Desktop Metal

CASE STUDY

Metal 3D Printing for University Curriculum and Student Projects

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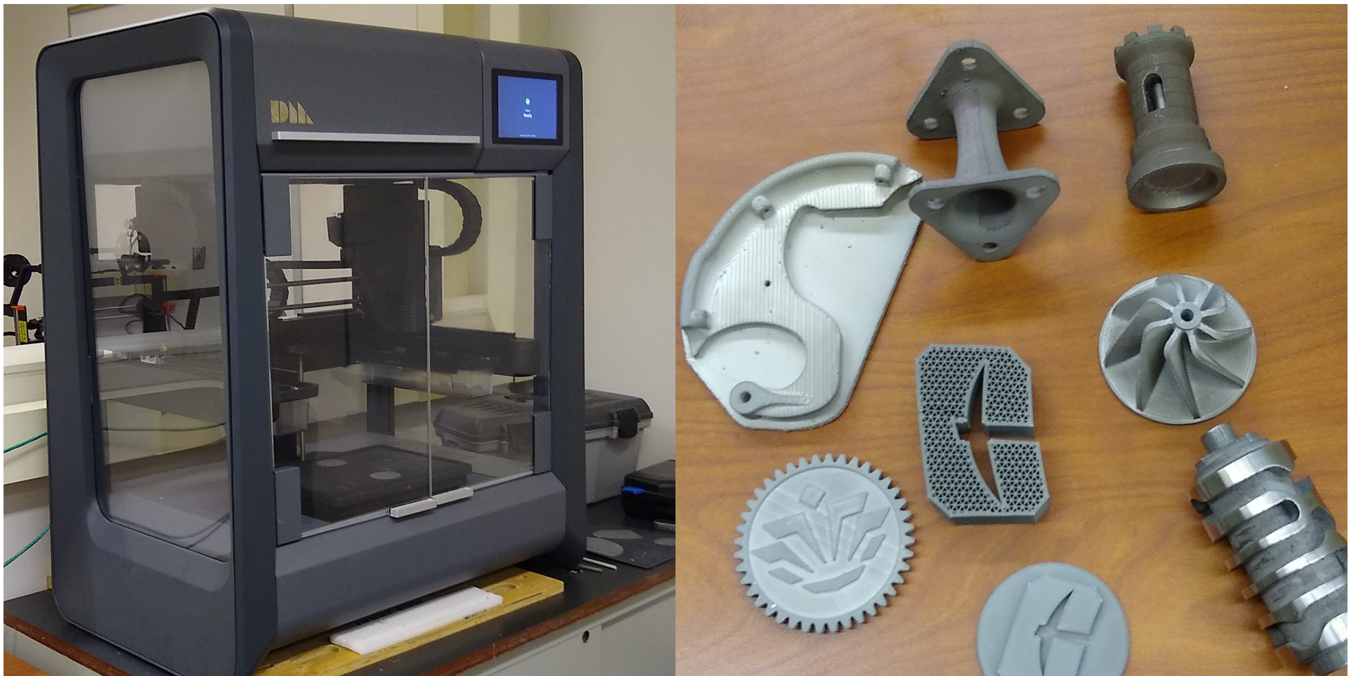
49er Rocketry Team at the University of North Carolina at Charlotte uses the Studio System™ in NASA Student Launch project



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The Studio System allows students to 3D print complex metal parts in the Rapid Product Realization Lab at UNC Charlotte

Customer
University of North Carolina at Charlotte
Rapid Product Realization Lab

Location
Charlotte, North Carolina

Industry
Education

Application
Hinges for the split airframe payload design of a High Power Rocket

Machine
Desktop Metal Studio System™

Material
17-4 PH Stainless Steel

Additive lab as a resource for student design projects

The William States Lee College of Engineering at the University of North Carolina at Charlotte ties its success to its philosophy of teamwork and application. Starting from freshmen year, students participate in hands-on projects to gain valuable real-world experience.

