A LOCAL SOLUTION TO PLASTIC POLLUTION

by

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HONORS CAPSTONE

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ABSTRACT

Plastic pollution is a well-known issue across the globe with staggering facts such as: “Only 9% of all plastic produced has been recycled,” and “The Great Pacific Garbage Patch is a floating island of plastic waste spanning an area that is over twice the size of the state of Texas.” Locally, this issue persists as 73% of Texas resident’s recycling bins go to the landfill and most municipal recycling facilities only recycle two types of plastic. The driving question behind my capstone was: How can we as consumers take plastic recycling into our own hands? Over the past three years, I have been working to build a plastic recycling workspace on campus. Using the available equipment in the Ingram Hall Makerspace I have built a series of small-scale recycling machines to process plastic for recycling. Using compression and injection molding techniques, we can take post-consumer plastic waste and repurpose it into new products. But there is more work to do like improvements to the machines and optimized processes that future Texas State students can tackle in the next three-to-five years.

OVERVIEW

Hello and welcome to my honors capstone. Allow me to introduce myself and explain how I got to where I am today.

My name is Michael Quinto and over the course of my college career, I have been developing a plastic recycling workshop on campus. I am who some may say is the flame that has kept it going these past few years. If you are reading this out of your own free will, I hope to pass the torch on. But, without a passion for this project, a drive to keep innovating, a determination to push through the bureaucracy of the university, or a support system that keeps you alive, the flame will fizzle out. I know it's daunting. I have been fighting burnout for years now. But if it helps, I want to share my story of how and why I started this endeavor, so that you can spark your own flame for this project.

My high school physics teacher told me “an engineer’s job is to solve problems” and I believe that climate change is the greatest problem our society is faced with. This is why I chose to study engineering. There are so many independent variables in the multiple regression equation that predicts climate change, but I am only one person, so I chose one problem to solve. Fossil fuels account for over 75% of global greenhouse gas emissions (“Causes and Effects of Climate Change | United Nations”) and 99% of plastic is made from fossil fuels. (“From Fossil Fuels to Plastic Addiction: Unveiling the Hidden Link Impacting Our World”) To add insult to injury, plastic pollution adds 3.4% to global greenhouse gas emissions. (“Plastic leakage and greenhouse gas emissions are increasing”) With this in mind, I chose to study Manufacturing Engineering in hopes of learning how to build machines to either clean up plastic pollution or produce alternatives to plastic.

It wasn’t until my third semester at Texas State that my aspirations to save the world and the spark that started this project occurred. I was taking ENGR 2332 - Materials Selection and Manufacturing Processes where we were supposed to get our first introduction to the Ingram Hall Makerspace through labs that taught us to use various industrial manufacturing equipment. But it was the Fall of 2020 and the COVID-19 pandemic had sent all classes on Zoom/hybrid, so instead of physically performing labs, we watched videos of people using the equipment. I was distraught. I felt like I was missing out on such a useful and interesting part of my education. So I sought out a project that would allow me to learn to use the machines on my own.

I found an open-source company from the Netherlands named Precious Plastic. They had developed a series of small-scale recycling machines and a community of people who wanted to recycle plastic on their own terms. The documentation to build their machines were free to download and copy because they wanted their movement to spread globally. With a lack of experience in engineering and a mind full of passion, I took their plans and ran.

I started by building the basic shredder as it is the first step to recycling plastic. I spent hours of my free time and hundreds of dollars out of my savings building it. But I was having so much fun. I cut out all the blades and spacers on the tiny waterjet in the Alkek Makerspace and could be seen carrying a box of metal parts around campus. After about a month of this, I got the attention of Dr. Austin Talley.

At the time, Dr. Talley was advising a manufacturing senior design team that was machining compression molds to recycle plastic into new products. This team was cutting up the plastic by hand, so a shredder would be extremely helpful. He sought me out and invited me to the Ingram Hall Makerspace, which was closed for solely senior design projects as the pandemic was limiting the capacity of rooms on campus. This was a major turning point for me.

