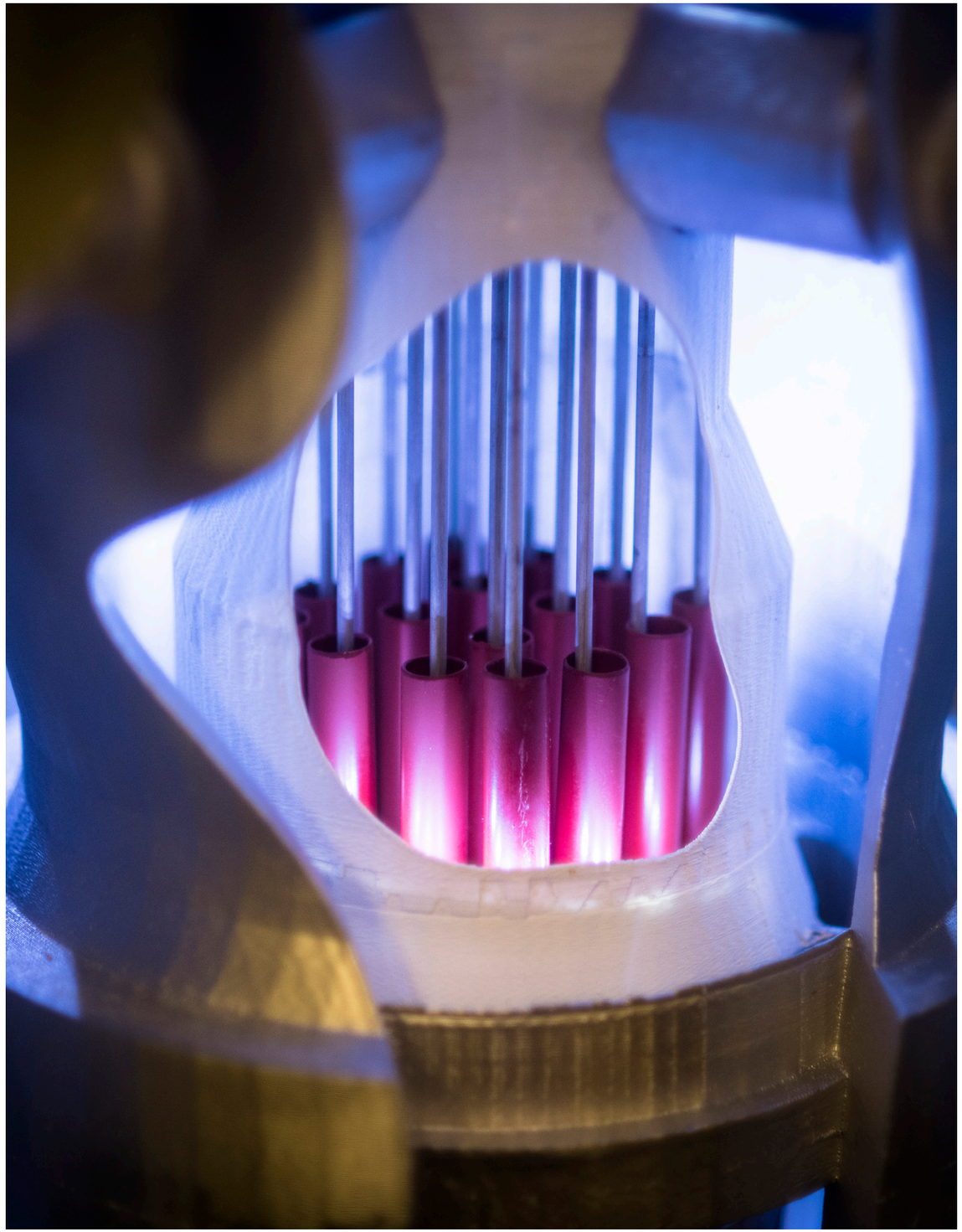
"We reached the point of being investment-ready, and in January 2008 we received the first private investments," Reyes said. He credited Oregon State University's support as key "to us getting through the valley of death." He added, "Going from academia to private business, well, there are sharks. Like on the TV show, they do exist. Then Fluor did come in, did its due diligence, and to their credit invested big time, even after Fukushima."

NuScale Chief Technology Officer and Co-founder, Dr. Jose Reyes, describes NuScale's SMR technology by using a model of the NuScale Power Module™ .

The tsunami-caused meltdown at the Fukushima Japan nuclear plant in 2011 (which caused no fatalities), raised the profile of Oregon State University's nuclear work, mostly in a positive way. "After Fukushima, I got a lot of calls from the Oregonian (the state's largest-circulation newspaper), Wu recalled. "They said, 'We understand you are looking at what this SMR could do. When reporters and others in the state began to become more educated on the MASLWR-enhanced design, "people started thinking more rationally."

"Integrated and collaborative research is at the very heart of what we do through NEUP. We want to make sure that the work funded under the Office of Nuclear Energy has a real impact on the future of nuclear energy. The NEUP projects bring together the expertise of U.S. universities, industry, national laboratories, and the government to deliver meaningful results."

– Alice Caponiti, Deputy Assistant Secretary for Reactor Fleet and Advanced Reactor Deployment



A close-up view of the nuclear core inside a model of the NuScale Power Module™ located in NuScale's Corvallis, OR office.

