# Greetings

Good afternoon, I’m Sehwan Park. Glad to meet you all, and thank you for having me.

# Introduction

**Tell me about yourself.**

I am Sehwan Park from Hanwha systems.

My background is helicopter aerodynamics and aeroacoustics. Back in graduate school of KAIST university, I have got advanced knowledge in rotorcraft aerodynamics and comprehensive understanding of aeroacoustics.

And for last three and half years right before I join Hanwha systems, I had been working for the UAM vehicle development team of Hyundai Motor company in Korea. There, I was in charge of aerodynamics and aeroacoustics analysis of eVTOL aircraft.

Then after the journey in Hyundai, I joined Hanwha systems this February.

And now I am applying to Overair, and I am very excited for the opportunity to utilize my knowledge and experience to help achieve your company’s goal of developing an UAM vehicle.

So as the other candidates you already have met today. I prepared the slide deck which can show you what I’ve done so far and what I can do. But before we dive into it, you can ask me any questions first. I believe you already received my resume hopefully, and so if there is anything you want to know more about me or if there was any concern you have about my resume, I think we can talk about it now. Or we can jump into the slides I prepared, and you can give questions later.

# Education

This is my educational background.

I studied rotor aerodynamics and aeracoustics in Aeroacoustics laboratory at KAIST university. And my phD study was about understanding aerodynamic interaction between main rotor and tail rotor of a helicopter. It was done with time-marching simulation using vortex particle method, but with special treatment that apply different times resolution for each rotor. And I was in charge of some more projects about aerodynamics simulation of rotating devices, which help me to have strong background in physics of rotorcraft aerodynamics as well as aero analysis tools such as lifting line theory, vortex lattice method, free wake model and vortex particles.

And my master thesis was about proposing the hybrid method which couples panel method with CFD solver. Fundamentally, in both PhD and Master studies, I tried to propose and use the most efficient methods for aerodynamic analysis which can help saving the computing resources and at the same time we could secure good accuracy.

Not only aerodynamics, but I had multiple chances to predict and measure the noise in graduate school, which includes aeroacoustics analysis of centrifugal fan and measurement of jet noise of korea space launch vehicle. and, on top of that, I was Teaching assistant of some course works like aeroacoustics, helicopter aerodynamics, advanced aerodynamics, and lab experiment. And Those kind of experiences helped me extend the boundaries of my knowledge on various fields, and had prepared me to the jobs in eVTOL vehicle development.

# Work experience

My professional experience.

I joined Hanwha Systems this February, and my job here can be described as two main jobs:

One is about doing conceptual design and aerodynamics simulation work, which is for developing an eVTOL flight simulator, and the another one is about supporting Hanwha’s UAM strategy and planning team by doing some preliminary sizing study on hybrid-electric vtol aircraft, as we are looking for its commercial and military use cases.

Right before I join Hanwha, I had been a part of Hyundai Motor Company’s UAM divison in Korea for three and half years. And my time in Hyundai had given me many eVTOL-related experience in aerodynamics analysis, aeroacoustics analysis and measurement, conceptual design and blade design optimization, and so on.

Any questions about my work experience?

## Roles in Hyundai

I covered a bit wide range of roles in Hyundai. To explain why, I think I should tell about more what was it like in Hyundai at that time. Hyundai Motors is really a big company, but my team was operating just like a small start-up. So each members had to be very proactive and do multi-roles.

When I first joined Hyundai in 2018, the team was not even called a team, it was a small group officially. And there were only like less-than-15 members, and surprisingly i was the only one who had a PhD degree in aerospace engineering, and again I was the only one who has a background about rotorcraft. So naturally, I had to do conceptual design works from the scratch, and of course performance analysis, design optimization of rotor blade planform, not only aerodynamics, but also aeromechanics and acoustics simulation as well. On top of that, I measured performance and noise of a scaled tilt rotor. I don’t know why, but my role was like that for the first two years, and I mean after those two years, Hyundai finally hired three more engineers who can take part of my jobs so that I could be more focused on specific area. One was conceptual design engineer who was familiar with fixed wing aircraft not rotorcraft, and the other one for rotor dynamics engineer who have experience in using CAMARDII back in graduate school but no experience in aircraft company, and the last engineer who has experience in aeroacoustics using STAR-CCM+ but has no background in rotor noise. So after that I could spend more time on aerodynamics simulation using medium-fidelity aero tools and aeroacoustics simulation.