Dr. Talley became my advisor, my mentor, and my friend. He helped me apply for Honors Undergraduate Research Funding to pay for the rest of the parts and reimburse me for what I had already spent. He introduced me to an industry sponsor who wrote me a check for $5,000 to continue developing the equipment. He connected me with people within the School of Engineering and the Ingram Hall Makerspace to help me for years to come. With Dr. Talley behind my back, progress sped up.

By the fall semester of 2021, I had mastered nearly every piece of equipment in the makerspace, and had a fully functional shredder. By then Dr. Talley and I had plans to start a plastic recycling workspace in the Ingram Hall Makerspace. He had two senior design teams working on advancing our recycling capabilities. The first team was building an injection machine and molds specific to it. The second team was pushing the size constraints of compression molding by making a recycled bench. Together we all went to the SXSW Innovation Lab Showcase in the Spring of 2022 and received loads of positive feedback from a variety of industries. Unfortunately, both teams graduated and left their projects behind with mild success.

Meanwhile, the plastic recycling initiative I had started was getting attention all around campus. I won first place in the Spring 2022 Undergraduate Research Conference. I worked with the Human Environmental Animal Team (H.E.A.T.) student organization to collect plastic to recycle during the San Marcos River Clean Up. I got to showcase recycled products at the 2022 Earth Day Festival at the Meadows Center. Dr. Talley won the Green Cat Challenge Award from the Environment and Sustainability Committee at Texas State University. There were plans to start a student organization on campus and start recycling workshops on campus the next semester, but then I took time off school.

I started a Co-Op at Apple working on their environmental supply chain innovation team. From May through December of 2022, I worked in the Material Recovery Lab in Austin researching advanced e-waste recycling methods, designing a rare earth magnet recovery machine, and optimizing industrial e-waste recycling equipment. I got to help repair, optimize, and write a standard operating procedure for their shredder. It put my little one to shame, but I came out of the co-op with an even greater passion for recycling and returned to campus in the Spring of 2023.

Upon my return, I began my senior design project which Dr. Talley and I decided would be a new and improved shredder. The previous one worked but was unreliable and lacked certain safety features to be used by the general public. The new shredder had to be robust and safe to be used for years to come. During the spring semester, my team and I spent the majority of our time in CAD designing and preparing to manufacture in the fall.

In the meantime, I applied for Environmental Service Committee funding to purchase a filament shredder. We already had an extruder sitting in storage, so with the Filabot Reclaimer [5] we could start producing

recycled 3D print filament for the printers in the Ingram Hall Makerspace. The Alkek Makerspace had already succeeded in producing roles of filament, so we just needed to copy their system. The reclaimer came in at the end of the semester so I assembled it, and handed the “Recycled 3D Print Filament” project off to the new Engineers for a Sustainable World student organization. Unfortunately, their progress is yet to be seen as I write this.

It is now my final semester at Texas State University, and I have spent all my free time manufacturing and building the shredder v2. By the time this thesis is submitted, it will be complete and ready for use in the recycling system. The journey to this point has been invigorating, with many roadblocks along the way. But I believe that it has the potential to make a real impact in the community.

BACKGROUND ON PLASTIC

About one year ago, I wrote an essay on plastic pollution. At the time I was focused on replacing plastic with natural alternatives. But the staggering facts and overall theme of reducing plastic waste rings true. Please read it for a background on the issue at hand.