Jeff Raquet, PhD, is an Associate Teaching Professor that explains how design-heavy curriculum places an emphasis on applied learning throughout the educational experience. Students learn both traditional and additive design principles throughout each year of their studies with integrated hands-on learning throughout. Freshmen students learn to model parts in CAD and make engineering drawings while senior students must manufacture a capstone project they've engineered to present a physical part at the end of the year.

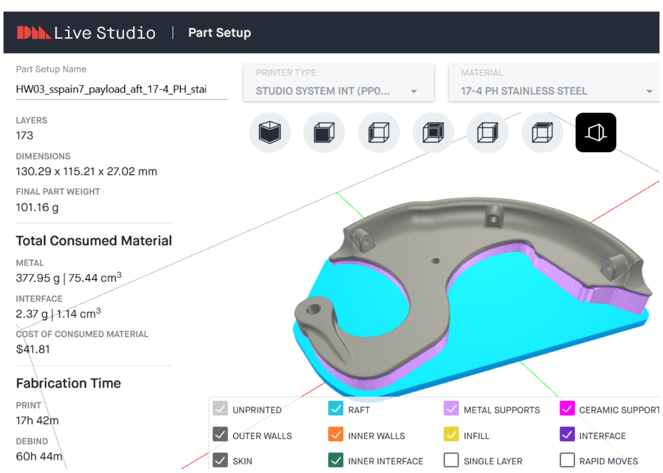
Students traditionally run mills and lathes in the university's machine shop, but as the Director of the Rapid Product Realization Lab, Dr. Raquet says an additive option is in the works. The lab provides students with real world experience in rapid manufacturing through design and production hardware and software. Along with CNC equipment, the lab runs a fleet of Fused Deposition Modeling (FDM) machines and some Stereolithography (SLA) and Selective Laser Sintering (SLS) technologies.

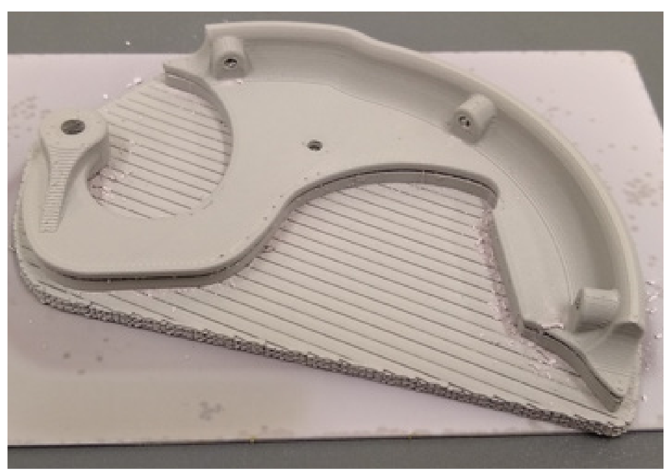
When looking to invest in a metal 3D printing process to add to the lab, Dr. Raquet had one main criteria he was looking for: "Something we could run in a classroom space." While many metal additive manufacturing systems require special facility requirements – from high power electrical outlets to extensive PPE to handle loose powder – the Desktop Metal Studio System offered a simpler solution.

> The university was looking for "something we could run in a classroom space."
>
> **Jeff Raquet, PhD, Associate Teaching Professor and Director of the Rapid Product Realization Lab**
> **University of North Carolina at Charlotte**

Using Bound Metal Deposition™ (BMD) technology, the Studio System extrudes metal rods into complex shapes layer-by-layer, similar to the FDM process for polymers. Rods of pre-bound metal powder are loaded into the machine, eliminating any loose powder handling from the process. With all the necessary software and hardware to go from green part to final sintered metal component, the university installed the Studio System and Desktop Metal furnace in 2020.

