

Grad Student Builds 3D Printed Rollercoaster

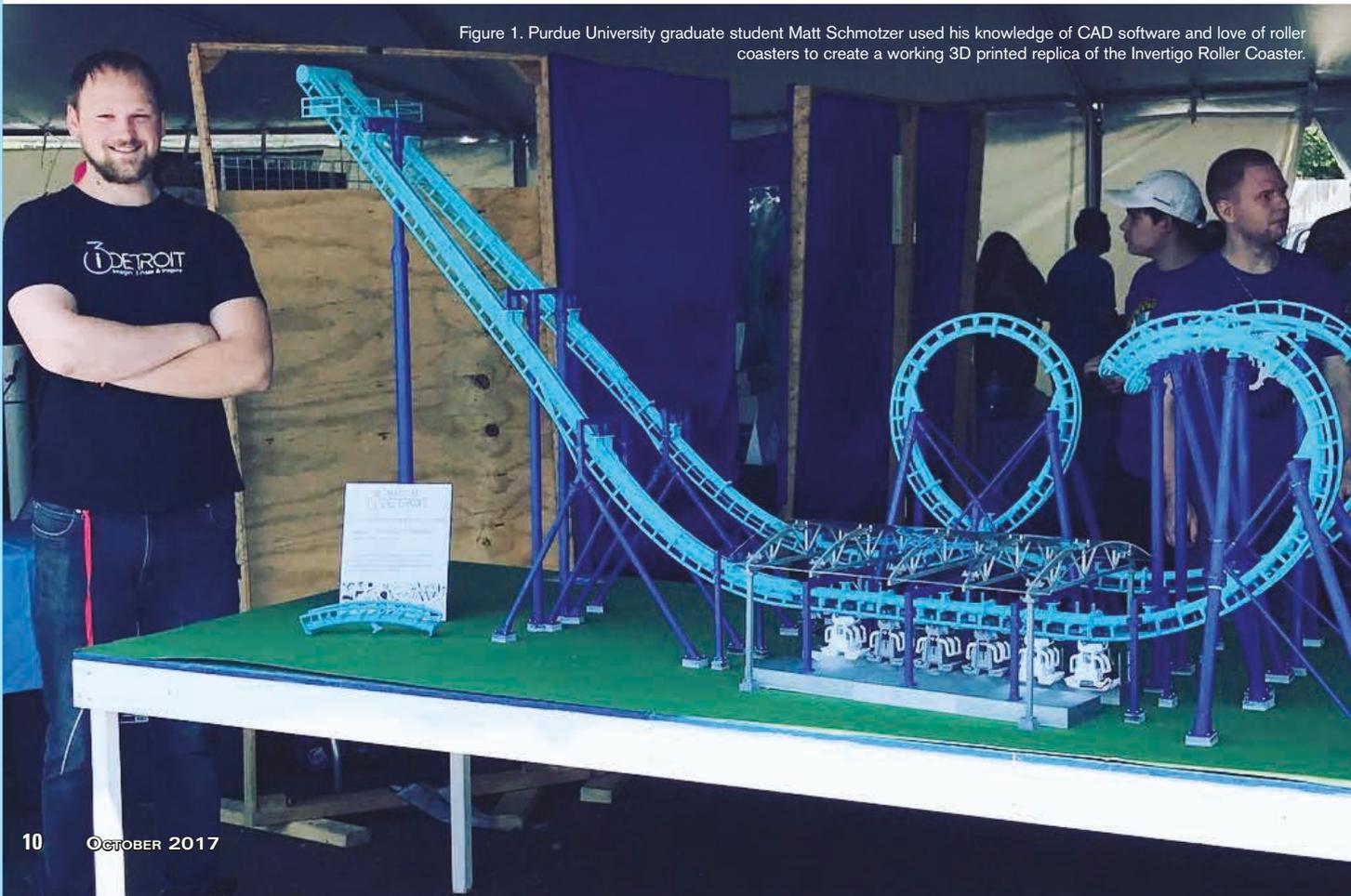
By Spencer Chin, Managing Editor

Matt Schmotzer, a graduate mechanical engineering student at Purdue University, has always had an affinity with both roller coasters and 3D printing. While studying for his master's degree, as well as working at Ford Motors, Matt decided to combine his passions for both by designing and constructing a replica of the Invertigo Roller Coaster (Figure 1). Haven't heard of this roller coaster? It is the one of three inverted boomerang styled roller coasters in the United States. This particular ride is located at King's Island Amusement Park, in Mason, Ohio. Schmotzer recently displayed a replica of the roller coaster at the Detroit Maker Faire.

Schmotzer's extensive background in CAD/CAM software gave him some of the necessary technical background he'd need to learn 3D printing. Armed with a good working knowledge of Dassault's CATIA multi-platform suite and the SOLIDWORKS CAD platform, Schmotzer's next decision was which roller coaster he would model. "I wanted it to be a ride I've ridden on myself, and I wanted it to be a ride that's small enough so that when I build it, it can fit in my garage; because roller coasters can have a giant layout and they're all unique in their design."

The young engineer actually started the design back in January, when he was taking a break from designing a fuel sender, an assignment for one of his classes. "I did that project and I just was playing around, making the roller coaster design in SOLIDWORKS. Then once I got it about 80% complete, I was like, should just start 3D printing this!" Using SOLIDWORKS to create the coaster was a learn-

Figure 1. Purdue University graduate student Matt Schmotzer used his knowledge of CAD software and love of roller coasters to create a working 3D printed replica of the Invertigo Roller Coaster.



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by-doing endeavor for Schmotzer. The school basically said, 'Here's SOLIDWORKS. Just go at it!' A lot of kids struggled because they'd never used it, and the instructor essentially told us, 'You got to start playing around and using it sometime, because if you're going to be an engineer, you're going to have to be able to do design work.'

