Quanser Art Drone

Final Report

The University of New Mexico

Senior Design

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Overview

Executive summary

For our senior design project we were tasked with using drones to make art. This was an open ended project with room for exploration. The project presented many unique challenges and showed that sometimes projects are more challenging when you are given less parameters. Inevitably our project had to come to an abrupt halt due to the Covid-19 Pandemic. Before we had to end our work we were exploring many options for our project, detailed below. We explored the idea of using actual paint to create a physical piece of art but decided to pivot our project towards a more digital approach. Through our many different iterations one thing stayed the same, we wanted the art to be centered around the human experience rather than just a robot reproducing Picassos. In this report we will cover the purpose of our project, the brainstorming that went into our various approaches, and the overall lessons learned. Through this project we learned a great deal about the intersection of art and technology that challenged our perception of the fields.

Why are we doing this?

If academic disciplines were put on a spectrum most people would place art and technology on opposite ends. Many artists view engineers as in the box thinkers, complete with pocket squares and an apprehension towards creative thinking. On the contrary many engineers think of artists as carefree painters with no method or structure. But, underneath all these superficial differences lies great commonality.

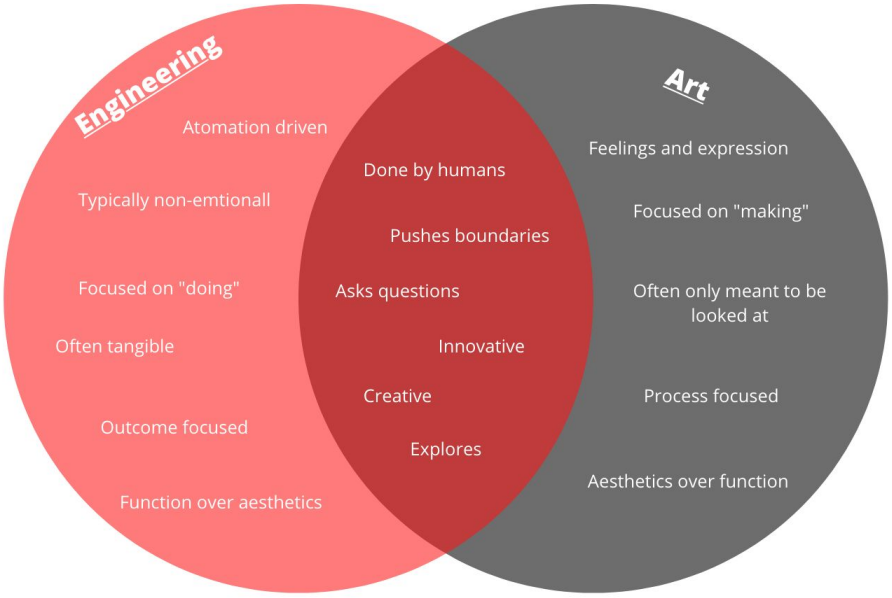
Scientists and artists are both trying to understand and process the world around them. They both approach their work by observing what they see and trying to tangibly understand and convey the lived experience. Yet these two disciplines keep each other at arms length. The purpose of this project is to question that divide and bring together artistic ideas with engineering concepts, and trying to understand how these fields fit together, how technology is evolving, and how that evolution changes its application.

What questions are we trying to answer

- What do art and engineering have in common?
- How does art change when merged with technology?
- What drives art and engineering apart?
- What makes an interdisciplinary project successful?

How are art and engineering connected?

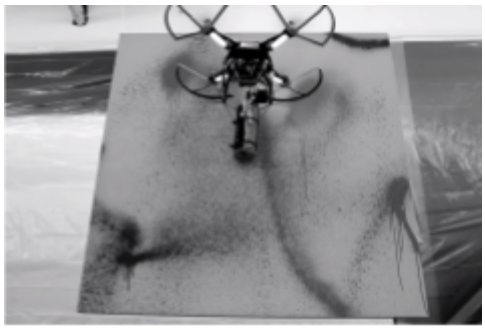
To tackle this interdisciplinary project we first wanted to think about all the similarities between these fields that feel so juxtaposed. How do art and engineering intersect and how do they diverge? After a great deal of brainstorming we came up with a basic venn diagram for the two disciplines. The things that bring engineering and art together seem obvious, what we wanted to begin focusing on is how to take the things that seem dissimilar and bring them together. How could we make engineering more emotional? How could we make art more tangible?