So as I said it was very like a startup, I mean every engineer should act like a chief engineer in his or her field because there was no backup member in the same area. And each one should clarify and plan what’s next, and we should have found an expert or university professor ourselves if there is anything we need help or discussion with specialists.

Thanks to that I could extend my capabilities: from just aerodynamics and aeroacoustics to conceptual design and performance analysis, optimization and a little bit about rotor dynamics. I think I was lucky (fortunate) to join such a team from the very beginning.

**Roles in Hanwha**

one of them is to setup and prepare the environment for Hanwha’s plan of developing a hybrid-electric vtol for commercial as well as military applications. Here, setting up the environment includes communicating with uam business development team, defining the aircraft requirements, establishing sizing and performance analysis tools, finding the optimal spec of turbogenerator for satisfying the required range and payload, doing technical feasibility study such as estimating weight and volume of powertrain system.

The second role is to develop a flight simulator for a general evtol aircraft. for the second job, I am doing a conceptual design of a tilt rotor aircraft, and is going to generate an aerodynamics database which will be used for input for the next step, flight dynamics things.

There could be two steps: first use simple model for flight dynamics and rotor aerodynamics, and then use the FlightLab for replacing those models. In any case, aerodynamics

# Research Experiences

**About VIPP project:**

The consortium Hanwha system is participating has been selected by Korean DOT (department of transportation) to develop a UAM virtual integrated operation platform, and **Hanwha is in charge of development of two types of variable flight simulators for eVTOL aircrafts**: fixed base simulator and motion simulator. Here the variable flight simulator means that it can be used for various types of eVTOL vehicles: generic tilt rotor / lift-plus-cruise / multi rotor types.

So the hardware is going to be shared but we can import any type of eVTOL aircrafts among those three.

Specific role of Hanwha is first, to manage some the other companies and universities regarding the simulator development. Second, design a generic quad tilt rotor type evtol aircraft, generate aero databse, and develop flight dynamics and flight control system of it, which will be plug into the hardware later.

We are in the middle of conceptual design process of the generic quad tilt rotor aircraft, and at the same time we are now setting up the required computing resource and software environment.

# Potential Areas to Contribute for Overair

Well, I’ve thought about it for long time. And I think there could be two main areas. One is aerodynamics which includes simulation of complete aircraft configuration using medium to high fidelity aero tools, and supporting performance test and evaluation.

Later if there needs to be any minor modification in rotor blade for later version of product such as OA-1 vehicle, I could contribute to those works, but that’s one of just a long term goal. For now, I think aerodynamics analysis and technical support to test and evaluation is right fit.

Second is aeroacoustics analysis and measurement. I am aware that Overair uses CHARM, CARMADII, FlightLab. And the acoustics code, PSU-WOPWOP is very convenient tool for acoustics analysis by coupling with those aerodynamics and aeroelasticity analysis tools. Because I have been using both CHARM, CAMRADII and PSU-WOPWOP, so I think I could give a value to overair’s flight science team right away. And I believe

For me, I actually think aerodynamics and aeroacoustics are very closely related. And it is very natural that one engineer do make aerodynamics data which can be used for aeroacoustics analysis because accuracy of noise prediction is heavily dependent on the accuracy of aerodynamics prediction; it should be more precise in temporal and spatial manner. And in the flight test of XP-1A and XP-1B, there needs to be a acoustic specialist who can take care of acoustic measurement. I believe I am good fit on those jobs.