When originally interviewed, Schmotzer said the model was not complete. "... It's a fully complete static model, meaning I have the whole structure built, all the supports and the track put together" he said. "The next thing I want to do is get the train physically running on the track, and the train was also designed in SOLIDWORKS and 3D printed."

Schmotzer kept working on getting the ride operational, and shortly before this story went to press, the tiny cars began running on his model coaster for the first time¹. Along the way, he encountered a number of challenges.

"The hiccup there is, when you do a scale model you are scaling everything, but you are not scaling gravity," says Schmotzer. "When you think about momentum and getting the train through the whole circuit, momentum is mass multiplied by velocity; so you need to make sure if you're scaling this down to 1/25th scale, your mass of the train

has to be at least 1/25th the weight of an actual train to keep the momentum to go through the whole circuit. I need to make sure I reduced all the friction on the wheels and the rails, so I've got to sand it to make sure it's all fine-tuned, and then I also have to make sure I get bearings on the wheels that are low friction bearings."

Schmotzer's expectation is that the train will be gravity driven, similar to how a real-world roller coaster functions. "Hopefully it's going to function like a real roller coaster, so it's going to be all gravity driven. It is a chain drive that, I don't know how familiar you are with the physical ride, but what happens is, it's a shuttle roller coaster. It starts you at the station and the chain takes you to the top, and then releases you. Then you go through the whole circuit up to the second tower, and it takes you back up, and then it drops you and you do the whole circuit backwards... So it's all going to be gravity propelled, just like the real thing. You just have to make sure that the coaster's 3D printed rails are finely sanded."

Schmotzer has six personal printers to handle his 3D printing tasks, and all of them were put to heavy-duty use in the project. With the average track section measuring 10 inches long by 2.5 inches wide, it took 12 hours to print one track per on average, according to Schmotzer. All the track pieces were printed on three LulzBot printers, two TAZ 5s and a TAZ 6. Schmotzer's other 3D printers -- a MendelMax, a VORON Core XY, and a Flashforge Finder -- were used to print the support structure and support materials.

