## **Bigger, Bolder and Faster**

At the University of Maine's Advanced Structures and Composites Center, producing the world's largest 3-D-printed boat is just the beginning

n September, the University of Maine installed the world's largest 3-D printer at its Advanced Structures and Composites Center on the school's campus in Orono. Immediately, the center's executive director, Habib Dagher, decided to test the machine's limits. "We bought this big printer not to start small, but to

go big," he says. "Why build the world's largest 3-D printer on Thursday, Sept. 17, at about 10 p.m., the Ingersoll 3-D to print a shoebox? We said, 'Let's find a boat and make a design that's complex and print it.'

Navatek, which is based in Honolulu and has an office in Portland, Maine, had a design for a 25-foot patrol boat. The engineering firm — which designs and analyzes hull forms, ocean structures, underwater lifting bodies and coupled hydrodynamic systems - supplied the CAD drawing, and



printer at Orono went to work. At 10:15 p.m., the following Sunday, the boat, 3Dirigo, was printed. Dirigo is the Maine state motto; in Latin, it means, "I lead."

"The question was, can we really print the whole boat at once?" Dagher says. "We weren't trying to print a boat with the best material properties. We were just trying to see if we could even do this. Can you print an entire 25-foot, 5,000pound boat in 72 hours without stopping?"

The answer was evident when Maine's U.S. Sens. Angus King and Susan Collins, and U.S. Rep. Jared Golden, sat with Dagher in the boat in the middle of the center's test tank during a media reception in October. The boat isn't seaworthy, Dagher says, but it is proof that the center can 3-D-print large objects.

When Dagher started the Advanced Composites Center 15 years ago, the facility installed a large extruder and began working with a variety of materials, many of which are

wood-based. That is a key element of the center and its 3-D-printing process because if materials derived from wood can be used, it would help Maine's timber industry, which has been hit hard, with a number of paper mills shutting down.

'We learned a lot about materials using the extruder, so the 3-D printer was a logical decision for us to go from a fixed extruder to a moving extruder," Dagher says.

Another item the team recently produced was a mold for a tender hardtop that Hodgdon Yachts in East Boothbay, Maine, built. The hardtop was made with wood non-cellular powder (a fancy way of saying fine sawdust) mixed with polylactic acid, or PLA, plastic. When the mold reaches the end of its life, Dagher says, it can be recycled and used to make something else.

## **Partner in Ideas**

It helps to have someone backing you up when embarking on new technology, and Dagher found that someone in James Anderson. The former director of engineering at Hodgdon Yachts, Anderson met Dagher at a conference at the Advanced Structures and Composites Center. "We started talking about 3-D printing," Anderson says. "Developing a large-scale printer for tooling was way too big for any one boatbuilder to develop and buy."

He joined the center in 2016 as the senior R&D program manager II. Anderson has a background in composites and aeronautical engineering, and he worked on cars that raced the 24 Hours of Le Mans. He also worked at composites supplier High Modulus in New Zealand, where he put together the materials list for an 80-foot carbon-fiber yacht that ran at 80 mph. He found his way to Hodgdon Yachts while working for composites supplier Gurit on a project with the builder.

"I said to Tim Hodgdon four years ago, 'Someone's going to print a boat in the next five years, and I want it to be me,' Anderson says. "I've wanted to print a boat since I got here."

Dagher and Anderson started talking with representatives from the Oak Ridge National Laboratory in Tennessee. Oak Ridge has its own large-scale printing equipment and had a relationship with the U.S. Army and the U.S. Army Corps of Engineers. After a few visits to each other's facilities, Dagher, Anderson and the folks from Oak Ridge decided to collaborate on future products.



Grants from the Army and the Corps of Engineers covered much of the \$3 million cost for the printer at UMaine. Other funding from the Maine Technology Institute is used to support the center's work with state boatbuilders, including Sabre, Hinckley, Hodgdon and Lyman-Morse. "Boatbuilders in Maine can adapt quickly and are very

innovative in their techniques," Anderson says. "These guys know their stuff, and they're not afraid to take risks. They're competitive with each other, and they support each other." After researching printer manufacturers, Dagher and Anderson agreed that Ingersoll would supply UMaine with the world's largest 3-D printer. During the unveiling of *3Dirigo*, a representative from Guinness World Records verified that the Advanced Structures and Composites Center has the world's largest 3-D printer and that the boat was the largest 3-D-printed object built to date. The machine measures 60 feet long, 22 feet wide and 10 feet tall, and can be stretched to 100 feet long. It has two heads: one for 3-D printing and

one for five-axis milling.

## **A Calculated Risk**

you know if it's even possible?"

Anderson had done some test prints with Ingersoll during the summer, and the center had printed a large mold for a composite girder for bridges. It was made of the same acrylonitrile butadiene styrene, or ABS, plastic that was used to print the boat.

The key to being able to complete the boat without stopping was the use of patent-pending slicing software that Anderson developed. The software tells the printer head how to move around and where to go next after it lays down a bead of material. There needs to be time for the plastic to cool before the next layer can be applied, and the software keeps the process on track.

The boat was printed with carbon ABS because the center was familiar with the material. There was no intention of the boat being seaworthy. "That told us what was possible," Dagher says. "The next step is how to design it with the right properties to make it seaworthy."

The mold for the Hodgdon hardtop was printed with cornand wood-based materials. "It's 100 percent recyclable," Dagher says, adding that the micro-cellulose wood powder drives down the cost by nearly 50 percent, and is lighter and stiffer than materials currently used to make molds.

can finally answer."



Habib Dagher

Anderson and Dagher both say Ingersoll understood what they wanted to do long-term - until Dagher informed them that he wanted the first printed item to be a 25-foot boat. "The Ingersoll people we were working with kept saying no," Dagher recalls. "We found the president on vacation in Italy, and he agreed that we should go for it. It was a calculated risk, but if you don't try, how would

"Wood is our largest natural resource, so it makes sense to use it," Dagher says. "Can we make it with those materials and have it properly reinforced? These are the questions we



In addition to moving technology forward, the center is training engineers. Since the facility opened, Dagher says, it has had 2,400 students. It annually sponsors 170 students as interns, and undergrads work up to 30 hours a week and full time during the summer. "By the time they graduate, everyone wants them," he says. "They learn by actually working together and solving problems and meeting schedules.'

Within a year, Dagher says, he wants to supply plugs and molds to boatbuilders. Additionally, the center has a wave tank and a wind tunnel. A boatbuilder could print scale versions of a potential new model, put them in the wave tank and see which one works best in a fraction of the time it would take to do things the traditional way. "Pick the one answer is, we're going to try."

you want and print it," Dagher says. "The ability to innovate has been turned upside down.'

Brian Barer, the deputy director of advance planing hull forms at Navatek, says he can't wait for the time when he can get a plug or mold for a hull printed at the center. "The big advantage for us is to get a perfect plug that is recyclable for them to just grind up when it's done," he says. "We can go from design to having a plug in days rather than months and weeks. There's no question that we feel 3-D printing has a future for building boats."

Dagher hasn't quite moved on from boats, but, not surprisingly, he is already looking forward. "Now people are asking, 'Can you do something bigger?' " he says. "And our