Exploratory Paper:

In the year 2023, most of the world is aware of the issue that plastic is polluting our planet. If you are not aware then let me enlighten you. Currently, humans produce about 400 million tons of plastic waste every year; this weight is greater than that of the entire human population (UN Environment Programme). The issue is that a majority of this plastic ends up sitting in an overcrowded landfill or littering our natural environment, where it will remain for a minimum of 400 years before completely decomposing. Even worse is when it ends up in the water cycle where it lasts over 1000 years. To put those numbers into perspective: about 400 years ago the pilgrims landed in America and about 1000 years ago the Vikings were still wreaking havoc and knights were fighting dragons. One can only imagine what our civilization will look like when your plastic bottle from yesterday's lunch finally decomposes. The worst part is that during the time it takes to decompose, it leeches harmful chemicals into our ecosystem, interferes with wildlife often resulting in death, and causes birth defects and major health concerns to humans. According to a study in 2018, on average humans consume about five grams of plastic every week which is equivalent to a credit card (Catarino et al.). Needless to say, this is a major issue for humanity and must be addressed promptly. Through my study of plastic pollution and its overuse on this planet, I found that we must limit our usage and its production to only mandatory applications, adopt its many alternatives for our daily use and new production, and find new ways to dispose of it safely in order to protect our environment and fix this devastating issue.

We can blame Leo Bakeland, a Belgian-American chemist, for inventing the first synthetic plastic polymer, whose discovery marked the transition from natural polymers like rubber to the man-made plastic polymers that litter our planet to this date (Bahraini). This transition has grave implications for humans and the environment that we live in. First, the presence of this synthetic material in nature is damaging natural processes and hurting the wildlife that lives in it. When plastic decomposes it breaks down into smaller pieces while simultaneously leaching off the chemical plasticizers that were used in its creation. Both of these are issues because countless animals have been found to consume these plastic pieces. This can block their digestive paths or poison them from the inside, both of which result in death. While this is horrifying to think about, as it affects many species of fish, birds, reptiles, and small mammals, plastic is also bad for humans. Recent studies have shown that a majority of humans (including infants) consume plastic on a daily basis from our contaminated food and water. Our food can become contaminated because the animals we eat are consuming plastic, and our water is filled with microplastics that most water filters cannot sift out. The plasticizer chemicals we consume can cause birth defects, reproduction complications, hormonal imbalances, and even worse heart disease or cancer (Knoblauch). These are just a few of the terrible results that plastic pollution is impeding on our daily lives, but enough to warrant the question: How do we address this problem?

The simplest solution to this plastic problem is to limit our daily use and production to mandatory applications only. The reason that synthetic plastic is such a problem is because it is such a universally applicable material. It is durable, lightweight, flexible, and relatively cheap to produce. It is great for the elderly with Parkinson's or similar disabilities, for children who are learning to safely move their bodies, and for countless applications in the medical fields

(Bahraini). But, we are overproducing and disposing of this resource in an unsustainable manner. For example, plastic packaging, utensils, straws, and other single-use applications can be made of many other materials that won't have the devastating implications that synthetic plastic has in the long run. You as a consumer can consciously choose to avoid such products to help solve our collective plastic problem by using any of the tried and true or newly innovated alternatives.

There are a variety of alternatives to plastic that are better for the environment and that can be employed by common people and production facilities. The most obvious, yet often forgotten, alternatives are what I would call the classics. To list a few examples: metal cutlery, glass or ceramic cups, or wooden anything instead of plastic. Synthetic plastic became a common material in production in the 1900s, so there are plenty of alternatives that we have used before that are still applicable today. But, we like the properties of plastic so scientists across the globe have invented environmentally friendly bioplastics. Cellulose is a natural fiber produced by many plants that can be used to make plastic that is much better for the environment. This is a great alternative, but most companies won't employ the change because it is too expensive. Luckily, recent research has developed hemp plastics which are, "...non-toxic, pesticide-free, recyclable and biodegradable within six months, not to mention both lighter and 3.5 times stronger than common polypropylene" (Barrett). This is a promising development, and I hope to see it take off in the near future as an alternative to synthetic plastic. Another substitute for plastic that needs more attention by consumers and manufacturers alike is bamboo. Bamboo is durable and relatively flexible like plastic, but unlike plastic it is completely natural and is one of the fastest growing plants in the world. If we take advantage of this resource, it could be an

extremely probable competitor for common plastic products. If we can all take the time and the effort to use some of these plastic alternatives, we can stop plastic pollution on our planet.

