MY name is Bonsuck Koo. And I am here to present myself for the New Grad Rotation program in GNC engineering. I will get right into it!

I am a student at the University of Texas at Austin. I graduate this December with a degree in Integrated Masters and Bachelors of science in Mechanical Engineering. My most recent hobby has been visiting national parks or going on a hike on a weekend. The pictures are the places I have been to, Grand Canyon, horse shoe bend, Antelope Canyon. I just love watching the scenery, and I am always amazed at the scales of things in nature. It’s part of the reason that I appreciate Earth, and this is something that I hope that we can conserve forever in time so future generations could see this too. That’s why I like the mission of Blue Origin, working for the benefit of Earth.

Also, I obtained my American Citizenship in July 2023, relatively recent, so I could work in the Space industry without much restriction, that’s all thanks to my parents!

I am currently working as NGC or GNC eningeering intern since the summer at Sandia National Laboratories. I am doing almost exactly the same thing I had done at Blue, which was working with MATLAB and Simulkink Simulation of a flight vehicle. I am helping to develop unclassified version of their flight simulation.

Before that I worked at Blue as a GNC engineering intern in the New Shepard team in 2023 Fall. I implemented the antenna parameter switching feature in the MATLAB and Simulink simulation for the rocket.

In 2022 Summer, I worked at Samsung Austin Semiconductors. I worked with computer languages that were completely new to me at the time to facilitate technician’s work process. This experience was a chance for me to display my grit by producing a result, despite given a completely unexpected work. I could talk a little bit more about it later if given time, but I belive this experience aligns with one of the Blue’s leadership principle: to “Deliver Results” .

And before Samsung my first internship was at Trane Technologies, which was a HVAC ,or Heating ventillation and air conditiong company. I worked to improve technician’s work process over there as well. You see here that I am working with copper pipes, and one of my job was to qualify a new component for HVAC system. It required lots communciations and understanding the standards.

This picture is a weather control room at Trane that goes through four seasons in only about two weeks. It snows, gets hot and rains. My component was being tested in that room, and I thought the snowing room picture is cool, so I thought I should put it there.

Lastly, I did a mandatory military service in Korea from 2018 to 2020 when I still had the Korean citizenship, I just wanted mention to explain my gap in education during those years.

I want to join Blue because it shares my professional goal, which is to benefit our entire society. In my previous internships, the magnitude of impact that I realized an engineer could have and the apperication I received for helping technicians was so rewarding that I wanted to seek bigger work that benefit a greater society. I believe the best way to do so now is to help facilitate space travel. To preserve Earth, I sincerely believe we have to reach out to space to find new resoiurces and new habitat. Also, as I said before, I want all my families, friends and all the future generation to see what I saw in nature. Putting my effort into to conserve it in some way wil help everyone in the world.

That’s exactly the mission Blue Origin has. Blue distinghishes itself from all the other space companies in that aspect. It emphasizes the bnefit of Earth rather than pure exicitement of space exploration.

And As one of the Blue’s leadership principle, which is “Passion for our Mission”, as that principle explains, it is the Mission or the goal in our career that motivates and drives people to work. So, I think it’s important for both the company and myself to have that common goal to produce anything meaningful.

And I can contribute to that effort with my experiences in developing simulations in MATLAB and Simulink. Experience in C++ which I will talk about soon. I also have the abiltiy to work independently and as part of a team on rapid development programs as shown in the aerial Robotics project course.

Last thing for introduction, I want to join Blue because I know it has a very supportive environment. While I was there last year, my mentor Phil, was always hands on and guiding me through my project. I learned a lot from him regarding using MALTAB simuloink especially GIT, Also, other people in NS team did so as well. And We have nick here and I remember asking him lots of questions and he helped a lot to finish my project during my internship. I really felt like everyone was willing to help. I really like that supportive environment. Besides that the people in HR, everyone I talked to were all helpful and I felt they were truly trying to help me advance in my career.

I want to be part of all that again.

