



Photo: Joseph Xu, Michigan Engineering Communications & Marketing

No longer reliant on concrete walls to provide shielding on all levels, the old Ford Nuclear Reactor building now has windows looking out over the fountain.

Breathing new life into a former research reactor building

With the refurbishment of the University of Michigan's Ford Nuclear Reactor Building, the current generation of nuclear engineering students, along with their faculty, has state-of-the-art laboratories in which to research, study, and learn.

By Colin Barras

On July 3, 2003, the University of Michigan (U-M) lost an old and dear friend. A few years short of its 50th birthday, the Ford Nuclear Reactor—so named because it was built with funds donated by the Ford Motor Company—was placed in permanent shutdown after the university determined that it could no longer justify the cost of operating the reactor.

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The move was a blow to the university's Department of Nuclear Engineering and Radiological Sciences (NERS). David Wehe, a professor in the department, told *Nuclear News* at the time that roughly one-quarter of the nuclear research then being conducted at U-M was fission related and that there were concerns that this research might be affected by the loss of the reactor (*NN*, Aug. 2003, p. 132).

More than that, though, the shutdown had symbolic significance. Wehe said that the reactor had served as the flagship feature of the department, and that students arriving at the university previously had

the opportunity to visit the facility and gaze down at the blue glow filtering up through the reactor pool—a sign, Wehe said, that “nuclear power is alive and well.”

For a decade after the reactor's shutdown, the Ford Nuclear Reactor Building served as a less inspiring symbol. Empty of its research staff, the most significant activity at the site revolved around the multimillion-dollar decommissioning process under the watchful eye of the Nuclear Regulatory Commission.

Then, in 2013, U-M announced plans to turn the vacant Ford Nuclear Reactor Building into a positive symbol once again



The old reactor space at the end of decommissioning.

with a major renovation of the space, transforming it into a suite of state-of-the-art nuclear laboratories. That process was completed last year, and on April 3, 2017, the building reopened under a new name: the Nuclear Engineering Laboratory.

“It’s a success story,” said Ronald Gilgenbach, the Chihiro Kikuchi Collegiate Professor of NERS and chair of the department since 2010. Gilgenbach was instrumental not only in conceiving the project and persuading the authorities that the renovation could succeed, but also in drumming up the financial support to make it happen.

Igor Jovanovic, one of several NERS professors who have moved into the refurbished building, said, “I think it projects the image of a modern field that has a future.”

Wins and losses

Back in the early 2000s, that kind of optimism was harder to find. University reactors had been shutting down since the late 1980s, including the one at the University of California at Berkeley, and more followed in the 1990s.

At the start of the 21st century, the reactors at Cornell University, the Massachusetts Institute of Technology, and U-M were earmarked for potential closure, according to Kenan Ünlü, a professor of mechanical and nuclear engineering and director of the Radiation Science and Engineering Center at Pennsylvania State University. “Only the MIT reactor survived,” he said. “We lost two beautiful reactors.”

Both losses struck a chord with Ünlü. At the time, he was director of Cornell’s Ward Center for Nuclear Sciences, where the university’s research reactor was located, and he had begun his academic career

at U-M. “For almost three years continuously, I used the Ford Nuclear Reactor,” he said. “It was the main part of my Ph.D. work.”

Ünlü acknowledged the vital role that the Ford Nuclear Reactor played in his career development. “I am where I am now based on the work I did at Michigan,” he said. His doctoral research involved neutron depth profiling, which led him to the directorship at Penn State via posts at the University of Texas at Austin and Cornell. Many academic careers in this field revolve around research reactors, Ünlü said, and the facilities are so versatile that they offer a wide array of other benefits, too (see sidebar on page 36).

It was an awareness of the potential benefits that first prompted U-M to invest

in a research reactor. In the late 1940s, the university was looking for a way to honor the memories of those from the U-M community who had lost their lives during World War II. The university’s leaders settled on a project to explore the peaceful uses of nuclear power and named it the Michigan Memorial Phoenix Project. The Ford Nuclear Reactor, which began operating in 1957, became a centerpiece of the project.