Despite a slow ramp up in adopting the technology into curriculum because of the COVID-19 pandemic, the technology is making inroads with students. The Rapid Product Realization Lab serves as an additive manufacturing resource for student design projects and played a role in supporting the award-winning UNC Charlotte NASA Student Launch 49er Rocketry Team.





A software-guided workflow navigates users through the metal 3D printing process, from printing to sintering with step-by-step instructions.

Blasting to 2nd Place in NASA Student Launch Initiative

NASA's Student Launch is a nine-month long challenge that tasks student teams from across the U.S. to design, build, test, and launch a High Power Rocket (HPR). It is a hands-on, research-based, engineering project requiring several design phases and milestones presented to NASA, ultimately culminating each year with a final launch at NASA's Marshall Space Flight Center.

Over 800 students from across the U.S. and Puerto Rico competed in the 2023 challenge, launching high-powered, amateur rockets to an altitude between 4,000-6,000 ft, while making a successful landing and executing a scientific or engineering payload mission.

The UNC Charlotte 49er Rocketry Team, comprised of students completing their senior design project, has participated in the annual competition for over a decade. The team spends the fall semester designing the rocket and developing a subscale before focusing on manufacturing the full-scale design in the spring semester.

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The 2022-2023 UNC Charlotte 49er Rocketry Team launches its rocket, Fidem ad Finem, near NASA's Marshall Space Flight Center in Huntsville, Alabama, as part of the culminating event for the agency's annual Student Launch challenge.

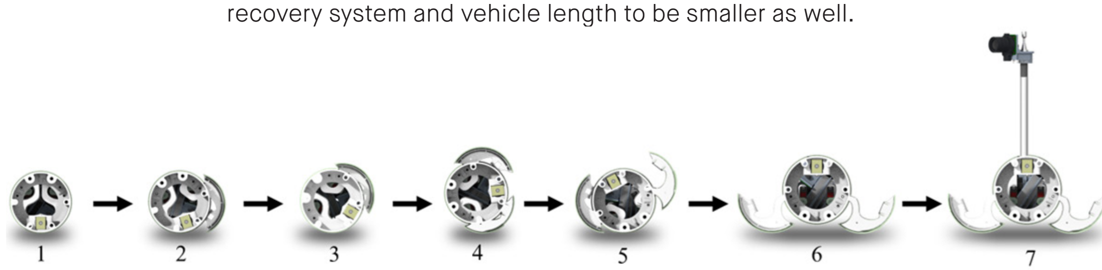
The 2022-2023 49er Rocketry Team built their rocket, *Fidem ad Finem* (Faith to the End,) with a payload mission that, upon landing, autonomously deployed and received radio frequency signals to command an onboard camera system and complete a series of tasks.

> “If 3D printing had not been an option, there would have been more complex and time-consuming composite work or machining operations for most of the components that made up the payload.”
>
> **Stewart Spain, graduating mechanical engineering major and payload integration lead on the 2022-2023 49er Rocketry Team**
> **University of North Carloina at Charlotte**

With 3D printing as an option, the 2022-2023 49er Rocketry Team was able to create complex geometries for their rocket that could be tested and iterated at a rapid pace. “If 3D printing had not been an option, there would have been more complex and time-consuming composite work or machining operations for most of the components that made up the payload,” said Stewart Spain, a graduating mechanical engineering major and the payload integration lead on the 2022-2023 49er Rocketry Team.

The team’s payload utilized 3D printed metal hinges for the split airframe payload design they named SIGHT (Self-leveling Image Generator with High-efficiency Transceiver). The hinges‘ primary purpose was to insure payload retention during flight, payload deployment upon landing, and structural support during all modes. Since the airframe was split axially, the hinges were also the supplemental supports for the lost hoop strength of the airframe.

During the designing stage of SIGHT, one of the biggest constraints from the team were the hinges. The driving dimension set for the payload section was doors no more than 20 in (508 mm) long to minimize decreased structural integrity. Spain also emphasized how the length of the payload affected the total length of the rocket, noting how a smaller payload would then allow the recovery system and vehicle length to be smaller as well.