Literature Review Summary of what exists already

There are a few examples of drones creating art, but from what we found they mainly use spray paint to convey their ideas. Another interesting commonality of these projects is the political message behind them. Many of the artists use these drones to convey something about the world around them.

In 2014, the graffiti artist KATSU used quadcopters mounted with a can of spray paint to create the Icarus, which is considered the first graffiti drone. With the drone he was able to reach new heights (literally) that had been previously inaccessible to tag artists. Most notably he tagged a large advertisement of Kylie Jenner, a video example can be found here. He went on to further refine his drone and released the Icarus Two in 2017, demonstrating its abilities by spray painting an Anti-Trump message. KATSU has also programmed the drones to take messages typed into a computer by a user,



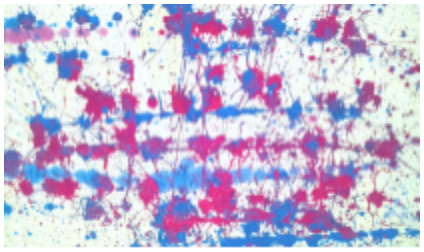
KATSU's Icarus One drone

Kylie Jenner graffiti - KATSU

and write them out autonomously[1]. Ultimately his projects work towards allowing graffiti to expand beyond its traditional scope and possibly prevent the arrest of an artist[2]. Similarly, a Mexican anti-government activist known as Droncita used a drone with a can of spray paint to protest president Enrique Peña Nieto in response to the disappearance of 43 students in 2015[3]. A video example can be found here.

Some less political examples include the Urban Flying Opera Project created by Carlo Ratti in 2018 and the Drone Pollock created by students during the 2015 Technica Hackathon[4]. The Urban Flying Opera Project crowdsourced its artistic ideas, allowing people to submit small illustrations online, and selecting 100 of them to combine into a single mural. The mural was painted over a 12 hour period, with four drones working separately to paint

Urban Flying Opera - Carlo Ratti Associati



Drone Pollock

[1] https://www.theverge.com/2015/6/22/8822961/open-source-graffiti-drone-katsu
[2] https://dronecenter.bard.edu/katsu-graffiti-drone/
[3] https://www.theguardian.com/global-development/2015/oct/15/mexico-droncita-rexiste-collective-president-enrique-pena-nieto
[4] https://newatlas.com/drone-graffiti-precision-trump-tag/47506/

it. The Drone Pollock used a paint bucket and did flips to drop paint onto the canvas creating a pollock like design and a paint covered drone. The drone pollock used user input to decide where on the map the drone would go next. A video example of Drone Pollock can be found here and a video example of the Urban Flying Opera can be found here.

Artistic Components

Our definition of art

Before we started work on our project we thought it would be important to define art and give ourselves parameters to work with. As engineers we wanted to work with a concrete definition, so we went with the Oxford dictionary definition:

> The expression or application of human creative skill and imagination, typically in a visual form such as painting or sculpture, producing works to be appreciated primarily for their beauty or emotional power[5]

For us the most important component of that definition, as it pertained to our project was "the expression of application of human creative skill and imagination". How do we have drones make art that is still reflective and expressive of the human experience? How do we make valid art that combines technology, but isn't a machine reproducing art. We wanted to make sure our project was not a factory of art, but rather an artistic experience in itself. The earlier mentioned examples all sought this in some way as well. Many of the projects used input from users and others functioned as extensions of the artist .