Now, many people will argue that there is no point in implementing these alternatives to plastic without first finding a way to restore and clean up our environment from plastic pollution. There is a massive accumulation of plastic waste in the middle of the Pacific Ocean equal in weight to 500 commercial jets and in size to double that of Texas named, The Great Pacific Garbage Patch. This is a notable objection to my argument that we must use alternatives to plastic, but I agree with most of this argument. Yes, of course we need to clean up the plastic, but what's the point of cleaning up if we are producing more than we can clean up. We must do both in order to combat this issue. Luckily, there are scientific advances in the realm of plastic waste management that show promise. A team of German scientists recently discovered a strain of bacteria that literally eats plastic (Davidson). Not only can this bacteria break down the toxic plastic chemicals, but it converts it to fuel, like humans do with food, allowing them to constantly reproduce and consume plastic waste. This is a promising venture to tackle plastic waste in landfills (which are controlled areas) but there is still the issue of plastic in our oceans. The most notable is The Great Pacific Garbage Patch which is a massive accumulation of plastic in the ocean that is over twice the size of Texas. The Ocean Cleanup is a company that is already attempting to combat this issue with a fleet of boats that collect floating plastic in not only the oceans, but river systems as well (The Ocean Cleanup). Needless to say, humans are aware of the plastic problem and are developing alternatives and methods of restoring our environment from it.

The verdict is out, plastic is bad for our Earth, and we must limit our use, employ alternative materials, and restore our environment to overcome the pollution it has produced on

our planet. Plastic is bad for our health and bad for our environment and we are producing way too much of it. In the Pixar animation movie WALL-E humans are forced to flee the planet due to its inhabitability caused by garbage. If we continue to overproduce and overuse plastic on the Earth, WALL-E may be a realistic projection of our world. We cannot ignore this issue any longer, so I urge you to avoid the use of plastic as much as you can in hopes that we can reverse our mistake before it is too late.

SOLUTION

Precious Plastics is a community of people who have the same purpose: to recycle plastic on a local scale without relying on the current systems and infrastructures in place. People from all over the world are building their own machinery to shred and manipulate this plastic into useful products like sheets, bricks to build walls, functional objects like chairs and plugs, and much more. I was very passionate about plastic and when I came across Precious Plastic, I decided to take up the challenge of building a plastic recycling workspace for the Texas State University.

While this may be the solution that I chose to pursue, I do not think that it is the end-all solution to plastic pollution. The only way to fix it is by replacing it with a different material on the manufacturing side or by not using it at all. We could go back to what we did before: paper bags, cardboard containers, glass bottles, etc. The federal legislation regarding solid waste suggests to manage plastic waste in this order:

