Key Note Presentation (Korea)

Introduction to Current VTOL R&D Projects in Korea

2023. 02.10 (Friday)

Choi, Keeyoung

(Prof. @ Inha Univ. , Former President of KSAS VTOL Chapter)

Contents

I. Overview

Overview

❖ **Korea Government have launched several national program in last 5 years.**
- In civil field : eVTOL Aircraft System Technology Development, unmanned eVTOL for AAM
- In military field : Light Armed Helicopter, Marine Attack Helicopter, Unmanned VTOL for Observation and Delivery Service

❖ **Industry, Institute and University have worked together to reach the national R&D target for the future market according to each capability**
- Industry : System Integration and Hardware Development
- Institute : Core Technologies Research & Development
- University : Basic Technologies Research & Development

❖ **Next Slides shows the each activities of University, Industry and Institutes related to VTOL Technologies**

II. Universities

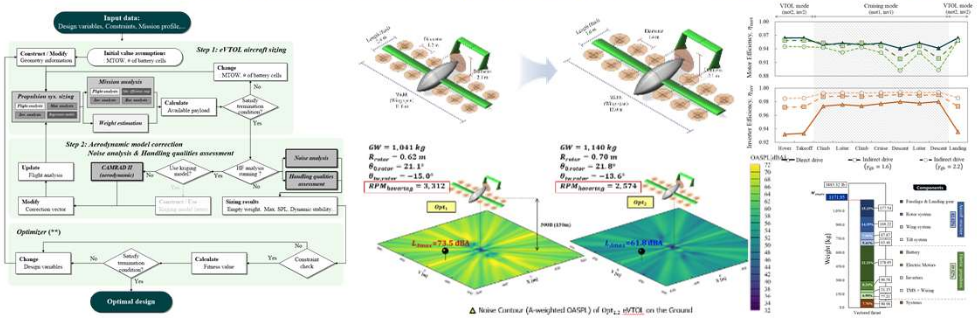
Seoul National University

Aerospace Vehicle Design Laboratory

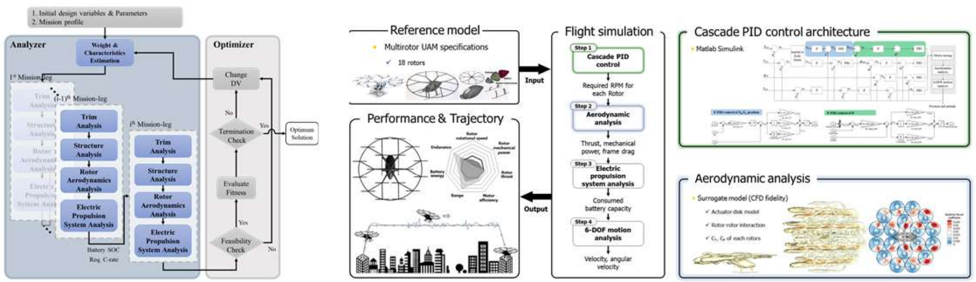
Prof. Kwanjung Yee | Ph. D. Candidate : 21 | Master Course : 9

Ongoing researches for VTOL (1/2) – Conceptual Design

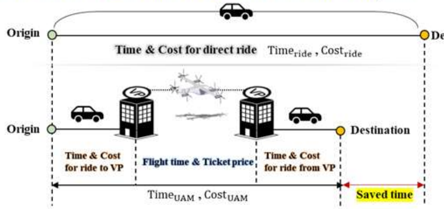
RISPECT+ (Rotorcraft Initial Sizing and Performance Estimation Code and Toolkit+)
Rotorcraft sizing, aerodynamic & acoustic performance estimation, fuel cell/battery sizing



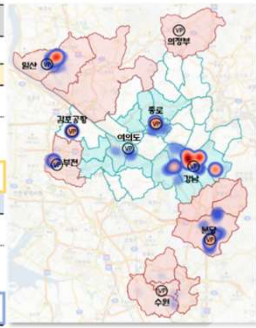
CLOUDS (Conceptual Layout Optimization for Universal Drone Systems)
Mission-oriented performance assessment, design optimization

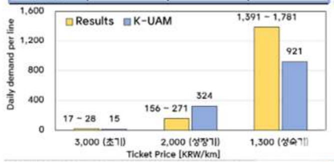


MADAM
(Multidisciplinary Analysis and Design for Advanced Mobilty)
UAM Cost & Demand Estimation Analysis



Stage	초기 (2025~)	성장기 (2030~)	성숙기 (2035~)
Ticket price	3,000 KRW/km	2,000 KRW/km	1,300 KRW/km
Research results			
Number of Lines	24		
Demand result	408 ~ 666 per day	3,751 ~ 6,498 per day	33,376 ~ 42,741 per day
Demand per line	**17 ~ 28**	**156 ~ 271**	**1,391 ~ 1,781**
K-UAM Result[1] (Distance ≈ 29 km)			
Number of Lines	2	14	123
K-UAM Demand result (Logit model based on SP survey[2])	29 per day	4,536 per day	113,179 per day
Demand per line	**15**	**324**	**921**





Result (2,000 KRW/km)
Daily demand: **3,751**
UAM modal split: 0.43%
Roughly, **42**~63 aircraft re
Daily 1,260~1,870 fli
Average 53~78

Seoul National University

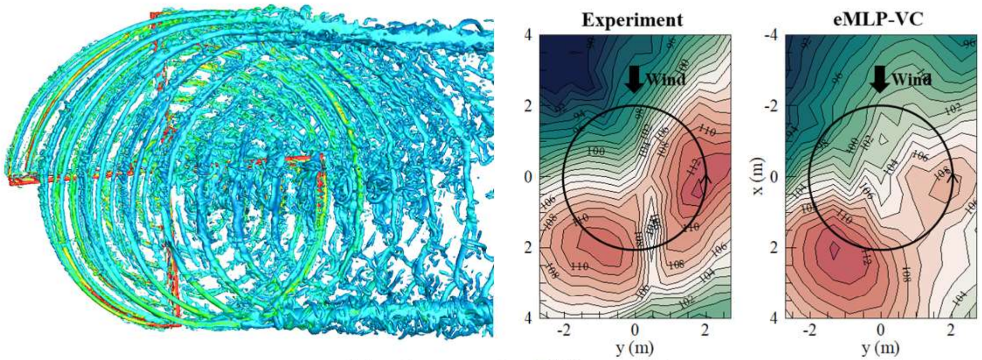
Aerospace Vehicle Design Laboratory

Prof. Kwanjung Yee | Ph. D. Candidate : 21 | Master Course : 9

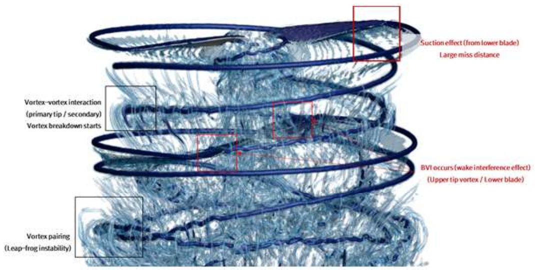
Ongoing researches for VTOL (2/2) – Detailed Design