The project I want to present is the Drone project I did in Aerial Robotics course last semester. (next slide)

This was a three people team competition. The goal was to create a path finding algorithm for the drone to find the fastest way to predetermined targets in a field of obstacles. The picture on the bottom is the field in a high fieldity simulation tool that was provided. This is where we implmented our algorithm in, and the targets were blue and red balloons you see here, and the black walls are the obstacles.

So for the competition, each team was timed on how fast the drone popped the two ballons from a designated starting point and returned to another desginated end point.

Here you see a picture of the drone, or the quadrotor that was modeled. Here is a picture of my teammates!

The tasks I worked on for this project was mainly two things. First to develop a 6-DOF simulation that mimiced our entire drone system in MATLAB. This is different from the HI-FI simulation tool I showed you in the previous slide. This MATLAB sim was a chance for us to see how to implement controllers and develop a 6-DOF sim by ourselves.

The second task was to develop the A\* algorithm as part of the path finding algorithm that finds the optimal path to the targets.

I first modeled the drone’s dynamics with 4 ODE.

The first equation was the velocity, which is just defined here.

The dynamic equation for the acceleration was determined by the forces acting on the drone. Here is the gravity acting on the drone. The second term is the upward force exerted by the fan onto the quad which keeps the drone up in the air, and we have four of those. We have the drag force acting against the motion of the quad at the end. Lastly, any disturbance force was modeled as a noise.

The third equation is for the angular acceleration. This is what you get if you take the derivative of angular velocity. Nb term is the torque combination caused by the propellers. Specifically, NB\_i is the torque caused by the propeller acting against the air, so it makes the drone spin on its own axis, like this. The R cross F term is the torque caused by the thrust force that keeps the drone in air, which could make the quad flip over.

Lastly, I have the equation for the change in the attitude matrix.

Here is the schematic of the control system I was simulating for. we used two controllers, one for trajectory control and another for an attitude control. PD controllers were implemented for both.

R star is the position of the drone, x star is the position of the x-axis of the drone’s body frame.

But Before actually implementing PD controllers, a basic PD  
controller in this figure for this systmem was tuned to see how P and D gains affect the system behavior.

The goal of this exercise was to make the closed loop system’s unit step response to have desired responses.

~~less than 0.25 second of rise time (Tr), less than 30 % of over shoot (Po), and less than 2 seconds of settling time (Ts)  
to within 2 % of reference value.~~ .This figure shows the step response of  
the closed loop system with the a specific gains I chose.

Talk about how does PD affects the behavior\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Increasing P gain generally increased the speed of response or reduced rise time and also reduces the setlting time.

The D gain generally improved stability and decreased overshoot

For The actual tuning of attitude controller was much harder, because P and D gains were in a matrix form for the attiude controller. I tuned it until the drone followed a desired circular and a designated height as closely as possible in a MATLAB simulation. Also I wanted the quad’s front to face the center of the circle throughout the flight.

In the left figure, you see the trajectory of the drone in the simulation as a blue line. It is a making a circle. The red arrows show you the direction of the quad’s “x-axis” or I can say the front of the quad. We see it is facing towards the center of the circle. In the right figure, the goal was to get the drone to fly at 0 m and we its steady state response at 0 m.

This was a simple tuning, but I think was most diffiuclt part for me because I almostly blindly tuned this until I got the behavior of the drone I wanted. Besides that I could not have been getting the correct trajectory because of other parts of the sim not the controller gains itself. For example, my dynamics model could have been incorrect.

And this is where separating the simulation into different subsystems or modularizing the sim came in handy. I was able check the validity of each subsystem separately

I would first test the dynamics model on its own without any controller to see if it produces the trajectory I want. And then I can confirm that dynamics model is correct. So I was able to confirm all the other subsystem was correct, and knew that it was my controller gain that was the issue.

At one point, I got stuck at this state where I see a steady state error in the altitude. One could ask Why didn’t I use an Integral controller to fix the error from here.

Well, since I used PD controller, these are the equations I used to calculate the force and the torque input to the dynamics model.