[5] Definition from the Lexico dictionary powered by oxford https://www.lexico.com/en/definition/art

Artist Collaboration

To ensure our art was of substance we met with Peter Lisignoli from the UNM Department of Fine Arts. He talked with us a great deal about the intersection of art and technology and about specific artistic concepts we could incorporate into our work. Together we discussed at length the role drones play in art and digital media and tools to make art more accessible as shown by KATSU and many low budget filmmakers who use drones to get panoramic shots that would traditionally be out of budget. He was a great help in our project and functioned as a person we could bounce ideas off of and get feedback from, he helped throughout the process.

Our Different Approaches

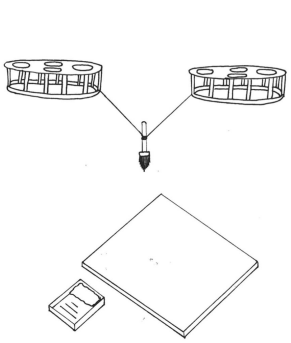
First Approach:

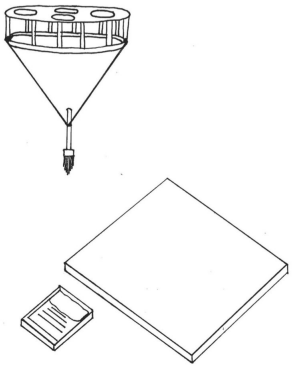
Chris Riggs Painting

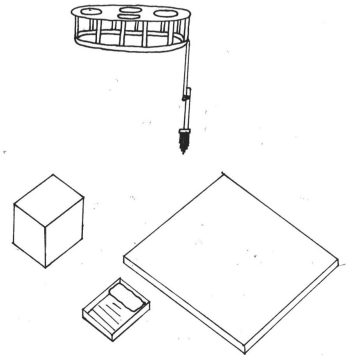
Chris Riggs Painting

Our initial idea was to program the drones to paint the alphabet and then have users input words that made them think of drones. The drones would paint them in an abstract way, transforming people's misconceptions of drones into tangible art. We were going to use a traditional paint brush and string to hold the brush. But as we began working with the drones we saw that the precision of their art was very limited and the words would be completely illegible. We were originally using sharpie for this because we wanted to limit

paint splatter but as we changed our approach we realized we would need to change the materials used.







Second Approach:

After meeting with Peter again he suggested we look into color field art. This is an area of painting that uses a limited number of colors and saturates the painting with only one plane of color. Color field paintings focus on color as the subject rather than a tool used to give other objects context and ask the audience members to examine how the subtle differences in brush strokes change the painting and how the overall color feels.

Paint by Mark Rothko

Painting by Barnett Newman

This concept was especially interesting to us because we knew the texture of the drones painting would change over the course of a painting and would vary between each painting even if using the same color. By putting all these paintings together viewers would be asked to think about the imperfection of technology, even though it claims to be something consistent and unwavering.

To begin working towards this approach we got the drones holding a brush with string and flew the drone in a circle mimicking the dipping of the brush into a bucket. Before we began with paint we tapped down a layer of paper on the floor. As the drone flew it became obvious we would need to secure the paper in a better way and invest in more tarps. But as concern grew about the splattering of paint on equipment we were told to move in a different direction but the owners of the lab.

Approach Three:

In early March Dr. Ramiro informed us that we would be moving towards digital art and that we would be using image processing and projection for our project. The idea was to have the drone “paint” with a projector by recording its flight as it projected and then collapsing the video down into one image, similar to long exposure photography. We first started working on this by getting some of the basic functionality working in photoshop and brainstorming how we could

iStock Photo

include user input into this new method. One idea was to have users use a haptic robot arm to directly control the drone. Another idea we had was to use audio input from users and either control the drones's trajectory with this or use it to change the size of the digital “paint brush”.

Technical components

Challenges

With the help of OptiTrack Motive and six infrared cameras, we could track the position of the QDrones in relation to the room. This same software also was in charge of creating the rigid bodies created from markers (passive retro-reflective) that are on each QDrone. We found out when too many markers were placed in close vicinity, markers could overlap on the camera view, and Motive didn’t resolve individual reflections. This increased the likelihood of label-swaps during capture. Once the room was calibrated, the next challenge was related to the wireless connection. Some of the drones weren’t correctly connecting to the router, and we found out that the reason was a loose connection with the internet cable attached in the QDrone. This issue was solved by ensuring the connection with the help of a glue gun.

