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Eighteen-year-old Justin Beckerman has always liked to build machines. So earlier this year, when he wanted to explore Lake Hopatcong near his home in New Jersey, he made himself a personal submarine.

Justin built the 2.7-meter (9-foot) sub, which he named the Nautilus, out of a plastic drainpipe. The sub has motors, water pumps, depth sensors, an electronic control panel, four battery systems, and an emergency air supply. It draws in air from a floating buoy attached to the sub by two long hoses.

Justin, now in 12th grade, can dive 9 m (30 ft) in the Nautilus and stay underwater for up to two hours, cruising at a top speed of 2.4 kilometers (1.5 miles) per hour. Every 30 seconds, he honks a horn on the buoy to let his parents know that he’s okay.

Kid inventor

Justin has engineered things since he was a toddler. Back then he used simple materials like fabric and string. As he got older, he started experimenting with electronics.

In sixth grade, Justin’s teacher said she wished she had a light-up sign to tell students to quiet down. Justin went home that night and wired light bulbs and switches into a box that could illuminate two different signs: “Quiet” or “Applause.”

When he was 15, Justin saw a movie at school about one of NASA’s Mars exploration rovers. He decided to build his own working rover out of a camera, a tripod, motors, and solar panels. He used a remote control to drive the rover around outside while he watched the camera feed inside on TV.

Justin has also built dozens of remote-controlled aircraft, miniature boats, and robotic contraptions. “Everything I do builds on the previous things I’ve done,” he says.
Learning Curve

Justin built his first submarine when he was 12. He made the body out of corrugated plastic, like the kind used for lawn signs, and sealed off the edges with tape. He added a motor and controls so he could get inside and steer the craft around. But when he tested it out in his family’s swimming pool, there was a problem: The sub wouldn’t go underwater. “I could float in it, but it really didn’t work as a submarine,” says Justin. “I didn’t understand buoyancy.”

Buoyancy is the upward force that water exerts on a floating object. The more water an object displaces, or pushes out of the way, the greater the buoyant force pushing up on it. To counteract this force and dive, a submarine needs to weigh more than the water it displaces (see How a Submarine Dives and Rises, right). Justin’s sub was too light.

A few years later, Justin tried again. He built a new submarine out of plastic storage bins, duct tape, and a Plexiglas cube. He also added weights, sandbags, and water tanks as ballast to make the sub heavier.

This time, Justin’s submarine went underwater, but then he encountered another problem: fluid pressure. As a submarine descends, the water around it pushes in on it with increasing amounts of force. This sub could dive about 0.6 m (2 ft) into the pool. Beyond that, the box-shaped body wasn’t strong enough to resist the increasing pressure. The walls caved in, the duct-tape seals pulled apart, and the submarine sank. Justin wasn’t deterred. “I really understood now why it didn’t work and how I could make it work,” he says. “This year I completely redesigned every part of it.”

Submarine Success

Justin spent a month planning out the Nautilus and gathering the parts he would need, which cost him just under $2,000. He recycled many parts, like batteries, from previous projects. When he found a discarded soda fountain in a shopping mall parking lot, he salvaged valves to use in his water tanks and dials for his controls.

He ordered other components online, including the large plastic drainpipe he used for the body of the submarine. He knew the pipe’s cylindrical shape would make it stronger under pressure than the boxy sub. “Tubes or spheres are much better [than boxes] at resisting uniform external pressure,” explains Andy Bowen, a submarine engineer at the Woods Hole Oceanographic Institution in Massachusetts. A box’s walls bend inward under pressure, but a round shape spreads the force out evenly.

Justin added three ballast tanks. He installed pumps to draw water into the tanks when he wanted the sub to descend, and a compressor to fill them with air and force the water back out when he wanted it to rise. Justin used about 610 m (2,000 ft) of wire to connect all the electrical parts to batteries and control switches. He capped the top of the sub with a Plexiglas dome. Then he sealed everything off to make it watertight.

In May, after five months of construction and tests, Justin was ready to take the Nautilus out for a dive in the lake. With the flip of a switch, he filled the ballast tanks to lower the submarine into the water. This time, everything worked just as planned. “Once you start going under, you just hear bubbles,” he says. “It’s pretty cool.”

Justin wants to study engineering in college next fall. His advice for other aspiring young inventors? “Just keep thinking, creating, and dreaming.”

—Mara Grunbaum

Core Question

What did Justin learn from his first attempts to build submarines that helped him design the Nautilus?