The timing was perfect, as just a few years earlier, in 1953, President Dwight D. Eisenhower had presented to the United Nations General Assembly his famous “Atoms for Peace” speech, which focused international attention on the benefits to be gained from the peaceful use of atomic energy. Research reactors would be vital for the exploration and expansion of atomic energy technology.

The Ford Nuclear Reactor was one of the first three university research reactors, according to Gilgenbach, and engineers had not yet settled on a standardized blueprint for building such a facility. Many research reactors built in later years were variations on the General Atomics TRIGA design, a pool-type reactor that requires no containment building, but the Ford Nuclear Reactor and the reactor building were unique, custom-made structures.

This proved to be a key factor decades later when the decision was made to invest in refurbishing the building. Even emptied of its reactor, it was a remarkable structure—a cavernous space with 3-foot-thick concrete walls to provide radiation shielding in addition to that surrounding the reactor itself. Those walls were never actually contaminated by radiation from the reactor, so some were left untouched during the decommissioning process.



Engineers at the console of the Ford Nuclear Reactor—back in the day.

Reactor building revival

When Gilgenbach became the chair of NERS in 2010 and began evaluating the department's assets, he recognized that the Ford Nuclear Reactor building's exceptionally thick walls were still ideally suited for radiation shielding, making the structure a perfect home for nuclear engineering research. He determined that it was worth saving.

U-M's College of Engineering commissioned SmithGroupJJR, an architectural, engineering, and planning firm, to draw up plans to turn the empty building into a modern suite of nuclear laboratories. The estimated cost was \$10 million, although this later rose to roughly \$13 million.

Armed with the plans, Gilgenbach met with J. Robert Beyster, founder of Science Applications International Corporation, who had received bachelor's degrees in engineering physics and engineering math from U-M in 1945, and master's and doctoral degrees in physics in 1947 and 1950, respectively, and had witnessed the launch of the Michigan Memorial Phoenix Project.

Beyster was enthusiastic about the refurbishment proposals, as Gilgenbach's ambitious plan held the promise of regeneration and renewal for U-M's former reactor building. Beyster pledged \$5 million to the project with the understanding that U-M's College of Engineering would com-



Photo: Joseph Xu, Michigan Engineering Communications & Marketing

Prof. Ronald Gilgenbach (right) with building manager Rob Blackburn during the early stage of construction.

mit to making up the balance. The college agreed, and the project moved forward. Like the mythical bird that gave its name to the Michigan Memorial Phoenix Project, the Ford Nuclear Reactor Building was set to spring back to life.

The renovation work was challenging. Gilgenbach recalls 5-foot-diameter saw blades running for months on end to re-

move some of the concrete structures inside the building. These had been left standing after the decommissioning process but were not going to be needed for the building's second life. "Something like 80 percent of the time it took for the entire renovation project was devoted to sawing out that concrete and demolition," Gilgenbach said. But destruction eventually gave

way to construction, and the new labs began to take shape.

Nuclear research spaces

The U-M NERS faculty laboratory directors were involved in this part of the project from the earliest stages. They liaised with the architects and engineers to “design their dream laboratories,” as Gilgenbach put it.

“It’s a very rare opportunity to be able to design a space to your liking,” Jovanovic said. “Usually you move into a space that was designed and built decades ago, and you must try to retrofit. It’s a long and time-consuming process, and the result is always less than perfect.”

Annalisa Manera, a U-M NERS professor who operates a laboratory in the refurbished building, recalled how useful it was to have ultimate freedom to design and organize the research space. “Typically when you have a room, there are few choices—the electricity is limited, and facilities such as compressed air and chilled water are not optimal,” she said. “The fact that we could design and choose the location of those facilities allowed us to build the most flexible space we could think of.”

Manera’s new lab needed to be designed to accommodate some particularly bulky equipment. But because the starting point was an empty building, the solution was

easy: split the lab over two floors—the basement and first floor—so that the equipment could be given the 26-foot vertical drop it required. “This allows us to build tall test facilities, which is important for our thermal hydraulic experiments,” Manera said.

Having laboratories placed in the bowels of the building was a key advantage, according to Manera. “We use powerful gamma ray sources, which require quite some shielding,” she said. The 3-foot-thick walls help provide that shielding, and the fact that the basement is underground is a bonus.