Rotorcraft Aerodynamics and Aeroacoustics

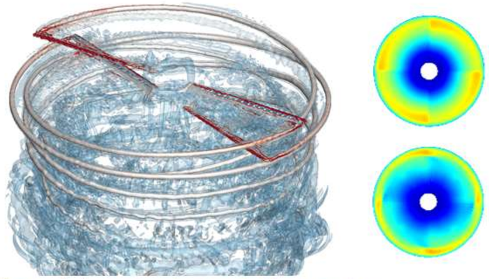
with high-order accurate scheme for vorticity conservation



Single rotor in BVI condition



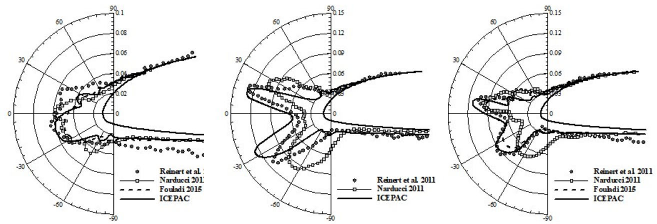
Coaxial, co-rotating rotor



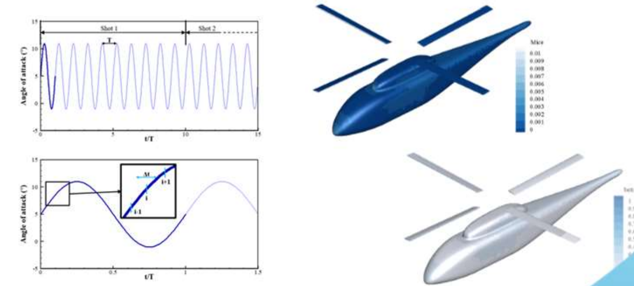
Coaxial, counter-rotating rotor

Aircraft Icing Accretion

ICEPAC (Ice Contour Evaluation and Performance Analysis Code)



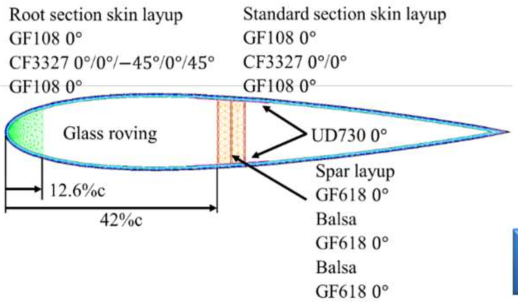
Improved prediction accuracy using transition model



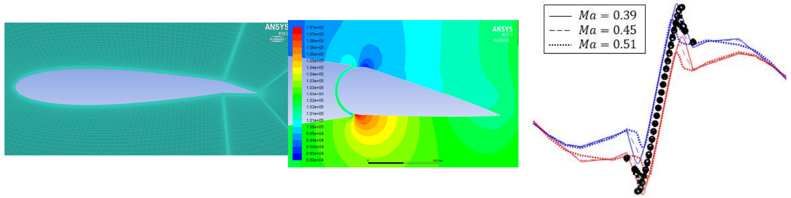
Prediction of Rotorcraft Icing Accretion