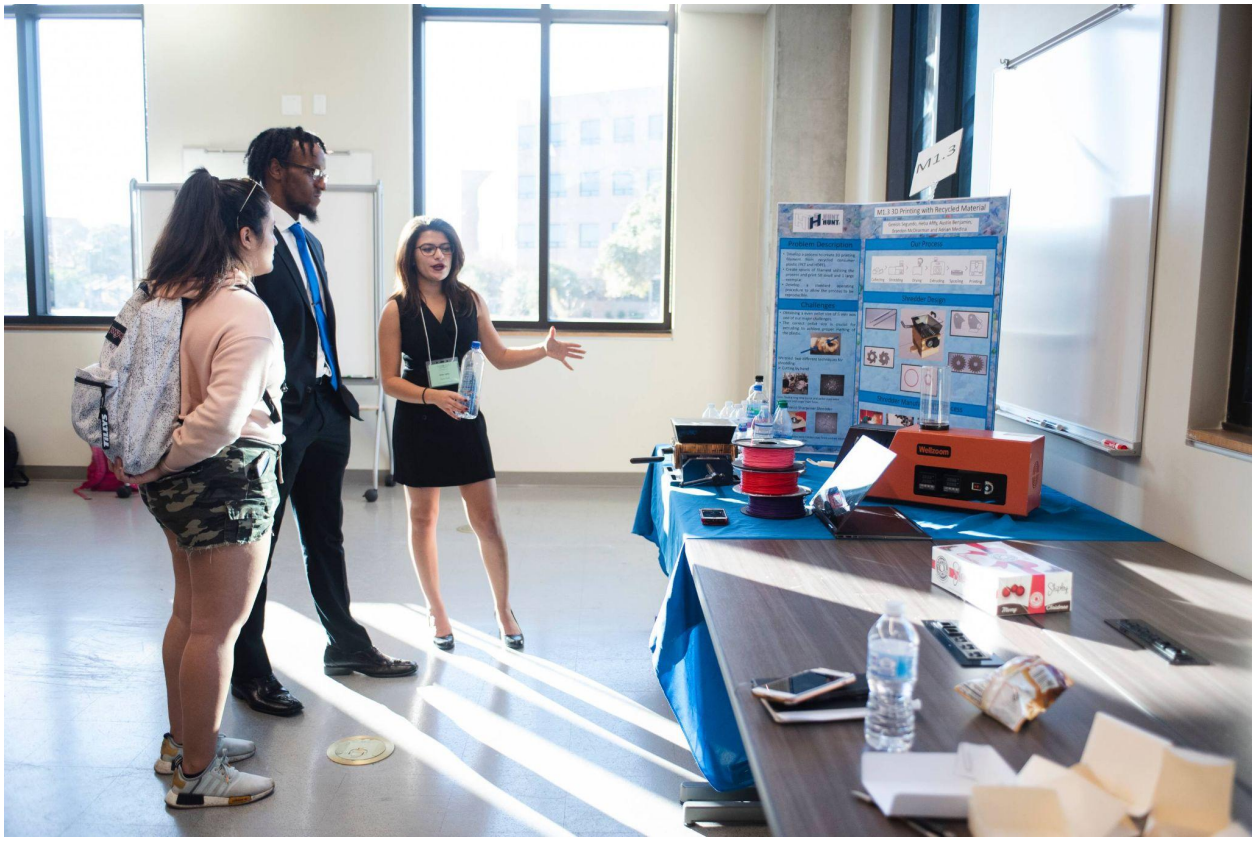
1) Waste Reduction - This is the best thing you can do. Limit your use by finding and using alternatives (e.g. reusable grocery bags, metal straws, bring your own togo containers, etc)
2) Re-use - This is the second-best option. Don't throw it away. Reuse it. (e.g. togo boxes can be reused as leftover tupperware at home. Empty jugs can be used to water plants, etc)
3) Recycle - recycle it on your own before putting it in the single-stream bin. Local recycling events like the e-waste ones. Bring it to our recycling workspace on campus. When you put it in a recycling bin be sure it is clean and be sure that your city's recycling center actually accepts that item.
4) Energy Derivation - This is essentially burning it to use as fuel
5) Landfill - this is unfortunately where a lot of it ends up

Our project will get people involved in the process which will increase their awareness of their plastic usage. It will also give their post-consumer plastic waste a new life as a new product. So in a way it does encourage the continued use of plastic, but it is continuing as a new product rather than ending its use in a landfill or in the ocean.

BOBCATS REPURPOSE INITIATIVE

This is everything that has happened regarding recycling plastic on campus. Over the years the projects have changed based on the immediate need and availability/capabilities of the students who took on the projects. There is plenty of work still to be done, but here is what we have accomplished so far.