A linear electron accelerator has been installed in the first-floor laboratory space for Sara Pozzi, also a NERS professor. The accelerator generates gamma rays and neutrons, and again, the building’s thick walls help provide the shielding that is necessary for the safe operation of such a machine.

Jovanovic has moved into laboratory space on the second floor. Having a brand new lab offers his team a very clean environment for assembling their newly developed heterogeneous composite detectors and carrying out optimization work. Once assembled, the detectors are moved to a lab in a nearby building for testing, he said.

Zhong He, another professor in the department, also constructs radiation detector systems, but his will be tested within the building. This led to the requirement for an environment with low background radiation levels. “We needed to be as far as possible from the accelerators downstairs,” he said, and so it made perfect sense to set up his laboratory on the third floor.

He jumped at the opportunity to design a laboratory from scratch. At present, his research team is focused on stress testing their detectors to make sure that they meet the stringent requirements of users, including NASA and the U.S. military. “The instruments have to work from -40 °C to +50 °C,” he said. Those tests require environmental chambers that can be tuned to a wide range of temperatures, but such equipment is very noisy. He made sure to locate the environmental chambers in a separate room to keep peace in the main laboratory.

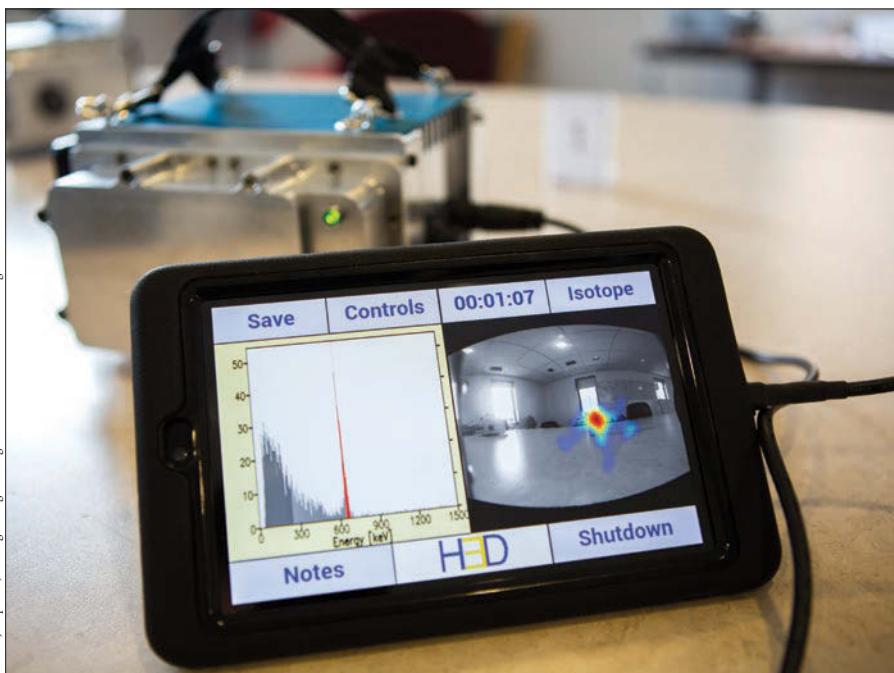
Also working in the building are U-M NERS professors Michael Atzmon and David Wehe. Atzmon will be using laboratory space on the second floor to continue his investigations into metastable materials. “The current focus is on mechanical properties of metallic glasses, which are frozen liquid metallic alloys that lack crystalline order,” he said. “These have superior strength and elasticity, making them attractive for sporting goods, as well as electronic or medical devices.”



Photo: Joseph Xu, Michigan Engineering Communications & Marketing

Victor Petrov, assistant research scientist, tests a column in Prof. Annalisa Manera’s old laboratory.

Photo: Joseph Xu, Michigan Engineering Communications & Marketing



A handheld, single-crystal version of the Polaris camera, known as Polaris-H.

The refurbished building also contains offices for research scientists and graduate students, a large student “collaboratory,” and meeting spaces that will accommodate all members of the U-M NERS department.