According to Schmotzer, the coaster used dowel rods for the cylindrical vertical supports, but everything else is 3D printed. "The cool thing about this project is that from the CAD, you can see the footer layout. You can lay down a sheet and extract all the footer locations as a DXF [file], and use the

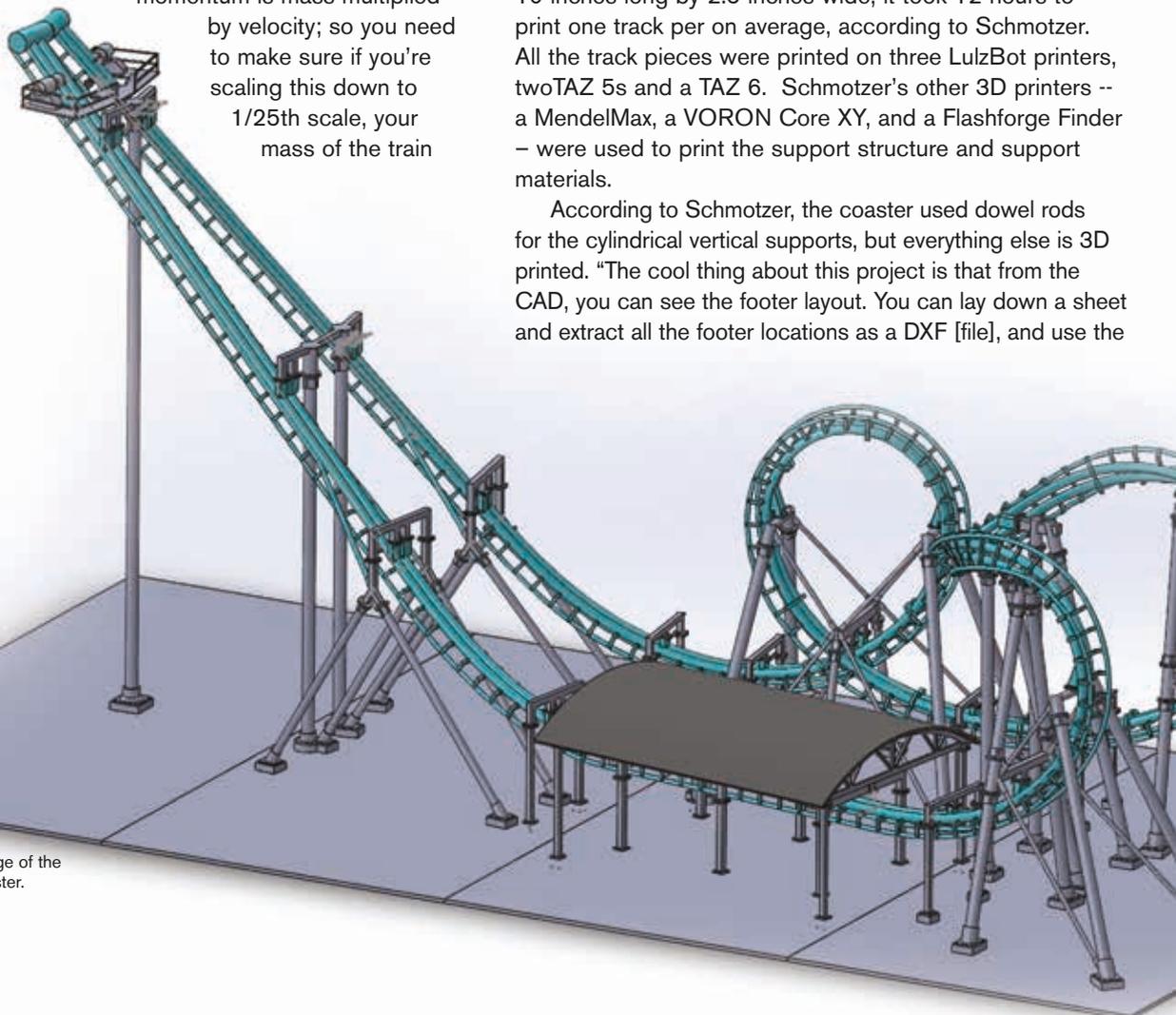


Figure 2. CAD image of the Invertigo roller coaster.

laser cutter at the shop to laser cut the plywood sheet, so I could get the actual exact location of the footers for all the supports."