Besides that PD reduces computational work by having one less term relative to PID controller and making it easier for me to tune the gains since there are 8 terms to tune already, I knew the integral term shouldn’t be necessary, since I already have the mg and the feedforward term here. So, the controller will always no matter what produce the force command enough to make the drone hover with the mg term, the errors it observe should produce the extra force command to the drone motor. So I knew PD should work. I later found out the correct gain and got it to look like the previous slide (previous slid).

We also modeled Measurements from the GNSS antennas to find the position of the quad.

Here is the schematic of the GNSS antennas. There is one big reference antenna in the field, acting as an inertial reference frame. Although it actually is not inertial, since it is rotating with the Earth, but the inertial sensor isn’t sophisiticated enough to know that, so I was able to assume that it is inertial.

And two additional antennas are attached to the drone at its center.

So in reality, if the drone was flying and receiving GNSS measurements, the measurements are obtained according to this diagram. The position of the primary antenna in reference to the fixed antenna, rp, and also the position of the secondary antenna in reference to the primary antenna, rb.

This measurement was emulated in the MATLAB simulation by taking the current actual position of the drone, adding antenna locations on the drone, and adding some noise. I was once asked what else could have been modeled that I didn’t consider and could increased fidelity of this model. I think one thing that could have improved this model would considering clock errors. Thermal noises, or clock errors on the receiver.

Here is the eqeuation of model for IMU measurments. The accelerometer measurement accounts for the accleartion of itself, gravity and the bias noted as ba and noise Va.

The accleartion term is defined in the equation below, the regular asccleartion equation lot of you know, but for this, I assumed the origin of the acclearomter was fixed to the origin of the Body, which cancles out these terms.

So essentially this FB bar omega b bar equation is what defined the IMU model.

Lastly, additional modeling and tool I used to complete the simulation were the camera model that also provided position estimates of the drone, and the unscented Kalman filter on MATLAB that was provided to combined all the measurements to produce state estimates. With all of these models, I simulated how well the drone achieves the goal in the simulation environment, which is to follow the reference trajectory and maintain 0m altitude. In the next slide you will see the result of the MATLAB simulation I ran, and the reference trajectory I fed into it was a path determined by an algorithm that uses A\* method I developed in C++, which I will explain more later.

You see here that the drone fooloows a certain trajectory and the x-axis or the red line always points towards the direction of travel of the drone.

After seeing the sim working well in the simulation, I now moved on to implementing a path finding algorithm using C++.

There were three algorithm options I considered. Depth First Search DFS, Dijkstra’s algorithm and A\* method.

How I chose one algorithm to implement was based on the two criteria.

The number of nodes explored and the number of nodes in the path.

A field can be gridded into cells and mapped into nodes. Like the picture you see. The nodes exist at the center of each rectangular cells. The red cells represent obstacles that the drone cannot pass through.

This sort of mapping of a field is what was provided for the actual competition. We were given a 3D occupancy grid that represented the actual field that the drone flew on. So for selecting an algorithm, I used a much smaller scale and simpler 2D occupancy grid that you are seeing right here.

So the criteria, then. Starting with the first criteria, the three algorithsm have different ways of selecting which cells or nodes should be explored or not. And sometimes that algorithm could explore multiple “incorrect path” before it finds the “correct path” or other times the algorithm is smart enough to weed out certain cells right away to find the “CORRECT” path instantly without exploring other “incorrect paths”. Definitely I should prefer the latter situation, so that’s what the first criteria evaluates. This also relates to processing time as well.

For the second one, it’s a much simpler criteria. the determined path has to be the shortest possible way, since this competition is time sensitive. These two criteria will make more sense in the next slide I will show.

I am showing you the path found by the three different algorithms. We see that the path by DFS is a bit complicated looks like its taking the drone on a longer path. So we weed that out. Dijkstra’s and A\* found the exact same path. But the difference is that A\* explored much less nodes. It explored only 20 nodes before it found this optimal path while Dijkstra’s explored 74 nodes before finding this path. This discrepancy is also reflected on its run time, Dijkstra’s took 18,163 microseconds to run while A\* only took 666 seconds to run.