Seoul National University

Structural design

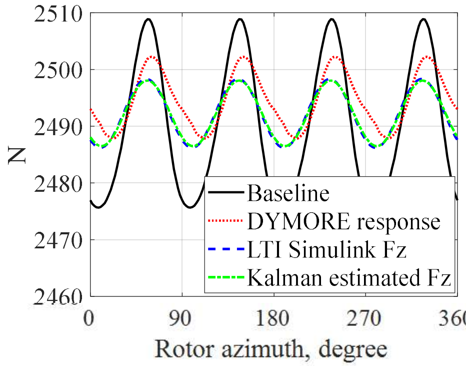


Active blade aerodynamics

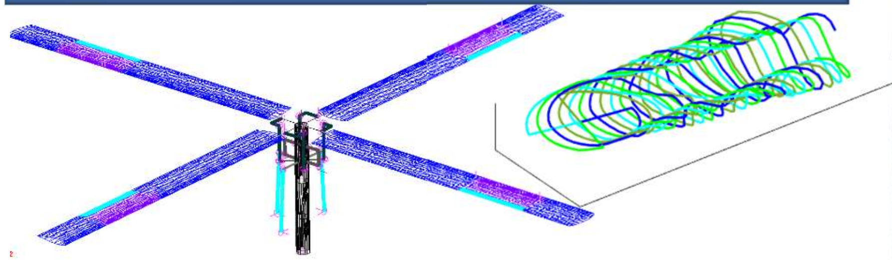


Rotor test and analysis

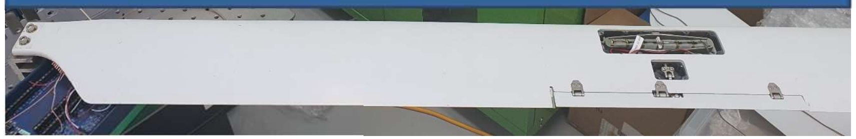
Controller design



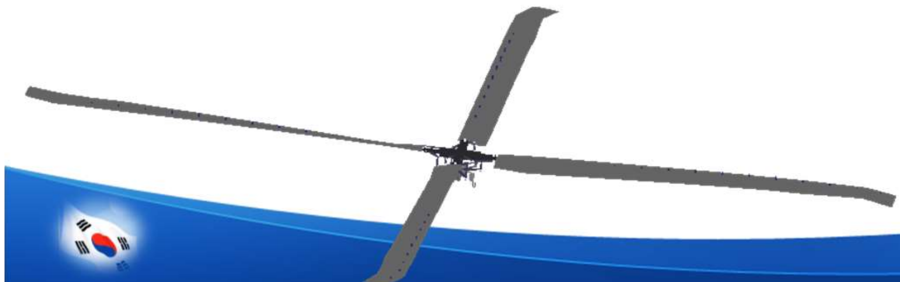
Multi-body dynamics analysis

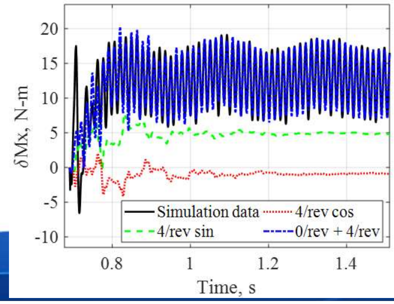


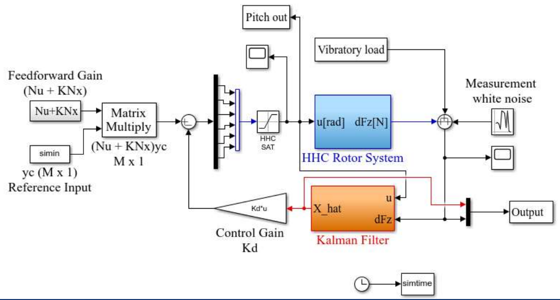
Blade fabrication and test



CFD-CSD rotor higher harmonic control







Seoul National University

Step 1	Initial deliverables	Step 2	Final deliverables

Group 1

Research on the Data-based conceptual design techniques

Mission profile

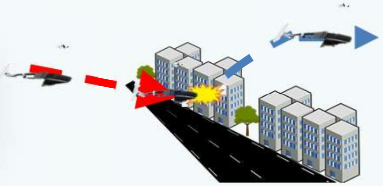
UAM configuration Design

Group 1-3 sharing

Group 2

Robust autonomy system design automation and verification

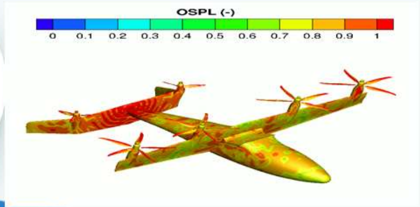
Prototype test



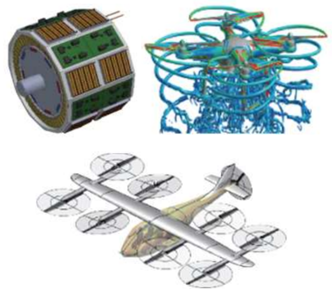
Group 3

High precision UAM flow/structure/noise analysis and crash analysis

Detailed design



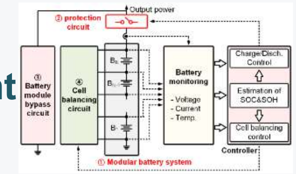
UAM multi-disciplinary integrated concept design software



1st Technology demonstration 1/5 scaled prototype

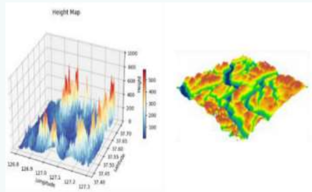
3D data sharing platform-based shape optimization

Battery life Improvement circuit

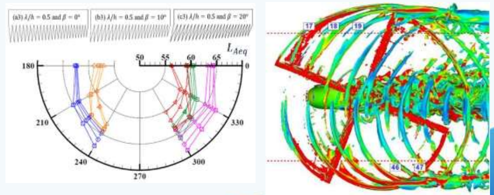


ATM/UTM coupled automated flight technology

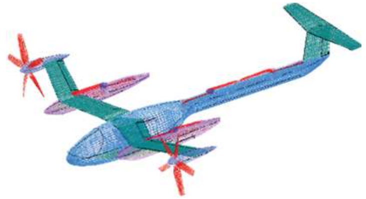
Mixed-reality operation simulation



Noise/vibration reducing design optimization



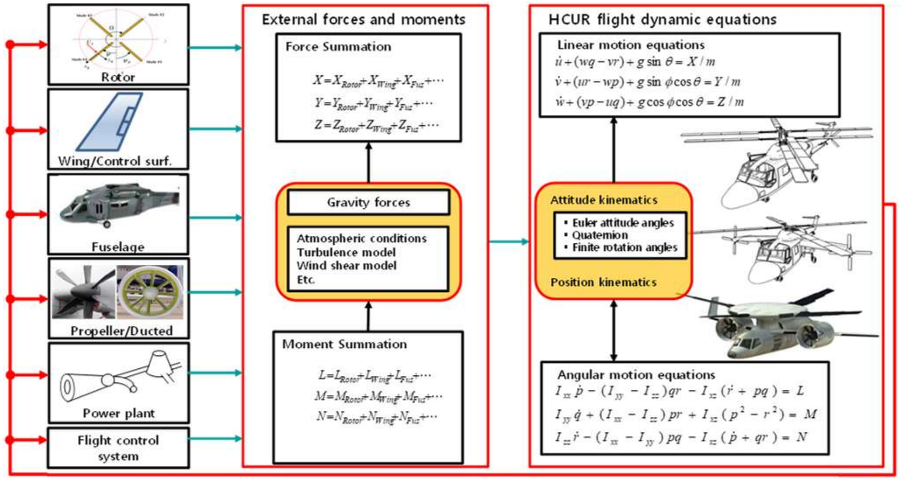
Digital twin UAM simulation



2nd Technology demonstration 1/5 scaled prototype

Konkuk University

HETLAS : Component-Model based Helicopter Trim, Linearization, and Simulation Program