I heard that overair is in the middle of expanding the team in fast manner, but I think if we encounter some limitation in human resource and time, I think I can do multiple jobs depending on the phase we are in. I mean in some phases, there could be less load on simulation works and at the same time there needs to be more people in test and evaluation side, for example, measuring noise during flight test of XP-1A in near term or OA-1 vehicle in long term. And of course, there needs to be ongoing simulation works with any change in aircraft design or operating condition.

My personal wish is that I could get to develop a professional long career in one field. and as the company gets bigger and bigger, it would be very natural that each member is doing the same job, one specific thing over time and get invaluable experience through many failures and many projects.

But I think overair team is in the middle of transition, expanding its scale, so I totally understand the role could change depending on the circumstance, and I want to say that I am ready to be agile in terms of roles and responsibility. Surely, we can discuss my potential role in overair later in detail. Any of us cannot join overair right now because of VISA issue, so we could probably join early next year or 2nd quarter of next year. So I think the jobs are very open to discussion.

(얼마나 시간 줄였어?)

# Appendix

## MS

My master dissertation was about coupling panel method with CFD so I could reduce the required grid domain size a lot even for viscous flow and transonic flow. Typically, the freestream velocity is used for outer boundary condition of CFD computation domain. Instead I used free stream velocity plus perturbed velocity induced by source and double panel around the airfoil. And one of lab mates extended this technique to rotorcraft simulations, so that we just need small grid around the blade and no additional grid domain for downstream to capture the wake flows. Instead the wake was modeled using free wake vortex filaments, and it shows good accuracy while reducing the computer resource a lot.

## PhD Study

Multi-time Step Time-marching Vortex Particle Method for Main Rotor-Tail Rotor Interaction in Hover

During my PhD study, I was a very heavy user of medium fidelity helicopter aerodynamics in-house code, which uses vortex lattice or lifting line for blade modeling, and free wake vortex filaments or vortex particle for wake modeling. I simulated not only hover and forward flight, but also descent flight including vortex ring state. When it comes to interactional aerodynamics, I studied rotor-fuselage interaction and main rotor–tail rotor interaction.

and propose and confirming that different time resolution is necessary for each rotor because they different rotating speed, I mean tail rotor rotates 3-5 times faster than main rotor. And with that measure, I could save computing resource while having good accuracy.

## VRS

Vortex ring state is typically defined as the flight condition when the descent rate is comparable to the rotor-induced velocity, where the rotor suffers from power settling and large fluctuation in thrust and moments.

Recently in the ERF 2022 in Switzerland, Dr. Richard Brown presented about the vortex ring state, I remember the title was like are eVTOL aircraft inherently more susceptible to the VRS than conventional helicopters? He mentioned that high blade twist is susceptible to more severe VRS, and for side-by-side rotor configuration, the aircraft can enter into VRS asymmetrically. And the rotors of eVTOL typically have very high twist so that it can be acting like efficient propeller in cruise flight. And to reduce the acoustic signature or to increase figure of merit, they have more unconventional tip shapes. And small rotors along the wing span are in close proximity of each other and to the other components, which is not helpful to aircraft’s susceptibility to the VRS. On top of that, operation in urban area brings more exposure to large fluctuation in wind direction and speed due to large buildings.

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## Rotor–Fuselage Interaction

## MR-TR interaction

This is about effect of tail rotor’s position in vertical direction compared to the main rotor disk. or high tail rotor position, the wake vortex structure of the tail rotor is more fully developed at downstream. When the tail rotor is below the main rotor disk, tail rotor wake was more submerged into the main rotor wake, and the tail rotor is naturally suffered from more fluctuation in thrust and torque.

The another takeaway from the phd study was there needs to be high temporal resolution for tail rotor because the tail rotor typically rotates 3-4 times faster than main rotor. My suggestion was use different time step for each rotor, I mean more sparse time step size for main rotor and very fine time resolution for tail rotor. And the key point here was how to calculate the convection velocity of the main rotor and tail rotor wake which should reflect the velocity induced by each other. I used the 2nd and 4th Runge-Kutta method which has midpoint in calculation process, and I leverage those information so that I could reduce the computing time but still secured the reasonable accuracy.

