



The conduct of irradiation tests in North Carolina State University's PULSTAR reactor pool in support of the Nuclear Reactor Program.

PULSTAR Reactor – a Research Reactor for the 21st Century

by Kate Meehan for DOE's Nuclear Energy University Program

The tree-lined, red brick campus of North Carolina State University houses an unlikely facility: a PULSTAR reactor, the only reactor of its type still in operation. This unique reactor operates at a steady state power of 1MW. The reactor provides the opportunity for researchers from around the world to conduct a wide variety of experiments, thanks to its intense source of neutrons.

Over the past decade, the Nuclear Reactor Program (NRP) at NC State has received substantial infrastructure investments from the Department of Energy's (DOE) Nuclear Energy University Program (NEUP), as well as from other agencies, allowing for a significantly increased research capability. DOE's Office of Nuclear Energy created NEUP in 2009 to consolidate its university support under one program. NEUP funds nuclear energy research and equipment upgrades at U.S. colleges and universities and provides students with educational support.

NC State has been awarded 10 NEUP grants for research reactor and infrastructure improvements totaling over \$4 million. These grants have allowed the NRP to add state-of-the-art equipment, including two facilities that are the only ones of their kinds in the United States – an intense positron beam and an ultra-cold neutron source. These grants have also funded

upgraded power of the PULSTAR reactor, the establishment of a hot cell capability, new reactor control console instrumentation and monitoring equipment, and other improvements that allow for greater research capabilities.

Dr. Ayman Hawari, distinguished professor of nuclear engineering and director of the NRP, began working at NC State in 2002. At the time, the PULSTAR reactor was an aging artifact that had been operating for 30 years with little change.

"We were not equipped, from the perspective of operational infrastructure or technical and scientific infrastructure, to fulfill mission objectives as a research reactor," said Hawari.

Hawari spearheaded a campaign to upgrade the reactor to meet the needs of 21st-century scientists. The NRP initially received funding from Innovations in Nuclear Infrastructure and Education (INIE) – the predecessor of NEUP. This program aimed to set up university reactors as effective tools of science and education.

Thanks to the ongoing cycle of grant funding from NEUP, Hawari has seen the PULSTAR become a sought-after, well-used modern reactor.

DOUBLING POWER

One of the first NEUP grants that NC State received for the PULSTAR was also its largest: \$1.4 million to double the reactor's operating power from 1 MW to 2 MW. This funding allowed the NRP to refurbish the whole reactor with new equipment, including the primary and secondary cooling systems.

"This almost gave us a brand-new reactor," said Hawari. "Only the core is not brand new."

NC State received the funding in 2010 and has gone through an extensive process to prepare the reactor for this power upgrade. The initial phase required the university to work with vendors, complete a safety analysis, and evaluate the core and the effect on fuel needs. The second and final phase is now nearing completion and will result in a license for the PULSTAR to operate at the new 2 MW power level.

Hawari gives two reasons for wanting to double the reactor's power: first, the increased power will enable more utilization opportunities for years to come; second, doubling the power means doubling the efficiency of neutron creation.

"We will double what we used to do in one day," explains Hawari.

One obstacle emerged during this power upgrade: the constant need for fuel. This is not a new issue, but it is one that becomes more urgent as the power upgrade comes online. A more powerful reactor is a hungrier reactor, consuming more fuel during its daily operations.