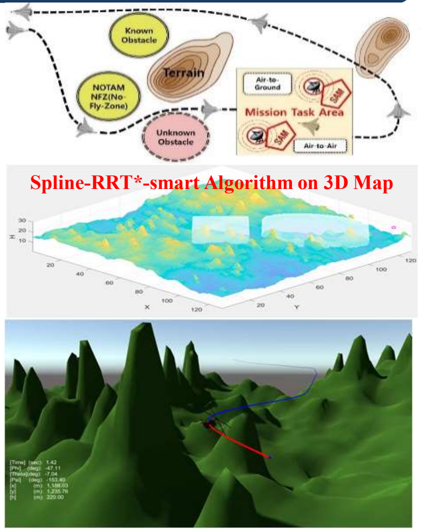


Autonomous Rotorcraft Flight Control for Offensive and Defensive Tactical Missions

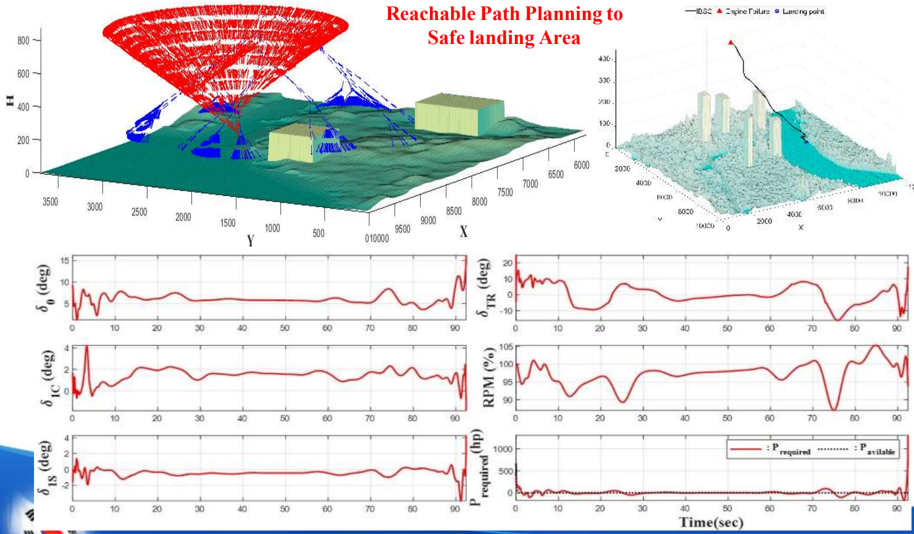
Mission Planner
- Real-time applications
- Near optimal path plan

Path Planner
- Low detectability/LethaL
- Collision avoidance law

Trajectory-Tracking Control
- Adaptive Incremental SMC
- Adaptive Incremental BSC



Autonomous Emergency Landing Flight Control

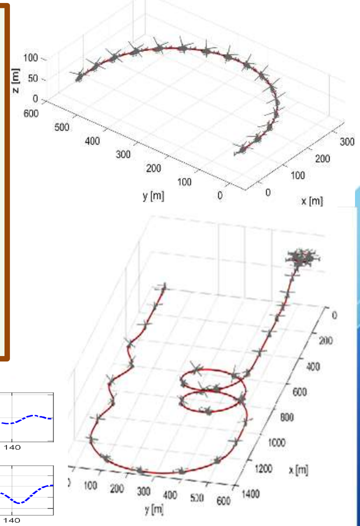


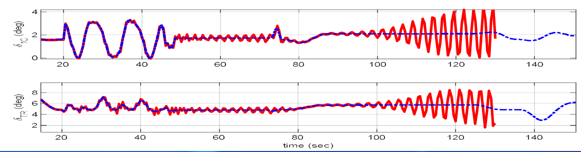
Adaptive Robust Nonlinear Rotorcraft Flight Control

Accurate tracking performance
- Nonlinear SMS/BSC Design

Robustness
- Incremental dynamics
- Immersion & Invariance (I&I)
- Tuning Function Method
- Variable Directional Forgetting LS Estimator

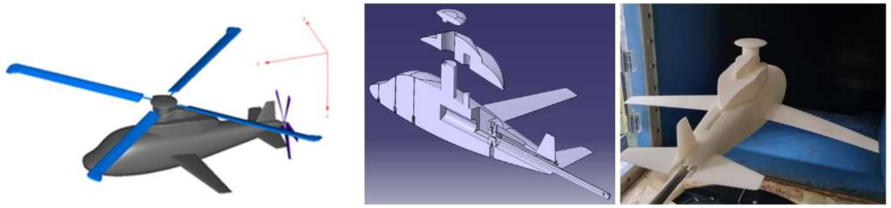
Guaranteed Stability/Performance
- Lyapunov-Function Based Design