Another important thing to take into account was battery life. The drones used Li-Po type batteries that lasted around 5-6 minutes of flight time. Following the QDrones Datasheet, the maximum payload they could support was 300gr. This reduced battery

life to 2 minutes approximately. The following figures will show the battery life comparing a 300gr payload vs no payload:

- Fig 1: Battery life with no payload: after the first falling edge (drone takes off), the battery level it's maintained at 11.7V.
- Fig. 2:Battery life with 300gr payload: after the first falling edge (takeoff), the battery level surpasses its safe level (>11.5V) until it lands again (rising edge).

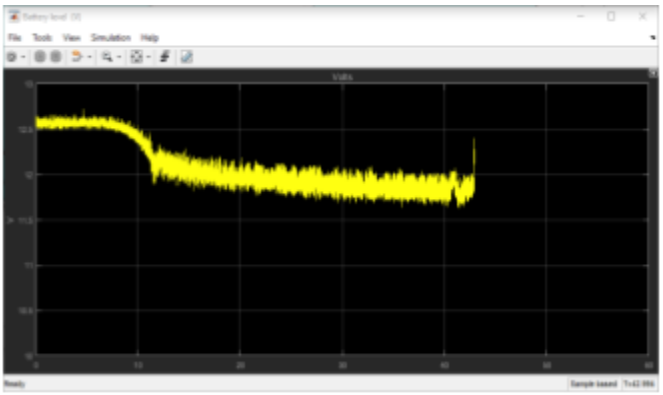


Figure 1 - Battery Voltage without Payload

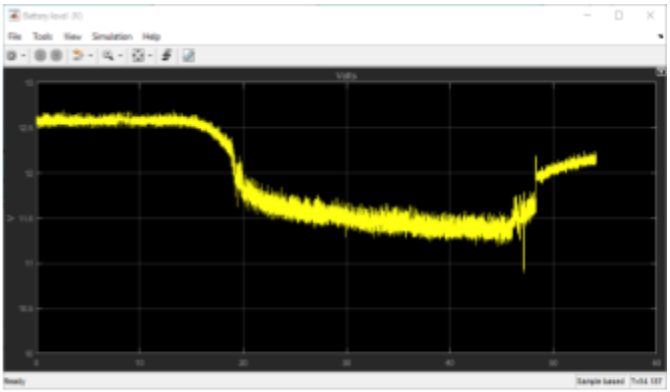


Figure 2 - Battery voltage with Payload

The next obstacle we faced was during the flight of multiple drones. Apart from the usual coordination of trajectory-type of issues that were solved through Simulink, there was a significant factor we didn't bear in mind at the beginning: the wind currents. Every time there were two or more QDrones in stage, they never could be flying one on top of the other, the wind currents they generated on one another made them unstable and ended up crashing. We had to set a distance of security (around 1.5m) between drones in order to reduce these oscillations.

The last challenge material-related. Every time we would use paint we had to protect the floor and take into account the air flow that would splash paint onto the walls.

Mechanical components

Our original plan to paint with drones by attaching one end of a piece of string to the bottom of the drone, with the other end tied to a paintbrush. The drone would dip the brush into a paint tray, and paint a canvas fixed to the floor. We ran a test using a sharpie attached in this way and saw that the string provided too much slack, making the patterns faint and hard to read. Adding weight to compensate for this would quickly overburden the drone so we resolved to use a meter stick instead of a brush and have the drone take off and land from a stool.

As concerns grew about the paint and the possible destruction of expensive equipment we needed to change the materials we used were instructed to make digital using light, video recordings, and digital image processing. We were also then given access to the HD² High Definition Haptic Device present in the WHY Lab. The device is used for advanced research both in haptics as well as robotics, and it usually works in environments such as medicine, as a virtual medical simulator. The HD² haptic robot was enabled so it could interact with a QDrone using programmable force feedback. Using its motion track and taking advantage of its six degrees of freedom (X, Y, Z, roll, pitch and yaw), the QDrone followed the trajectory of a person's arm using the HD².

