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 gradudate this december with a degree in Integrated Masters and Bachnelors of science in Mechanical Engineering. My most recent hobby has been visiting national parks or go on a hike on a weekend. The picture are the places I have been to, Grand canyon, horse shoe bend, antelop Canyon. I just love watching the scenary, 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 could 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.

There is a picture of me in fornt of the moon lander.

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.

I could talk about leadership experiences through my senior design project and Gudaloop which is a student hyperloop team, and more that I could match my epxeriencs with the qualfiication for this job.

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.

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. Notice I used the full rotation matrix to avoid singularities or gimbal lock, instead of Euler angles.

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. Also, it could have been other parts of the sim not the controller gains that were producing incorrect behaviors. For example, my dynamics model could have been incorrect. And this where separating the simulation into different subsystems or modularizing the sim came in handy. I was able check the validity of each subsystem separatelty. I would first test the dynamics model on its own without any controller to see if it produces the trajectory I want to confirm that the model is valid. 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 and if the drone was flying and receiving GNSS measurements, the actual drone would receive 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 whatelse could have been modeled that I didn’t consider and could increased fideltiy. I think one thing that could have improved this model is to

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 modleing and tool I used to complete the simulation were the camera model to detect the ballons, and the unscented Kalment filter on MATLAB that my professor provided for us for better 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 controllers working well in the simulation, I now moved on to implementing a path finding algorithm on C++

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

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

The number of nodes explored, number of nodes in path. If I explain what the picture on all the way to the right is, I think it will help understand the first criteria.

Say a field can be gridded into cells and mapped into nodes. Like the picture you see all the way to the right. The nodes exists at the vcenter of each rectangular cells. The red cells represent obstacles that the drone cannot go to.

This sort of mapping of a field is what was provided for the actual competition. The professor gave us the 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 on the top right.

So back to talking about the criteria. Starting with the first criteria, So 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 measures.

For the second one, it’s a much simpler criteria, that is the determined path has to be the shortest possible way, since this competition is time sensitive. For example, say if both the DFS algorithm and A\* algorithm explored the same number of nodes to find its path, but obviously I would choose A\* because the path it found is much shorter than the one found by DFS.

So with those criteria and also clearly seen from these pictures,

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

The A\* method was the most efficient path finding algorithm that explores the lest number of nodes and had least number of nodes in path.

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, which I didn’t notice at all by myself. 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

I really wanted to point this project out, because this course really felt like the software development process through SIL at Blue. Though this one is much smaller scale but it was more hands on for me since I got to develop most of the simulation and implement C++ code myself. I think these skills are super for this GNC engineering Early Career position that requires knowledge in Dyanmics, classical control theory, MATLAB, C+++ , communicatation skills, etc.

I hope this explained why this experience helps me prove I will be a good for this position.

I will spoil the result, we successfully implemented our algorithm in real life and in the simulation and ended up placing 2nd in the competition.

Before I begin explaining my contribution for it, I will show the result of my team’s work, first. What you will see in the next slide is the drone flying in an actual field with the algorithm we implemented.(next slide)

This is a place on top of school’s parking garage. 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.

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,

Forr the second one, it’s a much simpler criteria, that is…. The determined patha has to be the shortest possible path, since this competition is time sensitive. For eamples, say Dij, and A\* method both explored the same number of nodes to find their path, but I would choose A\* because it is a much shorter path than the path by Dij, as you see in these results. So with those criteria in mind, I coded all of them in C++ and tested them in the 2D occumpancy test grid. And these are the result of them that you are seeing. AS you can see, A\* method was the most efficient path finding algorithm of all. It explored the least number of nodes, and it found the path with the least number of nodes in path.

**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