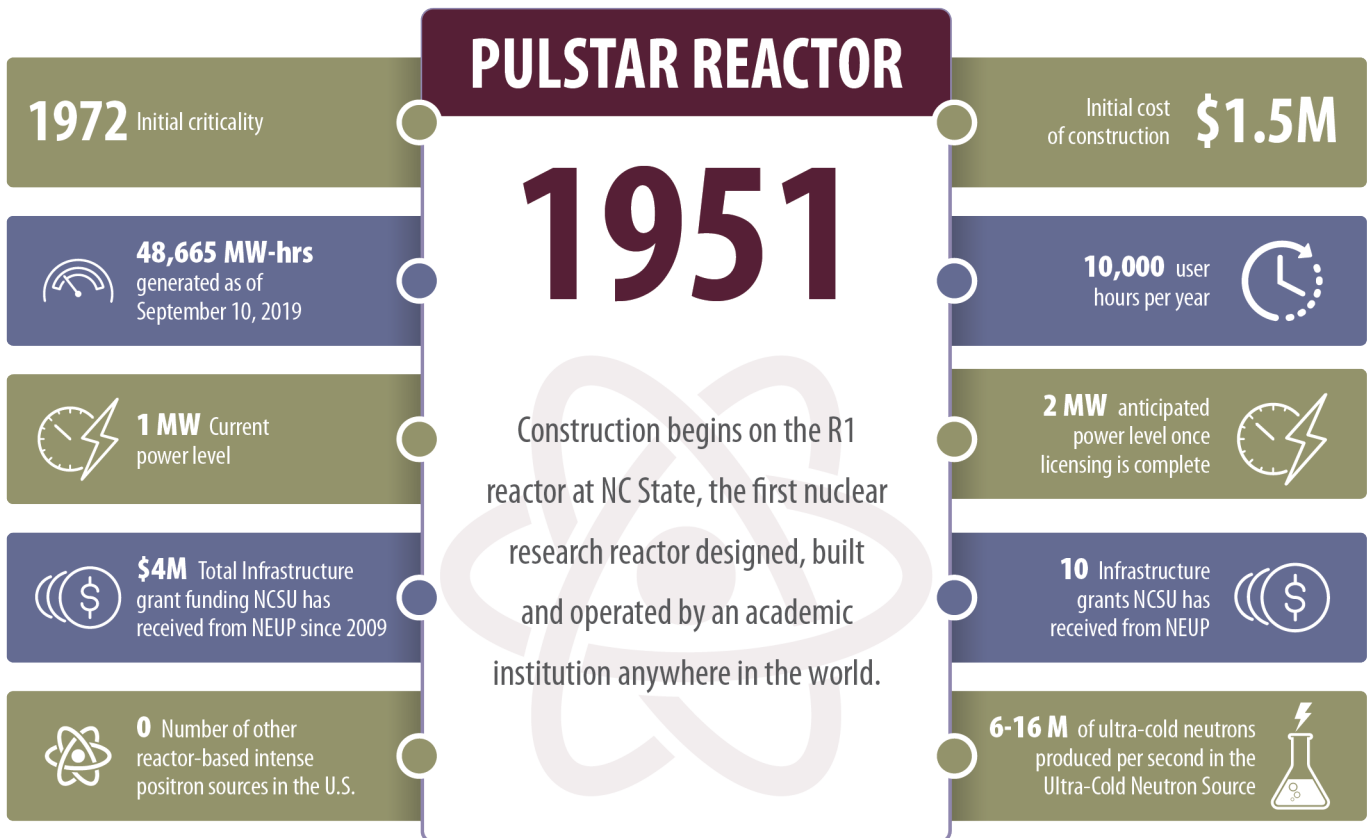
The search for fuel led NRP to Buffalo, NY. The University at Buffalo has a decommissioned PULSTAR reactor, the only other reactor of this type ever built. The pin-type fuel for these PULSTAR reactors is unique; the reactor in Buffalo uses fuel enriched to 6%, whereas NC State uses fuel enriched to 4%. The NRP received funding from DOE to ship the pins from Buffalo to North Carolina, and a license was obtained to feed the reactor a mix of 4% and 6% enriched fuel. For a modest amount of money, this process gave NC State a large infusion of fuel. That fuel has now been feeding the reactor for about two years.

Hawari estimates that at current usage rates, the PULSTAR has enough fuel to run for another 8-10 years. However, with the coming power upgrade, this will lessen the run time allowed by the available fuel to nearly 5 more years, leaving the NRP in search of yet another fuel source for the future.

INTENSE POSITRON SOURCE

One of the most extraordinary facilities in the PULSTAR reactor is its Intense Positron Source (IPS), which has been supported by multiple grants. The IPS creates large numbers of positrons, which are the antiparticle of electrons; they have the same properties as electrons but with a positive charge instead of negative. Positrons are useful for their ability to identify defects in materials at sizes as small as a single atom.

The IPS is a unique facility in the United States that Hawari describes as "a world-class user facility," attracting researchers from all over the world.



NEUTRON DIFFRACTION AND IMAGING

Multiple facilities at the PULSTAR reactor allow researchers to perform nondestructive examination techniques. The Neutron Powder Diffraction and Neutron Imaging Facilities direct the neutrons produced by the PULSTAR reactor toward an object in order to form an image or a diffraction pattern for that object. This capability has been supported by NEUP, particularly by a 2012 grant that established high-resolution digital neutron imaging using a digital image plate system. This capability is currently evolving to support dynamic imaging and capture phenomena in motion.

These neutron facilities provide a complementary function to the IPS. Testing materials both ways produces positive and negative “images” of the same material, which is like having both a photograph and its negative.

MOVING FORWARD

The PULSTAR reactor has benefited tremendously from its funding from NEUP, which has allowed for the construction of the facilities described above, as well as additional capacities like the ultra-cold neutron source and the coming addition of a hot cell capability.

“I feel that infrastructure funding is key to our success,” said Hawari. “It has allowed us to adapt with the times to ensure this nuclear facility is a tool of 21st-century science and education.”

Over the past decade, with the support of NEUP Infrastructure grants, the NC State Nuclear Reactor Program has also become a partner institution of the Nuclear Science User Facilities (NSUF).

“This allows us to tap into the reservoir of users NSUF created,” explained Hawari. “NSUF has been great to us.”

Hawari described how users come to the PULSTAR reactor through NSUF programs and then keep returning for further experiments. During his time at NC State, Hawari has seen annual user hours increase by an order of magnitude, from around 800-1,000 user hours in 2002 to 10,000 today.



A neutron image of jet turbine airfoils acquired using the PULSTAR reactor’s Neutron Imaging Facility.

He expects the popularity of the reactor to further increase as it keeps growing and improving.

In the next year or two, Hawari expects the reactor to receive its license to operate at 2 MW, add a hot cell capability (allowing for isotope production) as well as a fuel testing facility, and increase material characterization capabilities. The productive relationship among NC State, NEUP and NSUF will continue to enhance this world-class reactor.

Related [NEUP](#) Projects:

Infrastructure Reactor Upgrades: 10-9971, 12-9830, 13-6063, 16-10958, and 18-18471.

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