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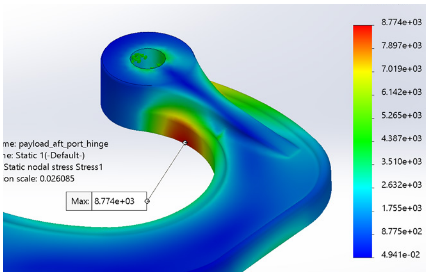
The payload mission of the 49er rocket Fidem ad Finem was to autonomously deploy, flipping the rocket if necessary, and receive radio frequency signals to command an onboard camera system and complete a series of tasks.



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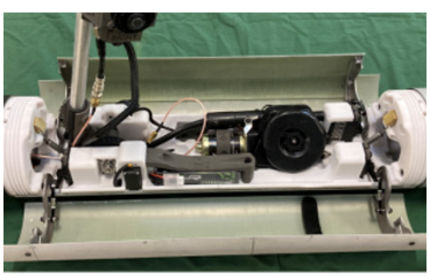
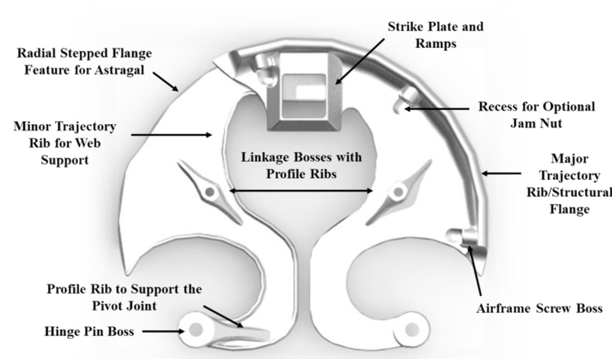
In finite element analysis on 3D printed polycarbonate hinges a weak link was identified at the base of the hinges where the hinge pin connects to the payload bed. This pivot point was analyzed for stresses exhibited in the event that the doors needed to be used to lift and flip the entire payload into the correct orientation, which would put extra stress on the hinges.

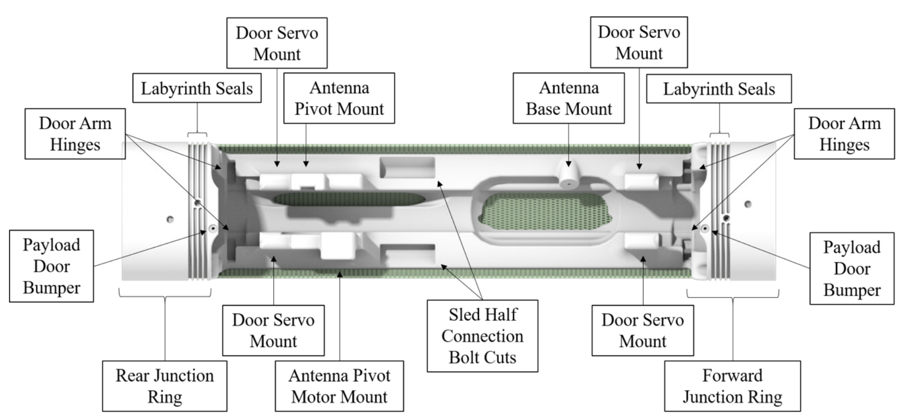
Because the hinges were responsible for keeping the payload bay doors closed during the entire flight profile while the rocket experienced around 10 G-force during ascent followed by the shock from parachute deployment and the impact of touch down after descent, the safety aspect of the hinges was one of the most critical design criteria. This led to many debates among the team about the shape of each hinge and the material that should be used for manufacturing.