I coded all of them in C++ and tested them in the 2D test occupancy grid this way.

The A\* method was the most efficient method.

Now you will see how the C++ A\* algorithm I worked on looks like in the game engine simulation I was provided to work with.

At the end, of course this competition was a team effort, and I could not have completed this project without my teammates.

The best part about having teammates is getting help from each other. When I was struggling with my part of work, my teammates had conversations with me about the relevant topics or concepts that my code pertained too. And while talking to them I would notice errors to my code. Or sometimes they would simply look at it and notice small bugs as a third person. We would also talk to each other give feedback to how certain codes can be better implemented, each of us would incorporate that.

I really like that and I knew the feedback would help the team, so at the beginning of this team project, I told my teammates that our team should try to communicate with each other as often as possible whether that’s text, zoom meetings or in-person meetings, so that we all will be comfortable with each other and exchange feedback and not be afraid to get or give help to each other. Our response to that was having a in-person meeting at least twice a week, we would also talk after lectures, and I really like the meetings because since we are all in the same space, giving feedback was much easier than sending a text or email. And also spending time together in person also pulled the team together to work with each other even more closely.

I think it worked really well and we got a good result because of it.

I also notice the idea of active communication and feedback is one of the Blue’s leadesrship principle, “Embrace Team Blue” so I wanted to point this out.

And a short side note, I contributed to the team with my experience in GIT. I am very thankful that I struggled with GIT at Blue for a few month while I was there. None of my teammates knew how to use Git at first, so I was able to help the team set up Git repository, help if any members had issues with Git. I was glad I could do that for the team.

Explain the summary of drone project

As a result we did end up placing 2nd in the competition, being the second fastest to pop the ballons.

Although we only worked with MATLAB simulations and the hi fidelity simulation tool provided and aslo we didn’t have any access to the actual drone, we were still given a chance to run our path finding algorithm in the actual drone. The Hi fidelity simulation had been designed accurately enough that if it worked in the high fidelity sim, it generally worked in real life.

I will show the actual footage of the drone that is flying with my team’s path finding algorithm. You will see a place on top of school’s parking garage where the field was located on. (next slide)

The drone is flying inside this netted area and moves itself towards the ballons, and pops the red one.(wait)

Now, you see that it manuevers towards the ground, and that’s because there is an imaginary wall in the air, so it had to go below the wall ,and there are other imaginary obstacles in this field this drone tries to go around too.

After popping the second one, you see that it tries to return to an ending spot by going around obstacles again.

I would like to end with why I want to join NGR program specifically. I like the aspect that I get to explore different teams before I settle on a single team. I believe this will ensure that the team your on will be the one I want after experiencing other teams and I get to network with different people at Blue and I believe they will be valuable to me and others. I really hope I could get into it and make a contribution to Blue and for Earth.

Passion for our mission:

Tell me about a time when you were working on an initiative or goal and saw an opportunity to do something much bigger or better than the initial focus. Did you take that opportunity? Why or why not? What was the outcome?

**Guadaloop**

I was the lead suspension engineer for the team in Spring 2023. The suspension design when I became the lead did not have any sufficient engineering justification. Meaning, We did not run a thorough stress, cost analysis, or reviews from any professionals. so we could not answer any questions when someone asked why our suspension was designed this way. So, I took the initiative to scrap the entire design and begin from scratch. Of course, this required discussions with my teammates. I explained that we should not sacrifice long-term value for short-term results. Although we already had some sort of design that could make the process faster and maybe even start manufacturing an actual system, it’s meaningless if we don’t have sufficient engineering background to this design. We won’t be able to convince the judges in the competitions, and even people within Gudaloop why our design was the best choice. Also, if the system failed, it will hard to identify the cause for the failure. I tried to communicate my opinion as much as I can to my teammates, and I was able to convince everyone to agree with me. So we started everything over.