By using this we would be able to have the user control the trajectory and create their own drone art.We could then use its highly back-drivable joints and very low

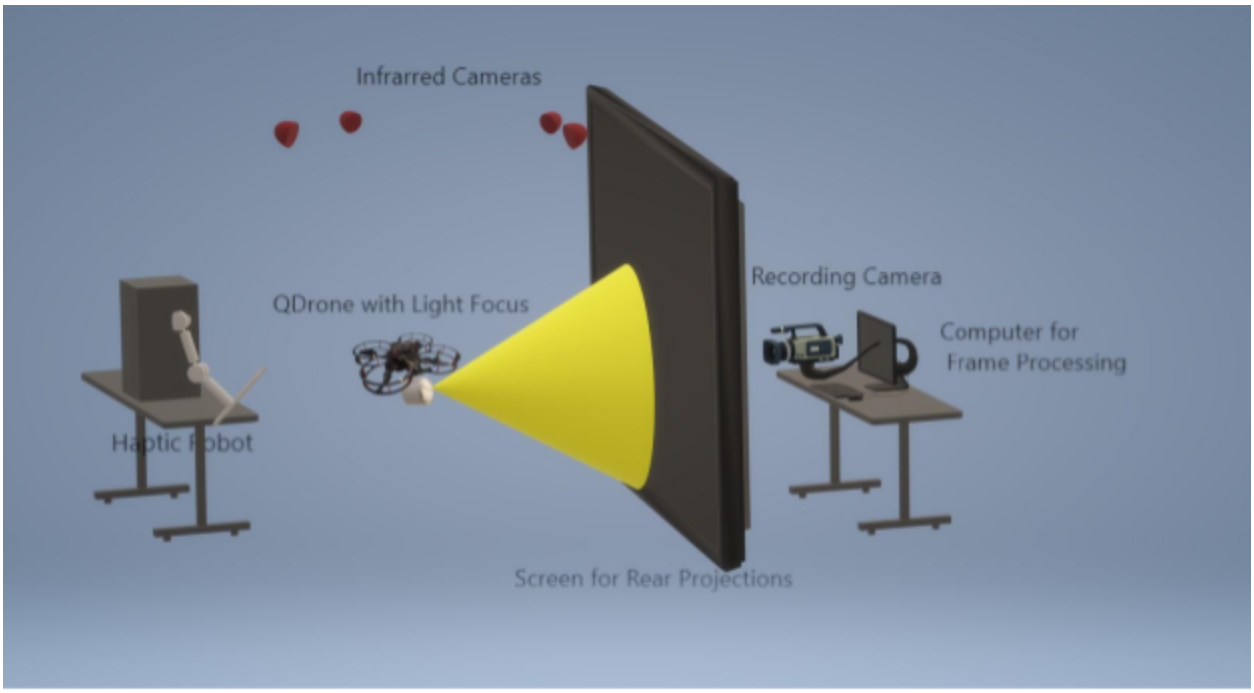
intervening dynamics to make the QDrone “draw” in the air a potential artwork, we just needed to figure out what was best to showcase.

Our first idea was to attach a potent light source to the QDrone, and then the drone would “draw” with this light onto a screen. This would all be recorded with a video camera and using digital image processing, and the trajectory of the light projected on the screen, would be shown as a continuous line (thus, a piece of art).

After talking to the art department and getting more engaging and ambitious ideas, we came up with more specific materials and various possibilities of outputs. (The materials are listed below).

We opted for a Pico-Projector as the light source, giving us a wide range of possibilities of shapes, colors and even movements. The one used by the art department featured up to 175 Lumens via a high-contrast optical engine, was lightweight (less than 300gr) and easily attachable to the drones.This would project onto a screen for rear projections, and the trace would be recorded with a camera.