Carrying the torch for nuclear

Much of the research that will take place in the Nuclear Engineering Laboratory is about the peaceful use of atomic energy, in keeping with the original aims of the Michigan Memorial Phoenix Project.

The experiments in Manera’s Thermal Hydraulics Laboratory will be vital for designing new, more efficient nuclear reactors. She is tackling the uncertainties in fluid flow behavior inside reactors. Current systems are designed to operate conservatively in case that uncertainty has the potential to lead to problems, such as a localized temperature rise. “Unfortunately, this conservatism is expensive,” Manera said.

Physicists are working on higher-resolution theoretical models—so-called numerical reactors—to reduce the uncertainties. While this will give reactor designers the information they need to make the technology more efficient, theoretical models still need to be validated experimentally. “The strength of our group is that we have unique facilities that can provide the high-resolution data needed to validate and further enhance the modeling of nuclear systems,” Manera said. “Some of our instrumentation is pretty unique. We just finished developing a gamma tomography system, which allows measurement of two-phase flow distribution in complex geometries—like the bundles of a reactor—with a spatial resolution of 1 millimeter.”

According to Manera, few other nuclear engineering laboratories in the world have the same potential to be as useful for reactor design. “We’re really excited about it,” she said.

In the Gamma Ray Camera Laboratory—named the Glenn F. Knoll Nuclear Measurements Laboratory after the former NERS department chair, college dean, and professor emeritus—Professor He and his students will continue to develop the revolutionary new radiation-monitoring technology that has earned them industry-wide respect. The Polaris camera systems that He and his former Ph.D. students brought to market through their company, H3D Inc., use cadmium zinc telluride crystals to detect the gamma rays released during nuclear

fission. Polaris, unlike competing systems for radiation imaging, can operate at room temperature and gives an instant snapshot of the nature and location of radioactive materials in the local environment.

The radiation camera is the culmination of nearly 20 years of work and has attracted a great deal of interest. “We have sold it to a number of government agencies in the U.S., Canada, Europe, China, and Japan,” He said. “If there ever were a nuclear accident, the sensors could be used to survey the area quickly, particularly if attached to drones.”

In addition to stress testing the Polaris detectors in his new laboratory space, He will explore whether other semiconductor crystals might prove useful for radiation detection. “In addition to cadmium zinc telluride, we are looking at thallium bromide and other alternatives,” He said.

Keeping nations honest

Research into the Polaris detectors will also feed into the Consortium for Verification Technology (CVT), a U.S.-wide initiative involving 12 leading universities and nine national laboratories. Pozzi heads the CVT, which is providing vital research and development to help confirm that countries and organizations are complying with the terms of nuclear agreements. “We worry about countries that might take a nuclear energy program and try to turn it into a weapons program,” Pozzi said. The CVT is developing the tools that will give nuclear inspectors—and the international community—greater confidence in identifying the moment a good nuclear program turns bad.

Research in Pozzi’s Detection for Nuclear Nonproliferation Laboratory will lead to imaging technology that makes it much harder for organizations to hide nuclear material from inspectors. Pozzi and



Prof. Sara Pozzi poses with the linear accelerator in her new laboratory.

her students are developing detectors that are sensitive to both the gamma rays and the fast neutrons released during nuclear fission. The images from the detectors are then input into an augmented reality headset, allowing the inspector to visualize the radiation and making the invisible visible. And because it is a significant challenge to build radiation shielding that blocks both gamma rays and neutrons, the new detectors will be able to identify nuclear materials even if efforts are made to conceal them.

The electron accelerator in Pozzi's lab will also play an important role in her CVT work. "The accelerator will enable new research for a homeland security application: the detection of shielded highly enriched uranium," Pozzi said. The gamma rays and neutrons the accelerator generates can induce fission in HEU. Studying the process is a key step in ongoing research to build new detectors that will reveal the presence of HEU. Current detectors can operate only when the accelerator is "off" or between accelerator pulses. The new research will enable detection while the accelerator is "on," reducing the time needed to detect HEU.