I led the team to take a methodical approach. Because this was a self-led project, we had to seek out the requirements for this design ourselves. I gave instructions to clarify performance specifications, brainstorm, picking a design and analyzing our selection. We used Pugh charts, gantt charts, multiple sessions of 6-3-5 method, and ran stress analysis through FEA for different design options. While leading these processes, I felt the that it was important to earn the trust of members to have your teammates follow you and lead them. I had to genuinely listen to them and create an environment where people can talk freely and show that your open to any novel ideas. I think keeping this in mind helped me propagate discussions for new ideas and consensus

All these activities provided a solid justification for our team’s design, and if anyone had asked why certain things were designed in such a way, we were able to give them a sufficient engineering reason. So at the end of the summer of 2023, the team created a final CAD of suspension system along with documentation of the entire engineering process and its justification. The team just had to manufacture it at the time! With this experience I was able to lead the team by earning the trust of the teammates and also to self-identify the requirements for the design.

Bias for Action

Give me an example of a calculated risk that you have taken where speed was critical what was the situation and how did you handle it? What steps did you take to mitigate the risk? What was the outcome? Knowing what you know now, would you have done anything differently?

**Senior Design Project**

**Talk about we initially planned to finished**

This project was heavily customer focused and time driven project. The team I led was tasked with designing an impact test machine for equipments on naval ships. It was important that we met our customer’s need and deliver a product in a timely fashion, since we were designing such a big system from the ground up in three months.

To understand our customer’s needs and also deliver the results on time, communication was key. Projects like these, I think it is important to have every member and our customer be on the same page without much confusion. Do each members know exactly what tasks to do. Do we understand why they are build this product, where are they going to place this? What are other specifications? Does the customer understand what we are going to do? If the team is confused, it delays the time for it to do actual work on the project, and rather have to do the work again, or be stagnant in confusion. In order to reduce such misunderstandings and miscommunications, we held meetings regualraly with the customer and amongst our team to give each other chances to communicate as often as possible, and at the end of every meeting, I clarified action items and each members due dates for everyone, so everyone knew what to do and made progress on the project until the next meeting. Also, I stayed open minded as a team leader. This was very helpful when we were brainstorming ideas on how to raise the hammer for the system and bolt down the system and etc. Having multiple ideas, allowed us to consider different options we were able to compare each of them and be confident on our choices of our design. We can say this was a better idea because of this reason. Another way I stayed open minded or tried to be communicative was when a member thought that he could not finish his work in time, I discussed about it before the due date with the team and tried to see if we can distribute the work or reach out to our sponsor and the faculty to see if such extensive study was necessary given the time. At the end, we successfully met every single deadlines and produced a CAD model of the machine. Presented them to an audience.

So, With this senior design project, I helped my team deliver the deliverable on time, stayed open minded to run the project efficiently, and focused on our customer to meet their needs.

~~In the fall 2022, I was the team leader for my senior design project. Our sponsor Southwest Research Institute requested our team to design a high-impact shock test machine, and this machine is suppose to test whether naval ship equipments could withstand certain impacts according to MIL-DTL-901E standard. Here is the cover of the specification standard I had to read and a diagram that roughly delineates what a impact machine should look like. Basically an equipment sits on top of this anvil plate, and you see a hammer here and it swings around to hit the bottom of this anvil plate. That’s the test. Here is the actual picture of it in another company.~~

~~And this machine is suppose to be really big. Just the hammer should weigh 3000 lbs, it’s also taller than me which is about 6 ft, and this plate is 60 inches x 60 inches big.~~

~~SWRI wanted to build and have its own shock test machine.~~

~~In less than three months’ time, my team had to deliver a preliminary CAD design of the machine and a Static Finite Element Analysis (FEA) result. It was daunting at first to build such a big system in a relatively short amount of time. But I took the lead to plan our project together.~~

~~First, I wanted to define the scope of the project to a reasonable scale. The machine has multiple systems and components, and it was not plausible for four of us to design all the systems. During my team meeting, I brought up my concern, and my team and I came up with a proposal to design only of the four main critical systems on the machine: a Mounting System that fixes and holds the machine onto the floor, Braking System to stop the hammer after the impact, lifting system to lift the hammer, and impact system, or the hammer. We conveyed our opinion about the scope to our customer or the sponsoring engineers and were able to persuade them by explaining that given the time and the resources we have, it is best to focus on those four mechanical systems. It was critical that we did that because Not only did we have less than three months, each of us were taking other Mechanical Engineering courses, doing researches in their labs, and looking for a job while this project was going on. Our team agreed that the best way to be resourceful of our time and ability is to focus on specific systems, so we can deliver a quality result to our customer.~~