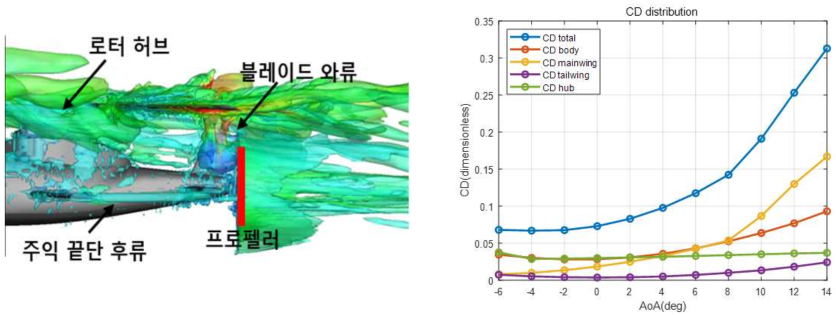


Konkuk University

HCUR: Fugelage Drag Prediction

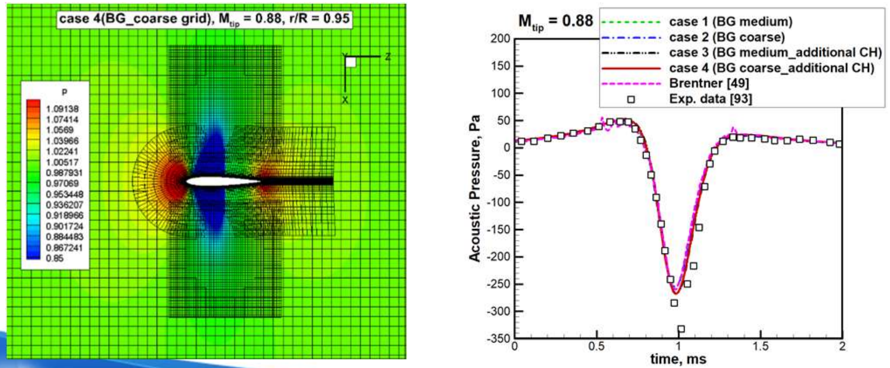


▲ Wind tunnel experiments for HCUR scaled model

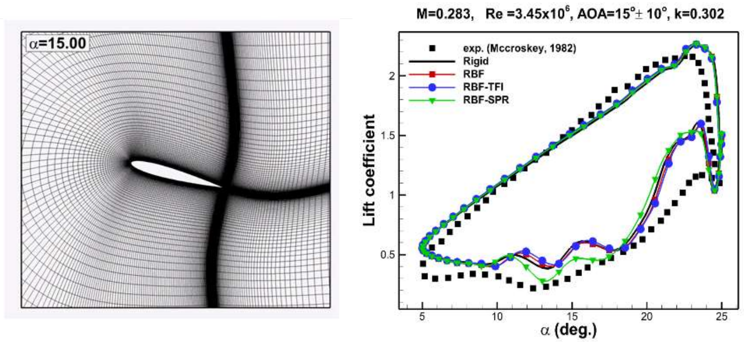


▲ CFD analysis & drag coefficient of each part with A.o.A.

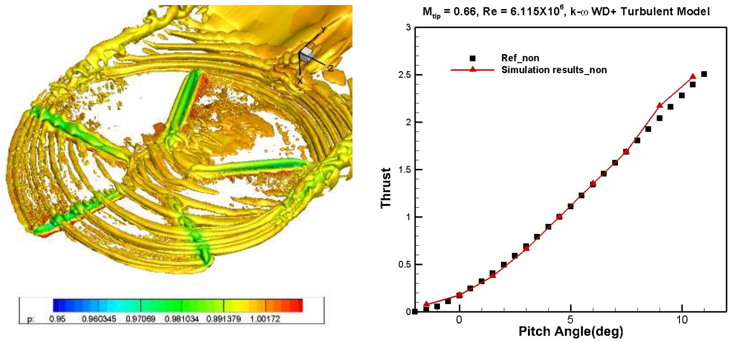
Farfield Noise Prediction: Adaptive Chimera Grid



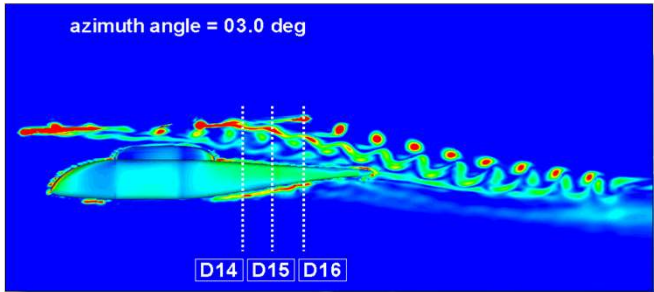
Rotorcraft CFD Development



▲ Dynamic stall prediction by using RBF-based grid deformation



▲ LCH 5-bladed rotor in forward flight (left) & thrust in hover

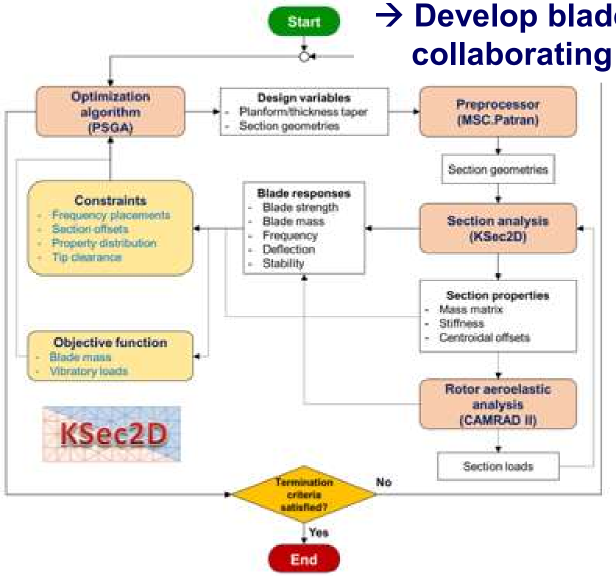


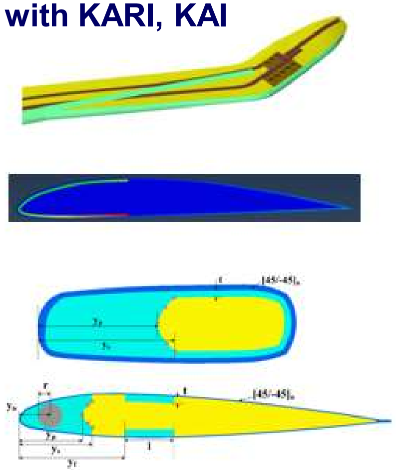
▲ Tip vortex-fuselage interaction

Konkuk University

Blade Design Optimization Framework

→ Develop blades while collaborating with KARI, KAI





4th Generation M&S Program Development

- Non-linear Blade Deformation
- FE-based Blade Cross-Section Analysis
- Rotorcraft Vibration & Noise Prediction
- Flight Dynamics & Control Modules
- Real-time Flight Simulation
- Rotorcraft Sizing & Performance Analysis

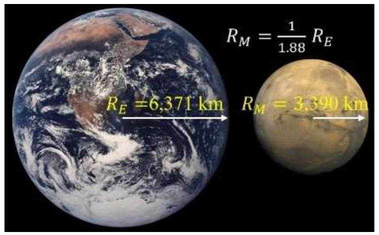
Comprehensive Rotorcraft Aeromechanics Analysis System

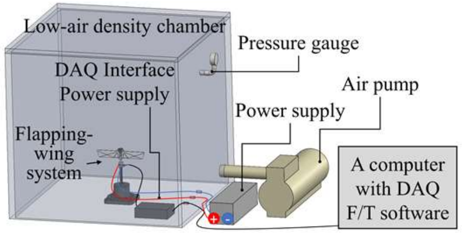
- Liftingline-based Rotor Aerodynamic Model (Rolled-up Free Wake)
- Hybrid CFD/Free Wake Analysis
- Full CFD Aero & CFD/CSD Interface
- Fuselage Interactional Aerodynamics
- High-performance Computing
- GUI Interface (Python)