Originally designed for 3D printed polycarbonate, the team ran a finite element analysis and identified a weak link where the hinge pin connected to the payload bed. Because of the hinge geometry and the constraints of the payload bay, polycarbonate 3D printed hinges required a thickness of 1/8 in (3.2 mm). However, the allotted gaps for the hinges continued to decrease throughout the design evolution as the size of the servos was scaled up.

For these reasons, metal hinges were considered based on the capabilities accessible to the students in the Rapid Product Realization Lab. Dr. Raquet consulted the team on features of the Studio System, including resolution and material properties. 3D printing the hinges in metal offered a comparable strength-to-weight ratio while halving the part down to 1/16 in (1.6 mm), a thickness Spain explains would have been difficult to achieve with traditional subtractive manufacturing techniques due to the potential warping that would result from milling operations. “The fine details of the part would have been difficult to make on that small of a scale, with the major diameter of the hinge geometry being 5 inches (127 mm) and all other features being even smaller.”

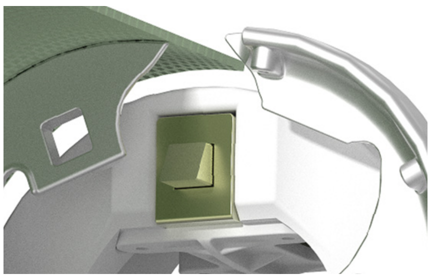






The freedom of design that comes with building a metal part layer-by-layer allowed the team to include complex design features into the hinges with ease.

- The exaggerated "S" shape of the hinges was designed to allow them to swing past a turnbuckle assembly added during later stages to help reinforce the ends of the payload bed
- The stepped flange allowed the astragal airframe to be overlapped by the port side door which prevented ingress of the rushing air into the payload bay during flight



- An optional jam nut recess in the event the tapped holes of the bosses get stripped, jam nuts can be used to secure the doors
- The port side hinges incorporated a strike plate with the socket for the linear solenoid latches to engage with
- The bottom bosses on the hinges required varying offsets to keep the mounting of the servos inline, dependent on its port or starboard side position. This also meant that the trajectory ribs needed to be placed in opposite directions in relation to the center planes of each hinge

- Careful consideration was made for the range of motion for the doors and the linkage mounting holes were easily placed based on providing the maximum range of motion, not for manufacturability ease with conventional methods

A total of six months of payload design iterations were needed to finalize the 63rd CAD revision for the hinge before printing started. The team dedicated the time in CAD software and double-checking measurements with mating components so that only one round of printing was needed. The parts required minor post-processing like tapping threads in the mounting holes.

Launching their rocket in Huntsville, Alabama, the 49er Rocketry Team took second place overall in the 2023 NASA Student Launch Initiative, continuing an impressive run for UNC Charlotte of placing in the top three for the sixth consecutive year. Additionally, the team placed first in the project review and safety categories.

49er Rocketry Team Excels at 2023 Student NASA Student Launch Competition

Overall: 2nd Place
Project Review: 1st
Safety: 1st Place

Altitude: 2nd Place
Payload: 3rd Place
Social Media: 3rd Place

About the 49er Rocketry Team at UNC at Charlotte

The 49er Rocketry Team from the University of North Carolina at Charlotte participates in the annual NASA University Student Launch Initiative (USLI) competition. The team competes against universities around the nation to build a High Power Rocket (HPR) with a payload designed to complete a specific task. Senior students from the William States Lee College of Engineering complete their senior design projects designing the rocket and manufacturing a full scale.

About Desktop Metal Inc.

Desktop Metal, Inc. is accelerating the transformation of manufacturing with end-to-end metal 3D printing solutions. Founded in 2015 by leaders in advanced manufacturing, metallurgy, and robotics, the company is addressing the unmet challenges of speed, cost, and quality to make metal 3D printing an essential tool for engineers and manufacturers around the world. In 2017, the company was selected as one of the world's 30 most promising Technology Pioneers by the World Economic Forum, and was recently named to MIT Technology Review's list of 50 Smartest Companies. For more information, visit www.desktopmetal.com.