H. SCOTT HALLIDAY

A Unique Technician-to-Engineer-to-Scientist Progression

How Navajo Tech's advanced manufacturing program fights brain drain from ancestral lands.

Navajo Technical University (NTU), in Crownpoint, New Mexico, was chartered by the Navajo Nation in 1979 and is one of 35 tribal college or universities in the United States. NTU offers vocational, four-year, and doctoral degrees. Since 2008, I've been working on creating a center of excellence in advanced manufacturing research—particularly, in metal additive manufacturing, which is similar to 3D printing but with metal. Over the past 20 years, the school has worked to provide the Navajo Nation with the tools to become a leader in advanced manufacturing, with the goal of creating sustainable jobs and economic development that reflects the community's values. This has led us to innovate on some of the time-tested models for technical education and to discover new ways to develop our workforce and local economy.

"Just go right in there and start operating..."

One of these pedagogical innovations starts on the very first day of school, in which students are introduced to a unique technician-to-engineer-to-scientist progression that enables today's technicians to become tomorrow's researchers. When a freshman comes to the Center for Advanced Manufacturing, they start operating our advanced equipment right away. That can include the CT scanner, the metal additive manufacturing machine, materials testing equipment, the metal fabrication process known as wire electrical discharge machining (or wire EDM, which uses electrical sparks to cut and shape metal), metrology equipment, laser scanning, and other machines. To reinforce the experience, students learn all four segments of the advanced manufacturing process—preprocessing, processing, postprocessing, and then validation—all under one roof.

I've had some instructors say things along the lines of, "No, students need to know every aspect about this—how this machine was built, how it operates. They need to know the nuts and bolts before they operate this machine." My response is: "Nope, just go right in there and start operating. If it breaks, we'll fix it. This is the time to break it. Hopefully, with the training, you won't break it, but if you do, better here than where you're going to work."

We at NTU also teach students every aspect of the manufacturing process, including where the parts came from and where they are going. In part, this is effective because our students are used to learning holistically. Without being reductionist, this holistic approach is part of Indigenous education. But the other part of the thinking is that if a workforce is needed, it is needed quickly, so we as educators must learn to meet that demand and build systems to support that workforce development.

Our philosophy is that students need to understand more than just one machine. We are not just training workers or operators—we're educating people who may become researchers or entrepreneurs, problem-solvers and

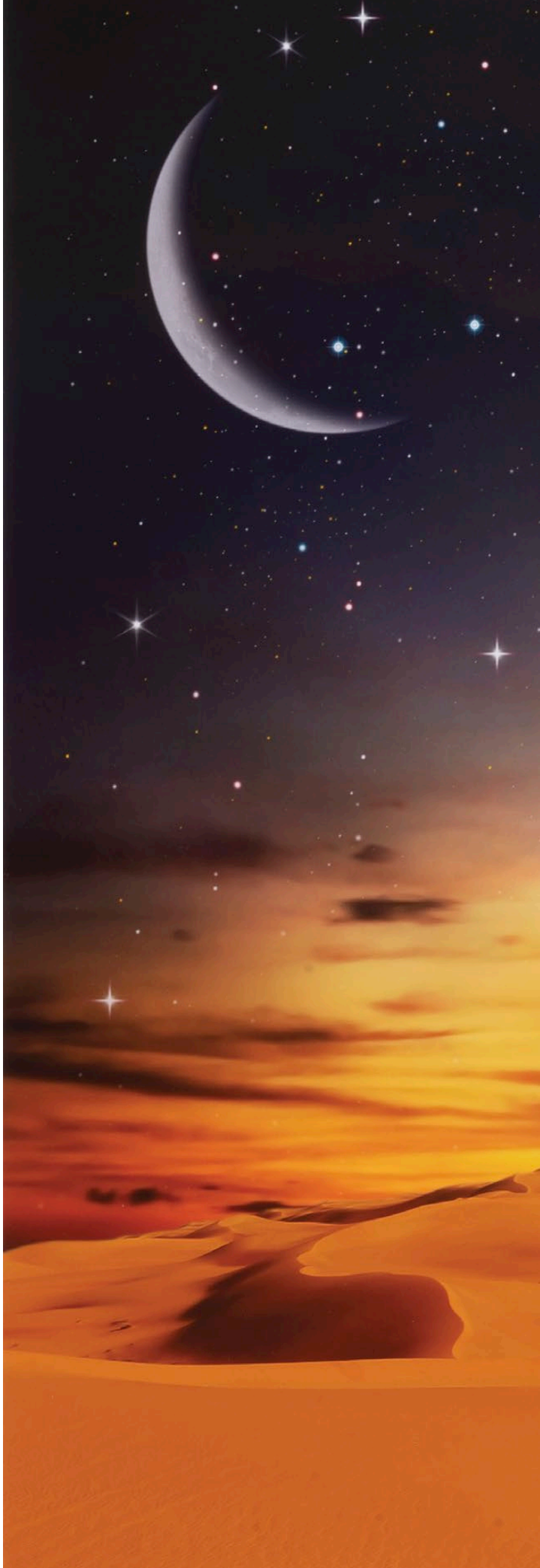
innovators. We teach students the whole value chain. That includes preprocessing, which involves computer-aided design, feedstock, and simulations. Processing includes building the object and operating the machine, and postprocessing means bringing the object into tolerance and finishing it with machining and heat treatment. Finally, validation involves testing the material, characterization, metrology, and CT scanning. Our technician-to-engineer-to-scientist progression gives students the ability to gain confidence; as they learn, they reach plateaus where they can reflect on where they have been and where the path forward can lead them.