- Optimum Design
- Module-based S/W Architecture
- Versatile Compound Rotorcraft Design
- DLL-based Program Interface

Next Generation Rotorcraft Modeling & Simulation Software

NRF-BRL: Mars Atmospheric Flying Robot Laboratory





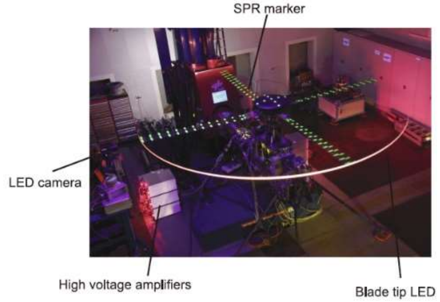
Int. Consortium Project: STAR (Smart Twisting Active Rotor)

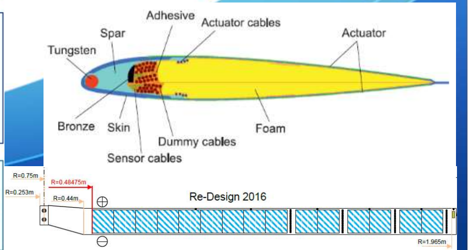
Goals
- Demonstrate noise/vibration reduction with performance improvement via ATR concept
- Realize active rotor technology

Members
- German DLR / French ONERA
- USA: Army AFDD & NASA Ames
- Korea: Konkuk Univ. & KARI
- Japan: JAXA
- UK: DSTL & Univ. of Glasgow

Flight Conditions
- Hover, Low speed descent
- Cruise/high speed
- High load
- High μ (at 50% RPM)

Schedule
- Launched at May 2009
- Wind tunnel test planned: 2024 at DNW, Netherlands





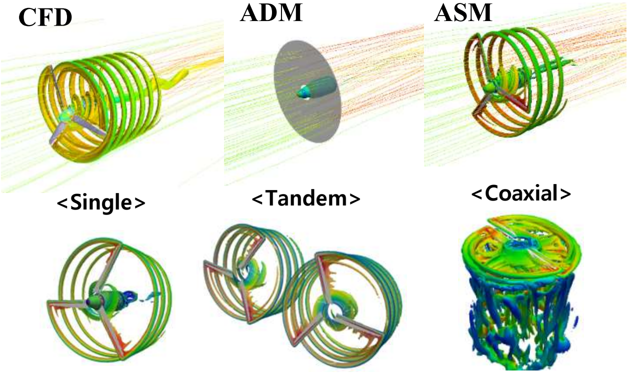
Pusan National University

Professor : Donghun Park & Sejong Oh (Emeritus prof.)

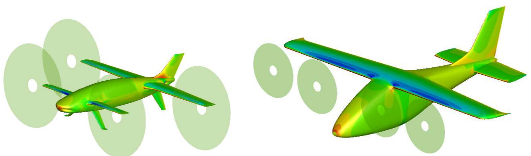
❖ Applied Aerodynamics and Design Lab. (AADL)

- Development of practical & efficient aerodynamic analysis tools (ADM / ASM / Panel)
- Implementation of aerodynamic tools for MDO framework
- Multi-fidelity based aero DB construction and design optimization

Actuator Disk/Surface Methods

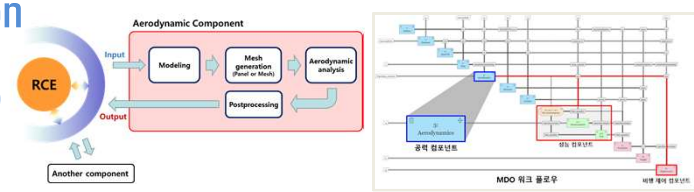


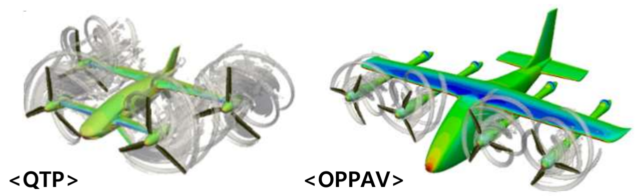
Practical/Efficient Aerodynamic Analysis Tools



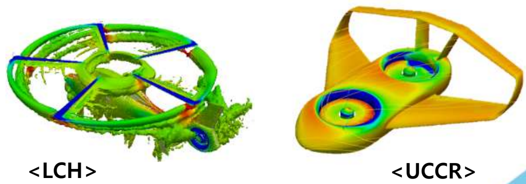
Panel Method + Actuator Disk Theory

MDO Framework Implementation

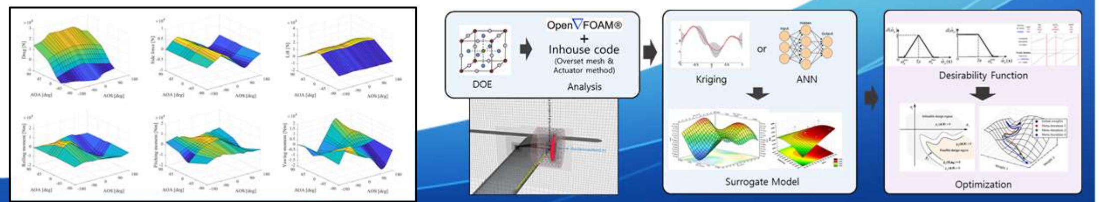




Aerodynamic Analysis



Aero DB Construction & Design Optimization



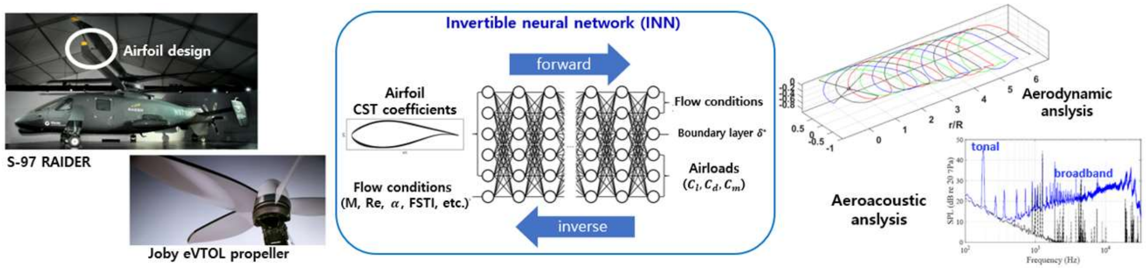
Pusan National University

Assistant professor : Yong Su Jung

❖ Computational Aerodynamics and Rotorcraft Lab (CARL)