3D Printing with Recycled PET: MFGE Senior Design (2019-2020)



- **Summary**: At the end of my first semester at Texas State, I attended senior design day and met the team working on this project. They had been collecting PET water bottles from recycling bins on campus and attempting to extrude it into 3D print filament. Since it was only the first semester of the team's senior design, they were still trying to prove the concept. If I remember right, they had successfully extruded 1 roll of 3D print filament, but had not produced a successful print yet. During their second semester they were experiencing problems with moisture absorption in their filament which resulted in print failures. Whilst troubleshooting this issue, the pandemic ended their semester abruptly and their project was retired.
- **Current Status**: Inconclusive. Project cut short due to pandemic
- **On-campus Contact**: Dr. Austin Talley
- **Off-campus Contact**: N/A
- **Location**: Ingram Hall Makerspace, Senior Design Room A, Kardex Tray 1
- **Other Information**: Equipment may be used for Ingram Hall Makerspace 3d print filament recycling

V1 Compression Molds: MFGE Senior Design (2020-2021)

- **Summary**: Starting in the fall of 2020, this senior design team was tasked with machining compression molds to recycle plastic in a process that would take under an hour. They designed a mold for screwdrivers, coasters, keychains, and phone stand/holders. The process involved cutting up HDPE plastic waste by hand, placing the flakes in the mold in a thrift store bought toaster oven, and then compressing the molds under a hydraulic press. The products chosen proved successful because they were still usable, even with defects. However, while the end product was successful, the hours of prep work cutting plastic by hand proved the need for a plastic shredder more than ever.
- **Current Status**: Molds are still usable, but wearing down. CAD/CAM files exist for remaking them. Round key chain mold was destroyed during an experiment with resin pouring
- **On-campus Contact**: Dr. Austin Talley
- **Off-campus Contact**: Sofia Murcia, Mohammad, Pablo, Juan
- **Location**: Ingram Hall Makerspace, Senior Design Room A, Kardex Tray 7?
- **Other Information**: Screwdriver shanks can be purchased on Amazon: link. https://www.engineering.txst.edu/senior-design/prior-events/2021-spring/sdd-spring-2021/m2-03.html

Precious Plastic Shredder: Undergraduate Research Fellowship (2020-2022)

- **Summary**: After researching Precious Plastic, I decided to download their CAD files and build their basic shredder. This is a single shaft shredder driven by a 3HP motor and gearbox that shreds plastic into 2 inch strips. The shredder was completed in the fall of 2021, but ran into a catastrophic failure when the shaft sheared in half inside the coupling. This issue was resolved by implementing shear pins that go through the coupling and the shaft, but over feeding the shredder is of concern because the shear pins break easily due to the stress.
- **Current Status**: Shredder still works. The mesh sieve, shaft coupling, and teeth grinding on the inner walls are of concern.
- **On-campus Contact**: Dr. Austin Talley
- **Off-campus Contact**: Michael Quinto
- **Location**: Ingram Hall Makerspace, Senior Design Room A
- **Other Information**:

Injection Machine and Molds: MFGE Senior Design (2021-2022)