Developing our first idea, we came up with other output possibilities. These were mainly focused on the audience, and how they would show interest (and maintain it). One of them was the idea of selling/showing a “Very Expensive Pen”, where the output would be unexpected, but somehow connected. A user would draw a shape, a letter, a symbol… with the haptic robot and the drone would then fly and draw, with the help of the pico-projector, something related to this.



Concept Diagram of Approach 3

Software components

Image Processing

As the drone projects onto the rear projection screen, a camera would be filming our shape moving along the screen, capturing the video at 30 frames per second, which gives us a time window of approximately 7 seconds, since we can process light traces of up to 200 frames per image - although, we can fly the drone for as much time as we want and select 7 seconds at a time and merge all the pictures at the end.

We were able to get a sample working with photoshop of the flight path using a flashlight and a piece of paper. We were hoping to create our more robust set up after

spring break. To first get this working on photoshop we uploaded the recorded image to the computer and imported the video as layers to photoshop and then selected the part of the video we wanted to convert into a light trace. To simplify and automate this process we created a script that stored a set of macros that will do all the steps for us automatically and merge every frame was created. This script (actions.atn) will convert all the layers to a single smart object and take the Standard Deviation of all of them combining them into a smooth trace. We would do this for each 7 second section of video and then merge all pictures generated at an opacity of 100%/(number of pictures), which when combined gives 100% total opacity.

The images shown display the tracing done with a flash flight and a piece of paper, compressed to show the entire path. The image on the right is an example of this tracing applied to two photos overlayed and the tracing used to reveal the bottom photo.

Photo of Trace Revealing 2nd Photo

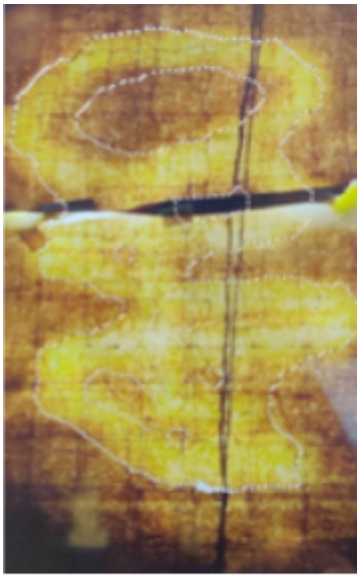


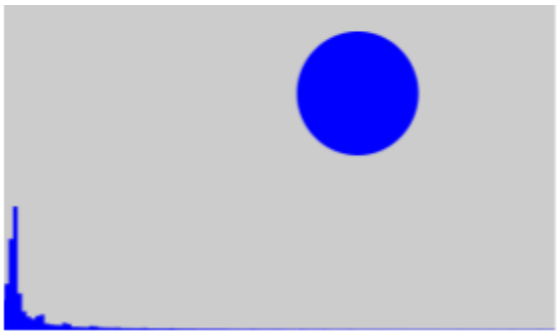
Photo of Trace Path

FFT and Audio

An additional idea we toyed with was having users input audio to control the drone. We saw this working in two different ways; either by controlling the actual trajectory of the drone, or by controlling the size of "brush" the pico project was using

by changing the diameter of the projection based on the sound. To begin working on this we used an application called Processing to perform a Fast Fourier Transform of an audio file and then used that audio to graph the FFT both as a bar graph and as a circle with a changing radius.

Fast Fourier Transform w/ Small Brush



Fast Fourier Transform w/ Large Brush

Summary of Materials

For Projection	For Image Processing
Screen	Photoshop
Camera	Matlab
Light	Processing
Screen	
SD Card	
Pico Projector	

Project Takeaways

Learned lessons (tech problems)

There were a couple of problems that we encountered while using paint. Because of wind currents, everything on the stage flew away. Everything needed to be correctly taped to the ground.The rubber material on the floor made taping stuff to the floor difficult, so we needed to make sure all the dust was removed beforehand. Rotation and movement of the brushes made oscillations that destabilized the QDrone. We solved it by attaching those brushes from side to side of the propeller's chassis. Trajectory height changes slightly depending on the position of the room. Watch battery life. With max payload (300gr) we got approximately 3 minutes of flight and with no payload it could take up to 6 minutes.