## Aerodynamics-Flight Dynamics Coupling

I coupled the aerodynamics solver with flight dynamics solver. Both were in-house tools developed in Fortran language. Here flight dynamics code was developed based on the theory and manual of GenHel which was developed by US Army for UH-60 helicopter simulator. To my knowledge, non-US citizen is not allowed to access the source code of the GenHel, so my lab mate and I had to study the GenHel documents and develop the code following the equations and replace the rotor aerodynamics model with our own vortex lattice method with vortex particle wake model. And we verified pop-up, pop-down, UTTAS pull-up maneuvers, and validated the flight dynamics solver by comparing the simulation result with GenHel data or the other prediction result which University of Maryland computed by coupling the free wake solver with GenHel.

This is the hovering turn of UH-60 completer helicopter configuration. Here, the collective pitch angle of tail rotor and heading angle are predicted, and it shows good agreement with test data. And this was presented in the European Rotorcraft Forum in 2015.

The developed flight dynamics code can simulate 6 degree of freedom motion, but for this case, I had some difficulty at that time, so it was technically 1 degree of freedom in yaw direction, but I trimmed the thrust of main rotor and made the flapping activated so that it could achieve the zero moment at the main rotor hub.

## Rotorcraft Aerodynamics Experience in Hyundai

In Hyundai Motors, I was in charge of aerodynamics simulation using low- to medium fidelity tools such as CHARM, CAMRADII, AVL, XFLR5, and XFOIL. I performed aerodynamic analysis of lift-plus-cruise type as well as vectored thrust type configuration.

Not only the simulation, I conducted ground hover test of a scaled tilt rotors and analyzed the data. We built a tilt rotor and lift rotor of 1/3-scale of SA-1 concept vehicle, radius of which is about 1.7 ft (0.53m), and the tip Mach number was 0.4. For fabricating the blade and hub system, I worked together with structure design group and powertrain group very closely.

I generated the aerodynamics DB using AVL, and shared with flight control group.

Fan Aerodynamics/Aeroacoustics

## Jet Noise Measurement

In 2010 and 2012, I measured the noise of Korea Space Launch vehicle at 5 different locations. The closest spot from the launchpad was only about 400 ft distance away and the farthest spot was about 6000 ft away from the launchpad. I prepare the pressure field microphones which can measure up to 170 dB and the measured data records nearly 140 dB. The sampling frequency was 100 kHz and Hanning window was used.

## Aerodynamics Analysis

I used a variety of aero tools from low-medium fidelity tools such as XFOIL, AVL, XFLR5, CHARM, CAMRADII, to high fidelity tools, STAR-CCM+ and PowerFlow. But I should say, it was a bit more leaned to low-to-medium fidelity aero analysis during my career as an aerodynamics engineer.

1. XFOIL, XFLR5

I use XFOIL or XFLR5 to generate an initial version of airfoil’s aero database, typically as C81 format, so that it can be used for CHARM or CAMRADII.

I used both AVL and XFLR5 for aero analysis of an unpowered aircraft. They shared the core codes, but I preferred to using XFLR5 for conceptual design and stability analysis. Thanks to XFLR5’s GUI, we could easily adjust position of cg and tail wing or modify tail wing size, and see the effects immediately by a few number of clicks.

For AVL, thanks to the python wrapper codes developed by Uber Elevate team and now also shared through OpenVSP package, it is very useful to automate running multiple jobs and generate aero database, which is to be shared with flight dynamics and control team.

When I worked with Uber Elevate team for designing Hyundai’s SA-1 concept vehicle, we used the AVL and the python package to find a wing shape such that we could get the max L/D for given cruise speed.

1. CHARM

After designing the wing planform which meets stability criteria for unpowered case, and designing the rotor blade planform, I jump into aerodynamic simulation using CHARM.

But in many cases, CHARM simulation was conducted as a prerequisite of acoustic analysis.