He added, "This was a life saver because when you're assembling it, it's kind of like an art in the sense of, 'Do I put the footer here?' You've got to measure it out, and it was super easy in this case. All I did was export the DXF and then the laser cut all the bolt hole locations on the ground, so I could just easily assemble the footer. It knew exactly where it was going to go."

While 3D printing does speed prototyping and development, Schmotzer still spent a lot of time tweaking the roller coaster's design. "If you asked me before I assembled it, I would've told you, it should probably take a day or two," said Schmotzer. "It took about a week and a half, and like two full days over a weekend to get it all assembled because each track piece is bolted together; just like an actual roller coaster."

Schmotzer continued, "When they manufacture a roller coaster, they manufacture each individual track section, and then they bolt it together on site. I wanted it to be as authentic as possible, so I wanted to do it the same way. I'll 3D print each individual track piece, and bolt it together with M2 fasteners. It took a long time because each part has about four M2 screws that have a nut on the other end that can fasten together. It just takes a lot of time, because you have to fit your Allen Wrench in between all these track pieces, and there's some that have a really tight clearance to get the wrench in there."

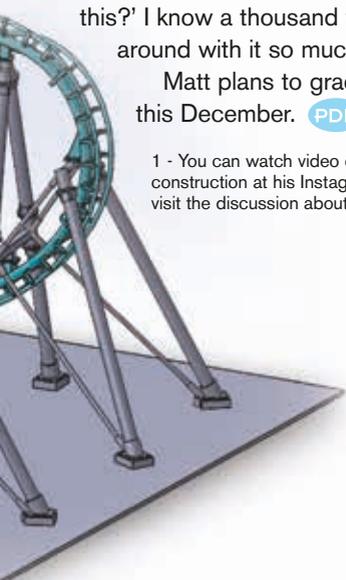
Once Schmotzer fabricated the Invertigo prototype, he had to transport the model to and from the Detroit Maker Faire at the Henry Ford Museum in Dearborn, MI, which created some interesting challenges. He could only come at certain times to drop off the project and had to wait on line to pick it up later on. Schmotzer wound up using his father-in-law's box truck and put the 6 ft high model on an 8 x 4 foot table.

Schmotzer hopes to put the Invertigo model design on Thingiverse so others can get their hands on it. "For future projects, as long as I still have access to [SOLIDWORKS], I really want to do another roller coaster that's bigger; but before I get kicked off on that, I want to finish this one. I want to make it so I can take all the files and just upload them onto Thingiverse, so that anyone can just download it for free, and just kind of get momentum... but I haven't posted anything yet." One of the cool things about just knowing CAD design, engineering, and product development, is it always helps. It just shows that you understand the tool, and one of my professors always said, 'The best CAD software is the one you know, because once you know how one platform functions, you can switch between using software like CATIA and SOLIDWORKS!'

Schmotzer has thought about discussing his design experience on video. "Definitely, because even on Reddit people have been asking me, 'How the heck do you model this?' I know a thousand ways not to build a roller coaster, because I've just tinkered around with it so much."

Matt plans to graduate with his master's degree in Mechanical Engineering this December. 

1 - You can watch video clips of the model in action, and see some additional details of its construction at his Instagram page: https://www.instagram.com/print_my_ride/. You can also visit the discussion about his creation on Reddit at <https://tinyurl.com/Invertigo-Reddit>.



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