◆ **CFD Trained Invertible Neural Networks and Machine Learning for Rotor Blade Airfoil Design (2022~2024)**

- Development of forward and inverse machine learning models that are trained using RANS simulations

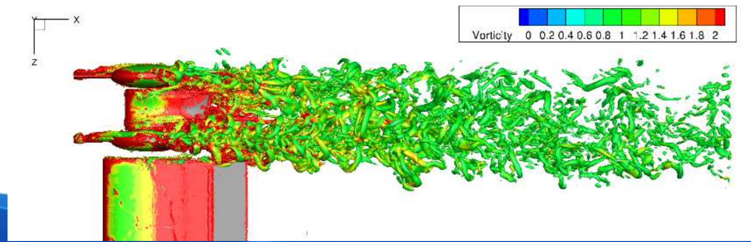


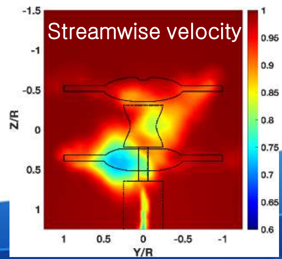
◆ **Line-based Unstructured Grid CFD Techniques for Rotorcraft Applications**

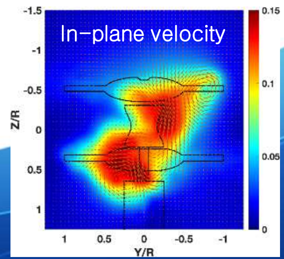
- Automated mesh refinement capability for 2-D Hamiltonian solver (2022~2024)
- Improvements on a laminar-turbulent boundary layer transition model

◆ **Interactional Aerodynamic/Aeroacoustics for Advanced Rotorcraft Configurations**

- Coaxial rotor hub flow simulations using hybrid RANS-LES
- Aeroacoustic simulations for a wingtip-mounted propeller







Chungnam National University

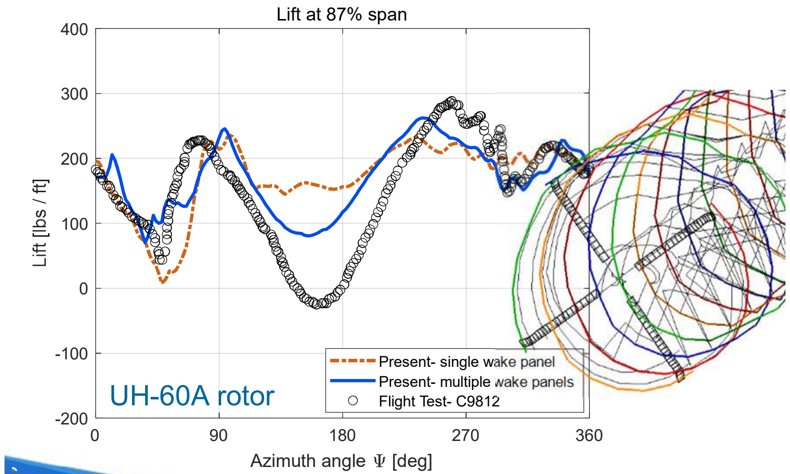
Professor Jae-Sang Park

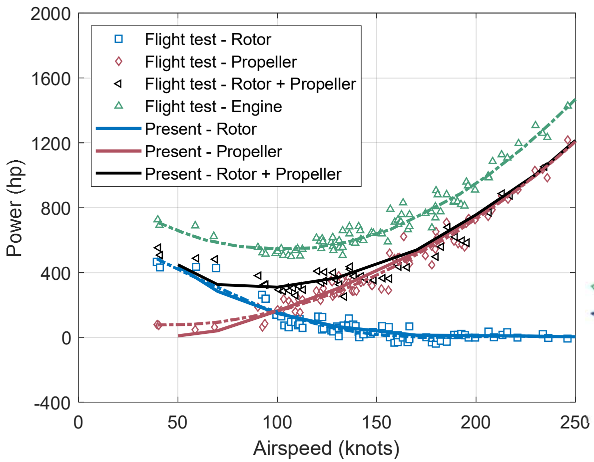
- Ph.D from School of Mechanical and Aerospace Eng., Seoul National University, 2006
- Professor in Dept. of Aerospace Eng., Chungnam National University, 2013 ~ Present
- Research interests : Rotor aeromechanics analyses, Active vibration controls,
  Conceptual design

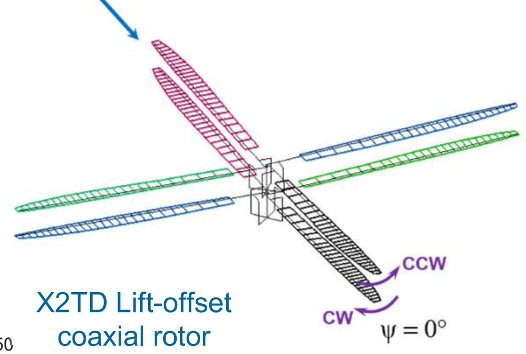
▪ Rotor aeromechanics analyses

- Rotorcraft comprehensive analysis tools : CAMRAD II and DYMORE II
- Conventional helicopters, Lift-offset compound helicopters, Tiltrotor aircraft