Lessons Learned (interdisciplinary work)

Many of our challenges were not specific to the intersection of art and technology, they are the same challenges that divide all fields and make interdisciplinary projects so uniquely difficult. A big lesson for us was that if you want to work interdisciplinarily you must think interdisciplinary. You can't divide a project in half and say "this is the art" and "this is the tech" - you need to wear multiple hats, sometimes at the same time.

Bernhard Knapp, a researcher at Oxford University who does interdisciplinary research and writes about how to make it successful says that two common downfalls

or interdisciplinary projects are unclear expectations and unclear rewards models. Different fields have different expectations for how things work and what the outcomes and rewards are. Success in art is very different from success in tech. This was an area we struggled with and looking back our project could have been more successful if we did not need to pivot our approach so many times. Each time we did so it felt like we lost momentum and a great deal of work was wasted. Having more lateral communication between our group, our art advisors, our teachers, and our sponsors would have helped with this. It seemed like everyone had a different vision and it was hard to marry them without joint communication. Just one or two zoom calls with everyone at the beginning could have insured more linear progress. Additionally, it was hard for our teachers to fully understand how all of this fit into the engineering curriculum and why it was a technical project not just an art project. We were asked to marry two different fields and we tried to do so without a real understanding of how that would change the traditional senior design model and without focusing on how to make it an interdisciplinary project. By focusing on “getting it done” we lost some of the communication across the fields . Having a more clear outline of what our technical goals were would have been helpful, either coming from us or from Quanser directly.

One of the hardest parts of this project was bringing technical and artistic ideas together in a way that was substantial. From the beginning one of the most tangible divides we noticed was the instinct to outsource the art. Our professors encouraged us to not worry so much about the art component and we even found ourselves doubting our creative ideas, belittling ideas by saying “well, we are only engineers”. We were told

“not to think about the art” and to just ask a “real” artist about that. This was interesting to witness because it began to function as a wall between the engineering side of the project and the creative side. Rather than becoming fully interdisciplinary the project started to feel helf engineering half art. From our own internal reflection this felt like an easy way to deflect failure. With engineering either something works or it doesn't, it is a success or a failure, with art that is much more subjective, someone might hate a painting that another person loves, this makes art much more vulnerable. To outsource the art was to outsource the fear of rejection around what we created. But this also served as an engineering lesson, not everything we do going forward in our careers will work, we are going to fail as engineers, it's inevitable. Even with this project the fear of messing up the drones or taking a wrong approach to the project kept us from trying things. But once we got the drones flying things felt more manageable, teaching us that you have to start and you have to fail before any gains are made.

APPENDIX:

Delaney:

The Covid-19 pandemic has forced the world, and American society, to stop normal operations. It is an uncertain time with no clear end in sight - but among all this uncertainty one thing is very certain; nothing will be the same when this is over. The United States will not be returning to normal, rather it will be creating a new normal and a new mode of function. This mark of transition is both exciting and terrifying, it can be used to address underlying inequality and shape a more just future, or it can be used to exacerbate inequality. There are many ways the corona-virus will shape the world for the better and to ensure we exit this with a more just society we must analyze the vulnerability Covid-19 has exposed to ensure we create more and we must analyze the government's response to ensure power is not abused.

Schooling and education cannot end because of the pandemic and because of modern technology synchronous learning can continue without in person lectures. Many classes are now meeting over Zoom. But in order to attend Zoom lectures a student needs steady internet access and a machine to log on. This shows how vital the internet and computers have become. In order to promote learning the internet needs to be treated as a public service rather than a utility and all students need free access, in the same way that public school students are given free access to busses and classrooms. Beyond this school's need to guarantee that each student has access to a computer to ensure that they can keep up with their courses. But the issue of parents in school who now have to take care of school children must be addressed and the learning environment of universities needs to adapt to the needs of students unable to meet during specific times. This can be done by allowing videos to be accessed at a later date.

Irene:

Viruses have marked the evolution of life on the planet. They have marked the evolution of human beings, plants, animals.