Jovanovic's work in the new Applied Nuclear Science Instrumentation Laboratory will also play a role in the nonprolifer-

ation of nuclear weapons. He is a member of the Department of Energy-supported WATCHMAN collaboration, which aims to develop detectors capable of discovering undeclared nuclear reactors and monitoring existing nuclear reactor operation from tens of kilometers—and ultimately hundreds of kilometers—away. The technology uses antineutrinos—particles that interact with matter to such a limited degree that they can readily travel through any object, including Earth, without experiencing perceptible attenuation.

"There are a lot of concerns internationally about certain reactor facilities perhaps being developed outside of international agreements, as well as existing ones being used in a way that maximizes the production of plutonium," Jovanovic said. "The goal of these detectors is to discover such activities. The technology is very exciting."

Some physicists have said that WATCHMAN-like projects should be viewed as part of a new "neutrinos for peace" initiative. The idea puts a 21st-century spin on the message at the heart of Eisenhower's speech from more than 60 years ago.

"It's fitting with the spirit of the times that new facilities are designed and used in such a way that focuses on these new challenges and new needs," Jovanovic

said. "And the fact we are using this original infrastructure built at the time of the Atoms for Peace program—there's a synergism there."

Bucking the demo trend

Others in the research community have welcomed the developments at U-M. "While I am saddened to lose the Ford Nuclear Reactor," Ünlü said, "I'm so glad that U-M utilized that space for a good purpose."

What is less clear, however, is whether there are lessons here for other universities and organizations with empty buildings that formerly held research reactors. In the past 18 months alone, at least two former reactor buildings—one at the University of Washington in Seattle and one at Iowa State University in Ames—have been demolished to make way for new developments. Even being listed on the U.S. National Register of Historic Places for its scientific and architectural merit was not enough to save the University of Washington's More Hall Annex.

The decision to demolish—rather than refurbish—might stem from the fact that reactor buildings do not typically have the architectural features that U-M used to such good effect in its recent renovation work. Scott Wendt, radiation safety

Survivors: Research reactors still in operation

Several U.S. universities have lost their research reactors since the late 1980s. Many were shut down because authorities at the universities argued that such facilities are costly to run and apparently underutilized by research staff. Those who run research reactors see things differently, arguing that the facilities are versatile and important.

Early in 2017, the University of Missouri Research Reactor (MURR) submitted a request to the Nuclear Regulatory Commission to allow it to produce fission product molybdenum-99. Mo-99's decay product, technetium-99m, is sometimes described as the "workhorse" isotope in nuclear medicine for diagnostic imaging. Tc-99m is used in more than 80 percent of all nuclear medicine procedures in the United States, but it has not been produced domestically since the late 1980s. "Currently, all of the Mo-99 used in the U.S. is imported," said David Robertson, professor and associate director of research and education at MURR. In the future, MURR could provide nearly half of the U.S. demand for Mo-99, helping to stabilize and support the nuclear medicine community in North America.

Pennsylvania State University is home to the Breazeale Nuclear Reactor—the oldest continuously running research reactor in the United States—which celebrated its 60th anniversary in 2015. Kenan Ünlü, a professor of mechanical and nuclear engineering and director of the Radiation Science and Engineering Center at Penn State, is in charge of the facility. "It is one of the most active research reactors in the country," he said.

More than 20 commercial customers—among them, Lockheed Martin—rely on the reactor's irradiation services every year. "We also are very active in teaching, research, and outreach activities," Ünlü said. "We have programs for elementary and high school children, and almost 3,000 people in total visit every year."

Others also recognize the value of the Breazeale Nuclear Reactor. Over the past seven years, Ünlü has helped secure a \$12.5-million investment, split roughly 55/45 between the university and the federal government, to upgrade the facility. Among other things, the funds have paid for the development of a new core-moderator assembly, new beam ports, and a new digital reactor control console.

From its earliest years, the Breazeale Nuclear Reactor played an important role in President Eisenhower's Atoms for Peace initiative. "Over 170 scientists from 39 different countries received training here, then went back to their countries to build research reactors there," Ünlü said.

Igor Jovanovic, a U-M NERS professor who worked at Penn State before his move to Michigan, said that the Breazeale Nuclear Reactor still helps train the global nuclear reactor workforce today.