The students are very happy with this—it's empowering for them. Someone mentioned that my interns have a different walk about them compared to other students on campus. It's because they operate $750,000 pieces of equipment.

Preventing brain drain through partnerships

Another way that our approach is different is that our commitment is to the tribal nation and their goals. In the traditional model of technical education, there is a tension in educating people where the jobs don't yet exist; the concern is that education ultimately leads to brain drain, because people must leave to get jobs. This might not be so bad, as the Navajo way is to go out, gain more knowledge, and then bring it back to the nation. But the missing link is that there are no opportunities for highly skilled individuals who want to use their skills on ancestral lands. To create a lab that supports the tribal nation, we had to reimagine what the jobs and possibilities are.

One solution was to partner with New Mexico State University, New Mexico Tech, University of New Mexico, Purdue University, University of Nebraska, Rowan University, and other schools. Through these partnerships, the students we've trained to be technicians can get master's and doctoral degrees, gaining more education and doing research without having to leave the reservation. These students have an opportunity to participate in cutting-edge research involving prominent universities. Our students won three of the six awards for the ZEISS company scholarship in coordinate-measuring machines and metrology. Three of the winners are now enrolled in a master's program at Purdue University. Los Alamos National Lab (LANL) hired seven of my interns, pays them, and lets them do the LANL work in my lab. This is important because all of them get to stay on the Navajo reservation and remain with their families. I'm not sure they would have enrolled in the program if they had to leave the reservation.



WENDY RED STAR, *Stirs Up the Dust*, from the series *Thunder Up Above*, 2011, feathers, beads, synthetic fabric. Courtesy of the artist. © Wendy Red Star.

CARA ROMERO, *Three Sisters,* 2022, archival digital print. Courtesy of the artist. © Cara Romero.

A roadmap to leverage niches

We started with a vision, a roadmap, and a strategic plan of where we wanted to go, and then we adopted new strategies as we discovered what we needed to do. The foundation for the roadmap is having a clear understanding of what the *Diné* (Navajo) people have to offer. Some have made claims that the Diné people and the Navajo Nation do not have a tradition of either entrepreneurship or working in manufacturing. This is just not true. Traditional handicrafts, like pottery, weaving, basketmaking, and silver, are all part of the Diné culture. These handicrafts have had generations of innovation in craftsmanship as well as market development. In this sense, advanced manufacturing—with its sophisticated singular products for individual consumers—is quite close to the Navajo tradition. First, it is small-scale. Second, it is sustainable. And third, it produces high-value products that are niche and adaptive.

So when we developed the vision for NTU's Center for Advanced Manufacturing, we looked for ways to actually be niche and adaptive, small-scale and sustainable—in line with the values of the community. What could we do that was unique? We weren't going to get there by following; we had to figure out how we could lead others in the region.

I realized that CT scanning was crucially important for the metal additive manufacturing industry, which constantly needs to validate new materials and prove their process is free of defects. But no one in our area had one. I figured that if we had the only CT scanner in New Mexico, the bigger schools would have to partner with us to conduct their metal additive manufacturing (AM) research. This model worked so well that many of our partners decided to purchase their own machines when they understood the importance of this technology. We still partner with schools and industry who can't justify acquiring their own CT scanner but still need access to the data it provides. NTU will always have these partners, partially because we have been conducting CT scanning for metal AM for so long that we now have a demonstrated track record.

Following that same template, we knew that the two national labs in New Mexico (Lawrence Livermore and Sandia), as well as universities across the country, would be interested in atomizing new alloys so they could start using them in their work. We are the first organization in New Mexico to own a metal AM powder atomizer, which will allow us to start making our own metal AM powder. The labs are already lining up at our door. Now we're recognized as leaders in New Mexico in metal AM. Big schools come to us for the technical aspects of metal AM, which is nice—and it's empowering for our students.

But this is really an unknown economy. When someone asks, "Who are your customers?" or "How much will you generate?" I say, "I don't know." We don't know what the metal AM technology will enable, nor how much new material people are going to develop, nor how much more demand there will be. We don't know what opportunities will be unlocked when more businesses have the opportunity to develop along with us. It's a "build it, and they will come" kind of faith: People needing manufactured parts go to where manufacturing happens.

This relates to the complicated question of what economic development looks like in the Navajo Nation. I think it will mean smaller distributive manufacturing businesses in the communities that want them. Different communities want different things: Some communities want farming and more traditional lifestyles. There is also a history of manufacturing operations that were brought into Navajo land that have not yielded the expected results. Fairchild Semiconductor's plant, which opened in 1965 and closed in 1975, is an example. Today we are working with the Navajo Nation Division of Economic Development to identify the communities that want advanced manufacturing and its smaller footprint, and we are working to create the infrastructure through a grant from the National Science Foundation's Regional Innovation Engines Program.

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But there are many hurdles. We still need broadband internet throughout the Nation. Even though bridging the digital divide has been a priority for decades, we still have last-mile issues. During COVID-19, students had to drive up to the highest point they could find, trying to get a signal to continue their coursework. Roads are also an issue. Developing shipping and supply chain solutions requires road improvements, which demands good geographic data that we don't have—and electricity and water are still challenges. Many families come into town to get water and truck it back to their homes. So these days, we're also working on building microgrids and water initiatives. I used to think our task at NTU was to create new businesses, give people jobs, and enable them to stay in their community. But part of what we also need to do is help foster quality of life.

H. Scott Halliday *is the coordinator of the Center for Advanced Manufacturing, Navajo Technical University's metal additive manufacturing research lab, and has been at NTU for 22 years.*