And, amid the havoc one of them is causing, they make us feel helpless.

Our societies have had experiences of great pandemics throughout history, and yet we are not prepared to face them. This world emergency is teaching us that we are lacking

a lot. It is, without a doubt, very sad to see human suffering, but also anger at the lack of preparation that societies have to face this type of problem. I do believe we will get out of this very difficult situation, surely stronger and smarter, but the most difficult part will be to go through these months that we have ahead.

And for that, we are already showing solidarity and generosity in different parts of the world, not only to help the most vulnerable, but to face one of the keys to preventing the coronavirus from spreading: social distancing.

Aristotle had already said it: human beings are "social animals" and, therefore, it is natural that they seek the company of others as part of their well-being. Many studies have shown that this world pandemic has activated a feeling of team working that has united peoples and the scientific community.

Regarding the future of universities: I feel we are in a very lucky position since we are prepared to hold online classes. Nevertheless, there has to be a new way of maintaining people's schedules and trust, regarding assistance and exams. Senior Design should now be more focused on various projects that could tackle this world pandemic in different fields of study, such as organized volunteering projects in order to distribute medical supplies to the most needed, regardless of the part of the world. It would be a great idea to put in contact various non-profit organizations with the coming students in order to develop engaging engineering assignments.

Joaquin:

COVID-19 caused people to adapt to working from home and in isolation. This pandemic is forcing us to find digital solutions to keep meetings, lessons, workouts and more when sheltering in our homes. By changing the way we see human interaction as a whole, we are cutting down many company trips to other cities or even countries, because we learn how to live with video calls, which can be equally effective as meeting someone in person. National or global apps could result in better early warning systems because they could report and track who is showing symptoms of an outbreak. GPS data could then be used to track where exposed people have been and who they have interacted with to show contagion.

Artificial intelligence could play a big role in drug development because it can accelerate and complement human's knowledge. Telemedicine could be a solution to not havig to go to hospitals or clinics, since most of the times all they do is check your temperature and blood pressure, and determine a diagnostic with their knowledge, but this could also be possible developing apps that put you in contact with doctors and over videocalls, make health meetings more accessible and cheaper. Some healthcare

providers had thought about this before COVID-19, but the interest has increased now that social distancing is mandated in many areas.

Zane:

It would be impossible to talk about this project without discussing the way it was, like so many other things in the world right now, ultimately defined by the ongoing Covid-19 pandemic. Currently, this virus, in conjunction with our response to it, is reshaping the world as we know it. It seems as though the world has come to a grinding halt as people, businesses, and governments grapple with trying to slow the spread. This virus has presented us with a number of new challenges. Clearly, we need to take drastic measures to socialy distance and limit the spread. But how do we implement this without damaging our society economically and socially? And how do we protect those less privileged among us from leaders who are more concerned about their own wealth and success than the health of the people they're supposed to be protecting? How do we make sure we have strong leadership to lead our response through this crisis, while still protecting ourselves from government overreach and abuse of power?
But I believe that, rather than simply lamenting these changes, we can use them as an opportunity to all take a step back and gain perspective on our society as a whole, and hopefully come out the other side improved as a result.

I've seen my life change greatly over the last several months. My school has been closed down, with teachers and students struggling to transition to an online education. I've seen many of my daily activities disrupted. However, I understand that while these may pose an inconvenience for me, I am much luckier than others being affected. I have a computer, and internet with which to attend my classes. I've been able to continue working and making money to live in a safe environment where I don't need to worry about exposing myself to the disease. People want to talk about how this experience will help us make a transition to working and learning and doing more things online. But that just isn't possible for many people in our communities. Before we can use this to change how our society functions, we must address the inequalities we've ignored to ensure that everyone can take part in this new reality. Failing to do so would only exacerbate these societal issues. One of our biggest takeaways from this crisis should be that we need to ensure everyone has access to a computer, the requisite teaching to be able to use it, access to the internet, and a safe environment to use it. The last few months have shown us that the internet isn't just a luxury anymore, it's a necessity.