~~Having this discussion and coming up with a proposal with my teammates helped each of us feel the ownership for the project. During the discussion, it was each one of us who said that it is plausible for us to design the four systems given this time, it was us who agreed that we can deliver the results to our customers given these resources. Because we proposed to do them,  I believe everyone in the team felt responsible and ownership of the tasks ahead of us.~~

~~So if I am in any other team projects, whether I am the lead or just a member, I like to clearly discuss the scope of the project and plan the project together to provide ownership of the project for everyone.~~

~~So far, I might have been giving the impression that we were too busy to do this project, but we were not. We instilled trust into the minds of our sponsor through planning and active communication. Here is the project Gantt chart. It outlines the entire tasks and dates of when we are going to work on them.~~

~~Here is a diagram explaining how we are going to brainstorm ideas, and select one idea to produce a CAD model for.~~

~~Here is the specification sheet of the machine that we created based on the requirements from the military standard and our sponsor’s demand.~~

~~We showed those charts for our sponsors to have certain expectations at different times and to know what we are working on at different points throughout the semester.~~

~~And every week when we meet, we told them our progress, what worked and what didn’t work. Or sometimes, I would brief them about the summary of the military standard I read, and I would confirm my understanding with theirs.~~

~~So, It was important to show our understanding of the project as often as possible, so that the sponsor understands that we are going in the direction, and we are sure of what we are doing. One time, we were not sure how much force we should assume that the hammer and the anvil plate will experience. Our sponsoring engineer advised us to multiply the static force we caclualted by rthree for the analysis, since the three signam is the industry standard.~~

~~This kind of active communication, I believe allowed our sponsor to feel comfortable working with us and entrusted us to finish the project.~~

~~I put efforts to keep a good communication within the team. Because any misunderstandings or miscommunication could delay our project, I made sure every single person in our team was on the same page and knew what their tasks were until the next meeting by summarizing the meeting and making a list of action items. I would always end the meeting by summarizing what we just discussed, showing the progress our team relative to the gantt chart, and most importantly, having each member state what their action item until the next meeting would be. This avoided confusion amongst the members on who is doing what work and for whom it’s for. I have been in a different team project when I was not clear on what I was suppose to do, and wasted time just trying to figure that out myself. Also, there were multiple parties working with in this project , such as the sponsor, course faculty members, and faculty advisor, it was confusing at times when multiple requests and tasks that needed to be delivered every week to different parties. So overall having teammembers communicate through summarizing the discussion and coming up with an action list every meeting prevented us from wassting time just trying to figure out what work we were responsible.~~

~~For best coordination and deliver the result for our customer, it was essential to have the best communication. There were multiple parties involved in this project: Engineers from Southwest Research institute,~~

**Additional Talks:**

Samsung

In 2022 Summer, I worked at Samsung Austin Semiconductors, working on projects to facilitate technician’s work process. Although I was hired as a mechanical engineering intern, I was given a computer science task. I have never created a website before, I had no experience with JAVA, HTML, CSS, and SQL. But I learned in for two months during internship, and at the end I was able to create a website and excel VBA tool for the tehcnicians that saved 1 hour for the tehcnicans every shift. Although this experience here doesn’t directly match with the requirements for GNC engineering, but I like to at least briefly mention this internship because it displays my grit. Despite being thrown into a completely unexpected work and something I had no experience in, I appreciated that I got a chance to learn these new languages and did my best to produce a product. And I did deliver something for the team at the end. I am proud of that and I think it also aligns with one of the Blue’s leadership principle: “Deliver Results” ,which states that leaders show grit despite adversaries and barriers to deliver a quality result in time. That one is a picture at a lunch with interns friends at Samsung