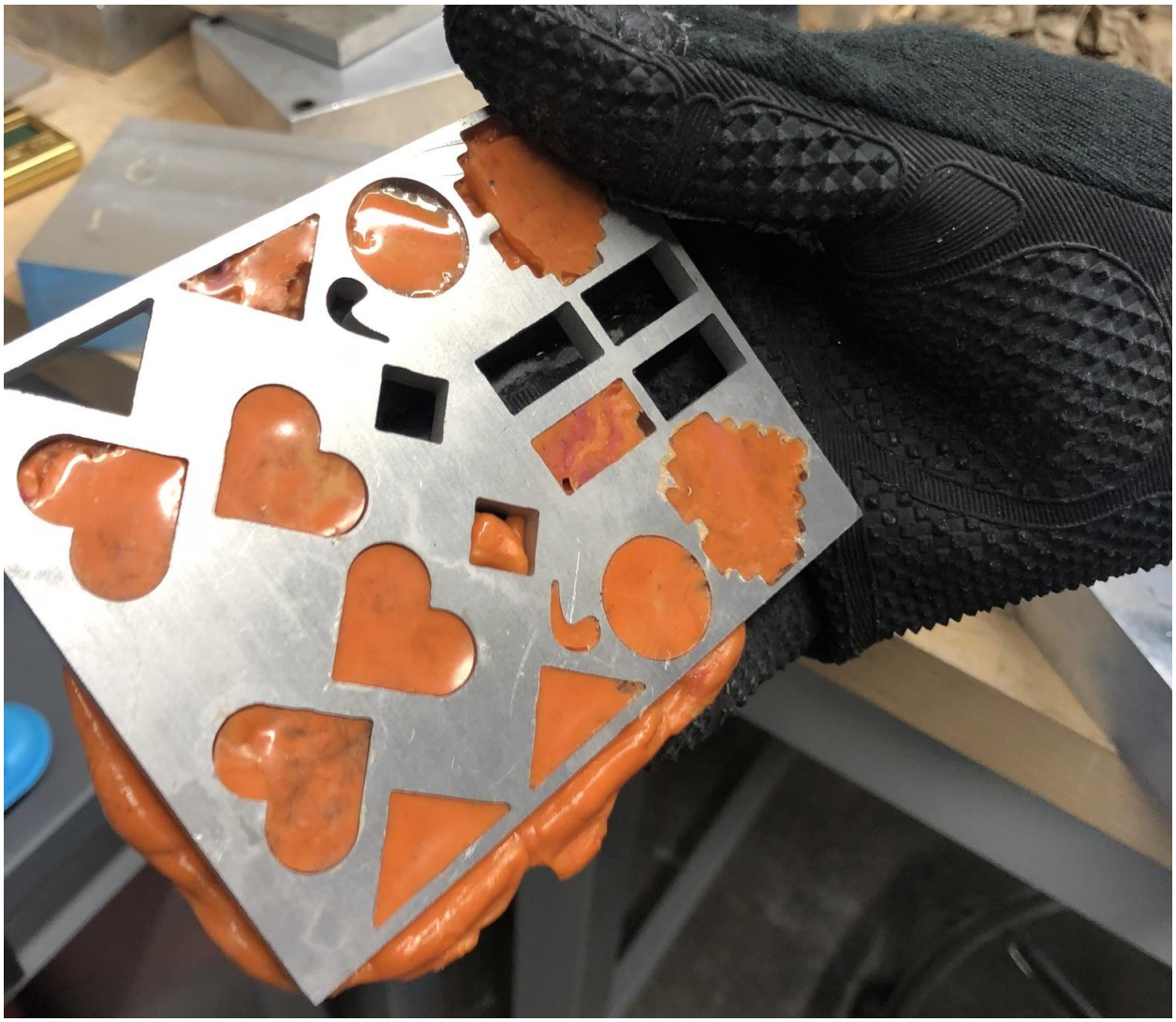
- **Summary**: This team was tasked with designing and manufacturing a plastic injection machine along with machining four molds to be used with it. They made molds for a screwdriver, keychain, multipurpose tray, and t-handle allen wrench, all with varying success. The main issue was that the heating elements produced inconsistent melting temperatures and viscosities resulting in a variety of issues. They did produce a few successful products, but ultimately the machine was shelved after a teammate got burnt by molten plastic.
- **Current Status**: Non-functional due to heating issues and safety concerns. Some of the molds can be used in the compression process.
- **On-campus Contact**: Dr. Austin Talley
- **Off-campus Contact**: Allison Cespedes, Will Atkinson, Jordan, Nik
- **Location**: Machine-Ingram Hall Storage Closet, 33##. Molds tray 7 or 12?
- **Other Information**: https://www.engineering.txst.edu/senior-design/prior-events/2022-spring/sdd-spring-2022/m2-04.html

Recycled Plastic Bench: MFGE Senior Design (2021-2022)