1. CAMRADII

It’s a bit complicated to explain. When I was graduate school, my lab doesn’t have CAMRADII so there was no chance to use it that time. But, at that time, one of lab alumni was working in the Agency of Defense and Development and his department purchased CAMRADII, and invited Dr. Wayne Johnson to Korea for 5 days of training course. He also invited me to join the training course, so I could luckily learn the basics of theory underneath CAMRADII.

And after I joined Hyundai Motors, I strongly believed that we need CAMARDII for evtol development and my team lead had the same thought so we got it and I used it for a while. For I couldn’t attend the training course again, because it was really expensive for private class. Instead I learned CAMRADII again from research scientist of Korea Aerospace Research Institute, who has actively used CAMRADII for several years. But we purchased the technical support option, so I personally contacted Dr. Wayne Johnson if there is any questions.

When I compared the CAMRADII predictions with the experimental data, there were some discrepancy when I plot the graph, thrust vs. collective pitch angle or power vs collective pitch angle. I found that there was a slight error between real collective pitch angle of the blade and estimated collective pitch angle. Because I remember my senior in the lab was suffered from the same phenomena, he used high-speed capturing camera and correct the pitch angle. I was pretty sure about the cause of the error, because variation of measured torque vs thrust was exactly the same with the predictions. But, in Hyundai, I couldn’t get the such good camera, and instead I just correct the pitch angle of the measured data so that it can fit into the predictions.

## Aeroacoustics Analysis

(More explanation about previous work on acoustic analysis)

I could say there were three different phases, and different method was used for each phase.

First, at the very early stage of conceptual design when I have to determine rotor size and operating condition such as rotating speed, I used semi-empirical formulas for noise prediction: Pegg model and Schlegel model for broadband noise and Gutin model for tonal noise. I had those codes in python and excel sheet version and used one of them depending on the situation.

And then for designing blade planform and its optimization, I used PSU-WOPWOP or in-house acoustics code by coupling with CAMRADII results.

Finally, after rotor blade planform is fixed, I used CHARM and PSU-WOPWOP for calculating ground noise contour. But, the problem was that, in many cases, the flight trajectory or aircraft trim solution was not given yet, so I had to cover all those things on my own before final version of transition corridor is passed to me. I calculated trim solution for takeoff and approach conditions using simple force and moment equilibrium total in three directions, and tried different approach angles to see its effect on noise signature on the ground. The figure I put is actually not my work, and it was done by one of phd graduate from Penn state university and it is about noise abatement by adjusting helicopter flight trajectory, which is very similar to what I did in Hyundai. I checked the influence of flight trajectory on noise including Lmax, EPNL and SEL.

The conclusion and what I recommend to the executives was there needs to be some buffer zone around vertiport or we need to find and select less populated area around the vertiport as a flight trajectory. The most critical flight segment in terms of noise is approach condition, which is already widely known fact in helicopter field. If there is not much resident very close to vertiport, the best way would be having slight angle of flight path as a means of reducing average noise magnitude. But if the vertiport is right in the middle of big city or residential area, then the best way would be to keep its high altitude as much as possible and have very steep angle of descent, which would make more noisy sound at the vertiport, but more quiet at the community around the vertiport.

The one last piece I missed when I was working in Hyundai, was that I didn’t check the effect of fleet number or flight operating frequency on the environmental noise level such as Day and Night Level, which is calculated by averaging the noise for 24 hours with different weighting value on day time and night, respectively. And last month in September, I’ve got training of AEDT which is used by FAA and airports to estimate the noise and emission levels from aircrafts for certain duration of time. So I can say I am all set when it comes to noise analysis.

How much are you familiar with certification?

To be honest, I have no actual experience with certification process as you might have guessed from my work experience. I joined Hyundai Motors right after my phd study, and Hyundai did not proceed that much after unveiling the conceptual design SA-1 in CES 2020. In Hyundai, we had repeated very similar conceptual design process for short range evtol, unmanned cargo vtol, and long-range hybrid-electric vtol so called RAM, and hydrogen-powered 19-pax ctol aircraft But we did never go beyond CoDR or PDR.