The reactor is also important for fundamental research. Jovanovic took advantage of the facility for research into new laser technology designed to monitor weapons-grade uranium from afar. To test the technology, Jovanovic and his colleagues needed access to U-235 samples. "Research reactors usually come with a historical library of samples that can be used in research," he said. During his time at Penn State, he had relatively easy access to that library. "These reactors are a very powerful draw," Jovanovic said. "They bring researchers to places like Penn State."—C.B.

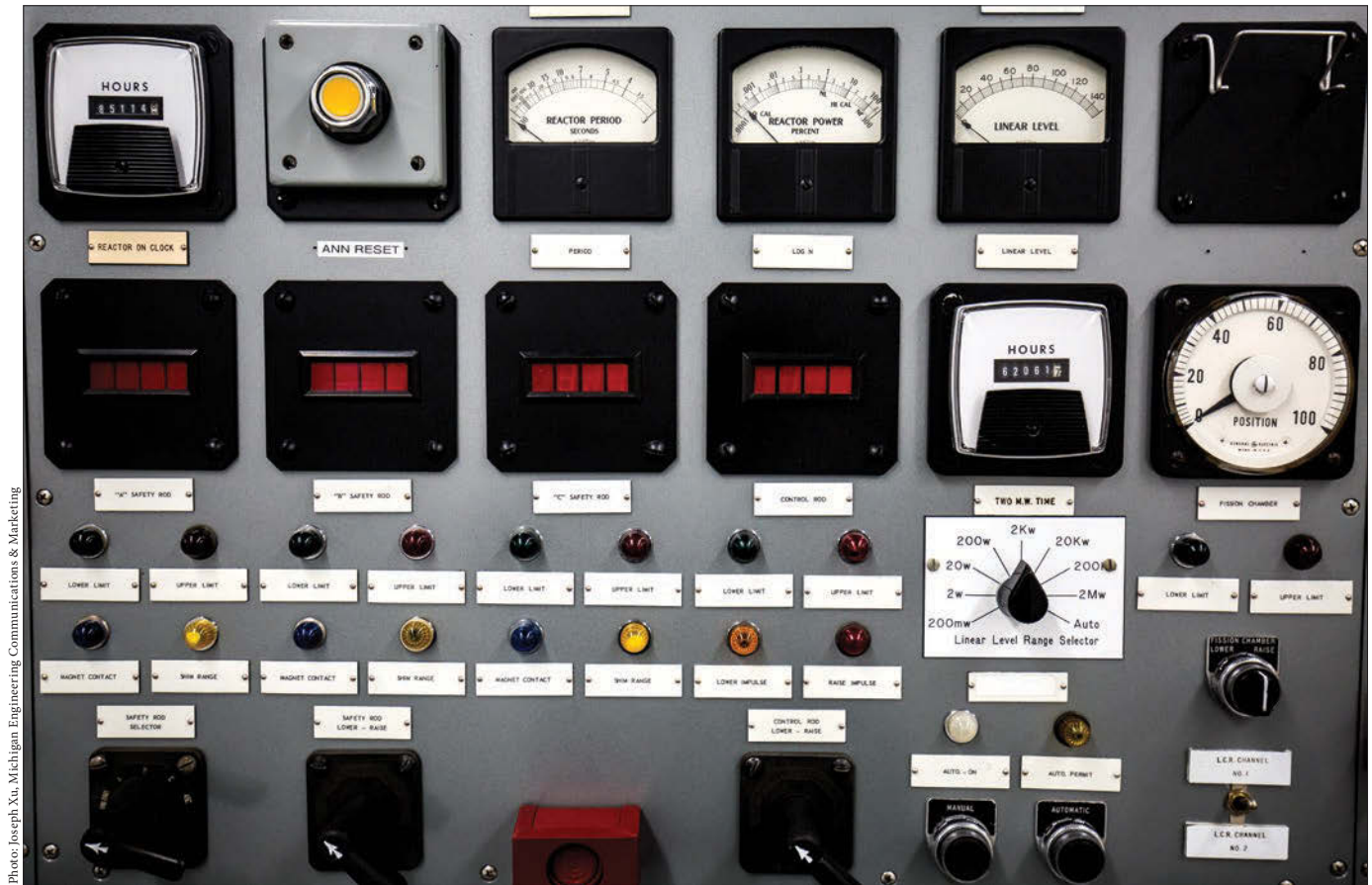


Photo: Joseph Xu, Michigan Engineering Communications & Marketing

The refurbished reactor console is on display in the Nuclear Engineering Laboratory building.