- **Summary**: This team ventured to test the limits of plastic compression molding by producing large block molds that would assemble like legos to make a bench. This required about 25lbs of plastic per block, so they spent the first semester collecting and cleaning plastic waste from different parts of campus. This was a slow process, so I used the precious plastic community to source clean, colorful, plastic can toppers that were used for the remainder of the project. The biggest takeaway was that melting large amounts of plastic in our on campus ovens took nearly 24hrs in the oven with varying degrees of porosity.
- **Current Status**: Complete as a great learning experience, but not an aesthetic show piece.
- **On-campus Contact**: Dr. Austin Talley
- **Off-campus Contact**: Abigail Cartwright, Bailey Beene, Jonathan, Nahama
- **Location**: Ingram Hall Makerspace, Senior Design Room A

- **Other Information**: Molds are in an unknown location https://www.engineering.txst.edu/senior-design/prior-events/2022-spring/sdd-spring-2022/m2-05.html

V2 Compression Molds: MFGE Senior Design (2022-2023)



- **Summary**: This team designed new small compression molds that were easy to personalize and produce in 30 minutes.
- **Current Status**: More mold options and printed SOP.
- **On-campus Contact**: Dr. Austin Talley
- **Off-campus Contact**: Korbyn Jones
- **Location**: Ingram Hall Makerspace, Senior Design Room A, Kardex Tray #
- **Other Information**: https://www.engineering.txst.edu/senior-design/prior-events/2023-spring/sdd-spring-2023/m2-04.html

Alkek One Makerspace (2023-Present): Filabot 3D Print Filament

- **Summary**: The Alkek One Makerspace has successfully implemented the Filabot recycling system and produced many rolls of recycled 3D print filament. Typically, students pay for their 3D prints in this space by weight, but they are able to print for free using the recycled filament. This not only incentivizes the use of the space, but also promotes recycled material rather than virgin plastic.
- **Current Status**: Functional, recycled rolls are in use
- **On-campus Contact**: Noah Brock
- **Off-campus Contact**: N/A
- **Location**: Alkek Makerspace
- **Other Information**: Most difficult part is sorting

Plastic Shredder V2: MFGE Senior Design (2023)

- **Summary**: The goal of this project was to design and manufacture an improved shredder that increases input restraints and safety while improving usability and reliability.
- **Current Status**: Should be complete by December 1st, 2023
- **On-campus Contact**: Dr. Austin Talley
- **Off-campus Contact**: Michael Quinto
- **Location**: Ingram Hall Makerspace, Senior Design Room A
- **Other Information**: https://www.engineering.txst.edu/senior-design/prior-events/2023-spring/sdd-spring-2023/m1-05.html

Ingram Hall Makerspace (TBD): Recycled 3D Print Filament System

- **Summary**: This project started when I learned of the bags of 3D print waste in the storage closet in Ingram. I applied for Environmental Service Committee Funding to purchase the Filabot Reclaimer used to break apart 3D prints for extrusion. By using the new reclaimer, and the filament extruders left behind from a previous senior design project, we can recycle plastic filament for our 3D printers. The project has been handed off to the Engineers for a Sustainable World student organization to implement.
- **Current Status**: Untouched
- **On-campus Contact**: Dr. Austin Talley, Madison Silvernail
- **Off-campus Contact**: Michael Quinto
- **Location**: Ingram Hall Makerspace, Senior Design Room A
- **Other Information**:

PLANS FOR THE FUTURE

The goal of this project is to open a space on campus for the Texas State University community to learn about and take plastic recycling into their own hands. For this to happen we need to improve the molding process. My suggestion is for a team of students to manufacture a new injection machine or extrusion machine. This will greatly reduce the time necessary for students to take plastic waste and recycle it into new products. This process needs to be refined and quick enough to hold students short attention spans.

With the equipment and tools ready, the next step will be public outreach. The student organization "Engineers for a Sustainable World" has agreed to forefront the plastic recycling workshops. With their connections, we can bring students from all parts of campus into the space. They will host workshops to teach about plastic waste and its recyclability, and then teach them how to use the equipment on their own.

I will be staying in the Austin area for the next few years and will continue to remain involved with the recycling space on campus. This means that I will continue to be a resource and continue to develop this initiative. Please reach out whenever you need to.

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