But what I can say is I naturally became familiar with certification part 23, 27, 35 in perspective of performance and noise as I went through conceptual design and acoustic analysis. But surely I think that the experience with real existent aircraft is really meaningful, and I hope I can do that with Overair Butterfly.

## Noise Measurement

I mentioned that I measured the performance of a scaled tilt rotor when I was in Hyundai. I measured the noise as well. I couldn’t bring up the picture which was taken in Hyundai, so instead I brought the other picture, which is quite similar what I did in Hyundai. This picture is taken by one of my lab mates in graduate school, who measured the noise of a small size rotor.

Well, I am a bit concerned about disclosing what I have done in Hyundai, especially when it comes to some numbers. So, let’s say this way. I compared the measured noise data with the prediction, and it shows reasonably good agreement.

When we talk about the accuracy of the noise prediction, we typically look at not only overall sound pressure level but also frequency spectrum which includes frequency and amplitude information. It depends on the measuring position, but I remember the error was less than 3 dB, and I could capture the blade passing frequency well, but there was some limitation in capturing the broadband noise in high frequency. My next plan was using some the other ways such as UCD-QuietFly or high-order CFD solver. But at that time, I was called to join the kind of Task Force team which was for exploring potential of hydrogen powered aircraft from various perspective with McKinsey, and I was in charge of assessing technical feasibility of hydrogen powered aircraft and give the technical opinion to the UAM strategy team as well as McKinsey.

## Aircraft Conceptual Design

rotor layout, studying and choosing the aircraft configuration including rotor layout was always the first step of conceptual design for me.

## Rotor Blade Planform Design Optimization

1. overall
2. Requirements

Gross weight, number of rotors

Required thrust (considering download and control margin, 1.2 – 1.5 x gross weight)

1. Initial sizing

Trade study (PL vs DL, Weight vs. R) 🡪 Disk loading 🡪 radius

Trade study (Noise vs. tip Mach number vs. Blade loading)

Tip Mach number 🡪 rotating speed

Blade loading coefficient 🡪 blade mean chord, number of blade (blade solidity)

Bi-linear twist (needs higher twist at inboard to overcome high inflow ratio; like ideal twist distribution)

1. Airfoil selection

Blade loading 🡪 cl

Lift, drag: Max lift, Min drag in operation range

Eta = TV/P ~ cl/cd

FM ~ Cl^1.5/cd

Generate C81 airfoil database (M=0 to M\_max, AOA=-15 to 20 deg)

Use empirical modeling for high AOA (ref. Leishman)

Use interpolation for non-convergent range at low AoA

1. Blade planform

Determine root cut ratio considering motor size, installation, collective pitch at root (e.g. 0.15 – 0.20)

Need to discuss with design + structure engineer

Define pitch axis

(place pitch axis at a quarter chord of camber line (twist center) or a quarter chord of chord line)

Airfoil ordinate vs pitch axis

Chord length / twist angel vs. pitch axis

Sweep: linear or parabolic

Anhedral: linear

1. Design framework

DOE: Latin hypercube to generate meta model (surrogate model) with 10 x number of DVs

Surrogate model (response surface model (polynomial), Kriging model

Optimization method: gradient/non-gradient method, single/multi-objective

Use python to generate a blade planform by changing DVs and as a wrapper to connect CAMRADII and ModelCenter

## Blade Section Design

Structural safety: avoid fatigue in operation condition

Dynamic safety: avoid resonance in operating condition

Select material and design section

Avoid excessive weight

Effect of section property on loading

Difficulty in fabrication depending on complexity of section shape

# Behavior Questions

## Strength and Weakness

# Questions

Any plan to measure the noise seriously in XP-1A’s flight test? Does Overair have many numbers of microphones to measure the noise, or will you get some acoustic consulting service?

# Closure

Today I appreciate for having me and giving me this opportunity to have an interview.

I strongly believe that my extensive expertise and passion for UAM will bring immense value to your team, and I would be delighted to be one of the professional engineers that will be joining Overair from Hanwha side. If you have any questions, please do not hesitate to reach me. Again thank you for your time and look forward to hearing from you.