manager at Iowa State, pointed out that the research reactor there had been placed in a preexisting building. “It predated the reactor by approximately 20 years,” he said. This meant that once the reactor had been removed and the decommissioning process completed, the building was a rel-

atively unremarkable structure. An overhead crane inside the building was the only reminder of the reactor’s former presence, Wendt said. Although the building continued to be used for general mechanical engineering research, the university ultimately decided to flatten it to make way

for the new \$84-million Student Innovation Center, scheduled for completion in 2020. Similarly, Washington’s More Hall Annex was demolished to make way for a new structure—a \$110-million computer science building.

At U-M though, the expectation is that the Nuclear Engineering Laboratory will become a worthy successor to the Ford Nuclear Reactor—a new flagship facility to let students and visitors know that nuclear power is still alive and well. The bones of the reactor building still show through, with some of the original concrete interrupting the clean white of the walls and ceilings. On the upper floors, where shielding is less important, the windows are set into alcoves that reveal the thickness of the walls.

Old photos from the Ford Nuclear Reactor days are displayed as art on the walls, and there are glass cases housing mementos from Beyster’s and Knoll’s engineering careers. Outside the meeting rooms on the top floor, the reactor’s control console looks like new, having been refurbished by a local auto restoration company, and the names of the reactor operators are displayed on a screen above it.

“The aesthetics of the space matters,” Jovanovic said. “It’s very good for attracting students to work with us. People will want to use these laboratories, and that’s very important.” **NN**

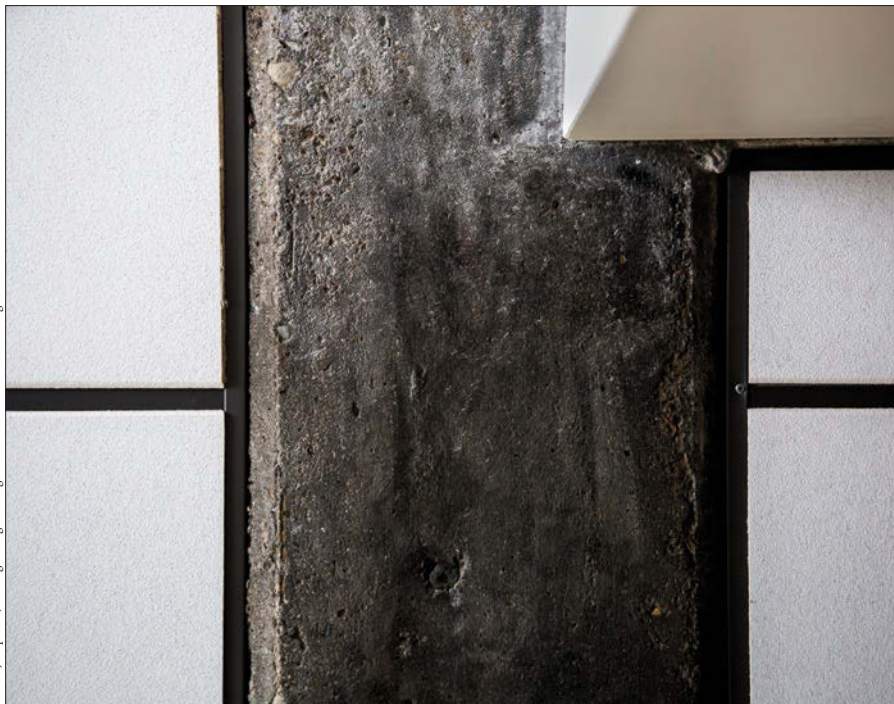


Photo: Joseph Xu, Michigan Engineering Communications & Marketing

An exposed concrete beam in the Nuclear Engineering Laboratory.