NEUP balances the competitiveness between universities – and between national laboratories – with those very same institutions' shared appreciation for collaboration. As an example, Wu notes several collaborating entities and their respective leaders, including:

- Idaho National Laboratory, Dr. Shannon Bragg-Sitton
- University of Wisconsin, Prof. Michael Corradini
- Texas A&M, Prof. Yassin Hassan
- University of Idaho, Prof. Richard Christensen
- Purdue University, Prof. Mamoru Ishii
- International Atomic Energy Agency

For Oregon State University, the DOE partnership is much broader and deeper than just having test facilities on campus. There are numerous "knock-on effects," as noted by Kathryn Higley, Head of the School of Nuclear Science and Engineering at OSU. Pointing to the MASLWR, as well as the Advanced Plant Experimentation Test Facility (known as APEX and key to licensing the Westinghouse AP1000), Higley says, "Success in these programs contributed to our ability to hire additional faculty. Those top-flight faculty then got key opportunities … which led to additional research, and a new building with amazing capabilities, which brings in more students interested in the field and sets us apart from our peer institutions. There's a cumulative impact."

The partnerships have enhanced Oregon State's College of Engineering's already strong position of fulfilling higher education's core mission – preparing students for the real-world companies and institutions who employ engineers.

"It's really opened up the market for our students, both graduate and undergraduate," says Wu. "We'll get calls from recruiters, saying, 'Hey, I want this student,' and when we let them know that student is a semester away from graduating, they say, 'No, I want them now!'"

In 2009, OSU student Alexei Soldatov won the prestigious Mark Mills Award, given by the American Nuclear Society for the best original technical paper by a graduate student; his paper evaluated various scenarios for optimizing fuel performance in the MASLWR.

Wu added, "Many of our students are now at the national labs, at Westinghouse, Areva, TerraPower – and NuScale, of course." Further, he says the 300 NuScale employees at its office in Corvallis, a community of 58,000 residents, have a major positive impact on the economy. He said OSU estimates NuScale's presence adds approximately $150 million to the economy annually.

In designing the NuScale Power Module™ and power plant, NuScale has achieved a paradigm shift in the level of safety of a nuclear power plant facility.

1994

The Integral Fast Reactor (IFR) project cancelled

1997

President Clinton orders Committee of Advisors on Science and Technology to review the national energy portfolio.

1999

The Department of Energy initiates NERI, the Nuclear Energy Research Initiative, to foster innovative public research. INEEL (Idaho National Engineering and Environmental Laboratory, now the Idaho National Laboratory) and Argonne National Laboratory tabbed as leads for the Department of Energy's nuclear reactor technology work.

2000

The Multi-Application Small Light Water Reactor (MASLWR) project is launched, consisting of a team representing Oregon State University (OSU), INEEL, and Nexant (a Bechtel subsidiary).

2003

MASLWR funding ends. OSU scientists continue work on design of a small modular reactor (SMR).

2007

OSU confers exclusive rights to the nuclear power plant design and continued use of the test facility to the newly formed NuScale, under a technology transfer agreement.

2008

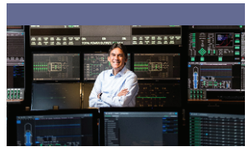
NuScale informs the Nuclear Regulatory Commission (NRC) of its intention to develop a 45-MWe power module.

2011

Fluor becomes NuScale's primary investor.

2012

NuScale's twelve-reactor control room simulator becomes operational for human factors engineering development.



2013

DOE announces selection of NuScale to receive up to $226 million in matching funds to support further design development and secure NRC design certification. Also, Rolls Royce joins Fluor as a backer of NuScale.

2014

The power module's output is raised from 45 MWe to 50 MWe.

2015

NuScale Power awarded $16.6M for the preparation of a combined Construction and Operating License Application (COLA) for the first customer, the Utah Associated Municipal Power Systems' (UAMPS). Also, Fabrication and assembly of a full-scale, upper-module mockup of NuScale Power Module™ completed.

2016

NuScale is the first to submit a design certification application (DCA) to the NRC.

2018

The NRC completes the first phase of the NuScale Power Module™ DCA, making it the first SMR application to undergo NRC review. Also, the DOE Office of Nuclear Energy awards NuScale $40 million in cost-sharing financial assistance under its U.S. Industry Opportunities for Advanced Nuclear Technology Development program. Further, NuScale announces the power module's output increased from 50 MWe to 60 MWe (gross).

2019

NuScale has more than 350 employees across seven offices, including one in the United Kingdom. Approximately 300 are in Corvallis, home of Oregon State University.

2020

NuScale makes first submittal of its pre-licensing vendor design review (VDR) to the Canadian Nuclear Safety Commission (CNSC). To date, more than $900 million has been invested in NuScale, with the DOE contributing approximately $340 million of that through cost agreements.

Qiao Wu (center), professor of nuclear engineering and Oregon State lead on NuScale-related research and testing, discusses the scope of work with graduate student Ryan Baldwin (right), and undergraduate student Harrison Liu (left).

"About 40 percent of our company is under the age of 40, adds Reyes. "That brings a lot of innovation, and that spirit of innovation is what we've brought from Oregon State."

That student development has also been an objective since early on.

"University involvement in NERI-funded research has been particularly important in renewing student interest in pursuing degrees in nuclear engineering and related sciences and enabling educational institutions across the country to stay at the forefront of nuclear science research," William Magwood IV, then director of the Office of Nuclear Energy, wrote in the 2003 NERI Annual Report. Magwood is now director general of the Paris-based Nuclear Energy Agency.

That 2003 report highlighted 10 NERI research projects, including "Testing of Passive Safety System Performance for Higher Power Advanced Reactors," in which Westinghouse Electric Company, LLC, was the collaborator. Who was the principal investigator? Jose Reyes of Oregon State University.