X2 Technology Demonstrator





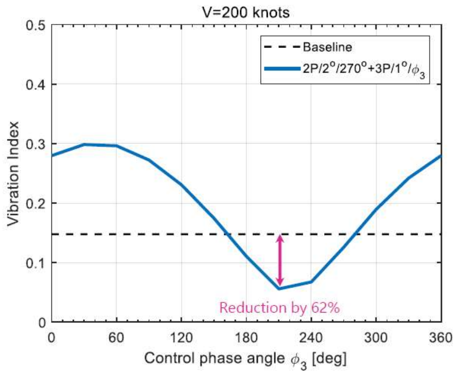


X2TD Lift-offset coaxial rotor

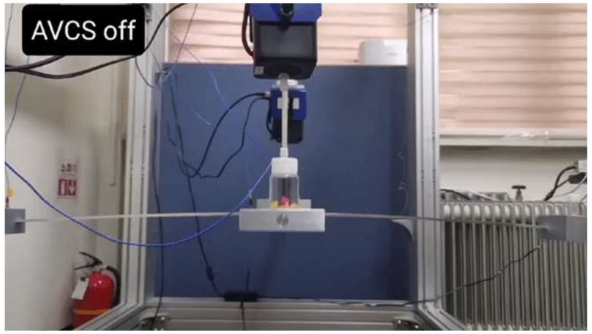
Chungnam National University

▪ Rotorcraft active vibration controls

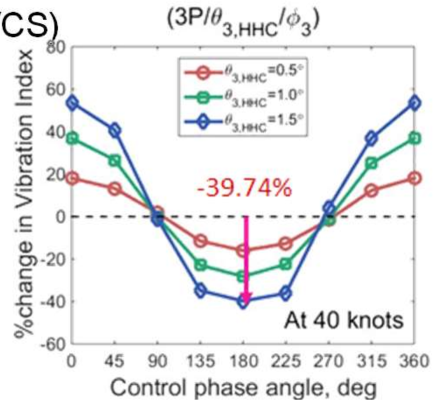
- Active rotor vibration controls using Individual Blade pitch Control (IBC) or Higher Harmonic pitch Control (HHC)
- Active airframe vibration controls using Active Vibration Control System (AVCS)



Active vibration control for X2TD rotor using Individual Blade pitch Control



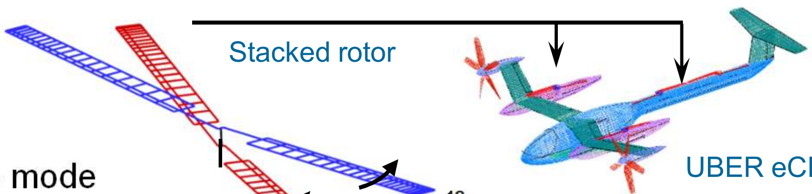
Active vibration control system (AVCS) for small-scaled compound helicopter model

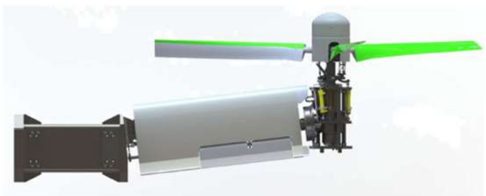


Active vibration control for medium utility helicopter using Higher Harmonic pitch Control

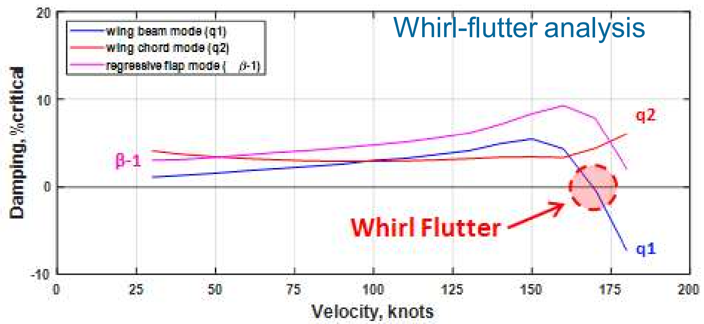
▪ Tiltrotor and eVTOL stacked rotor

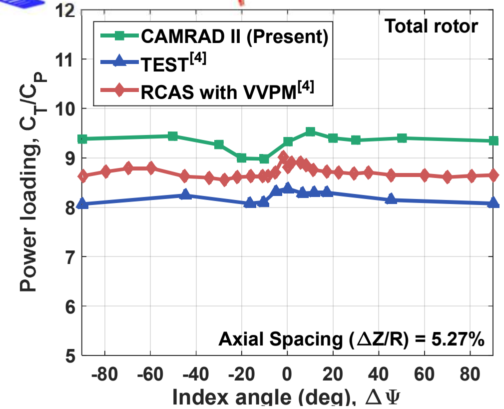
- Whirl-flutter analyses for tiltrotor aircraft in airplane mode
- Hover performance analyses for stacked rotor of eVTOL aircraft





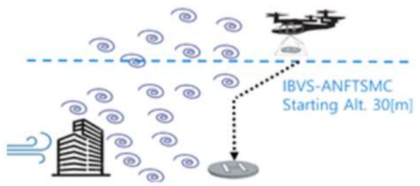
TiltRotor Aeroelastic Stability Testbad (TRAST, US)

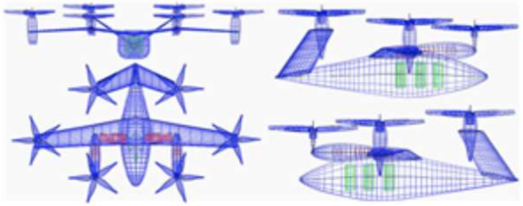


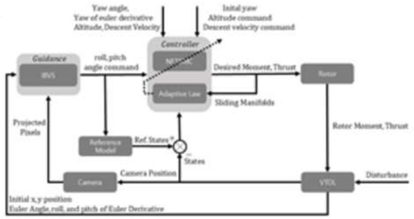


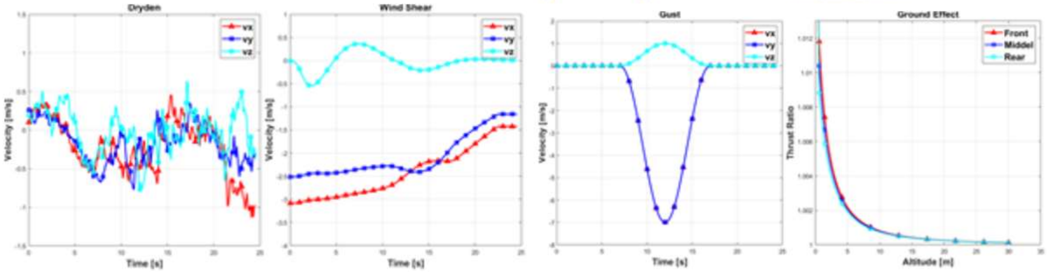
Inha University

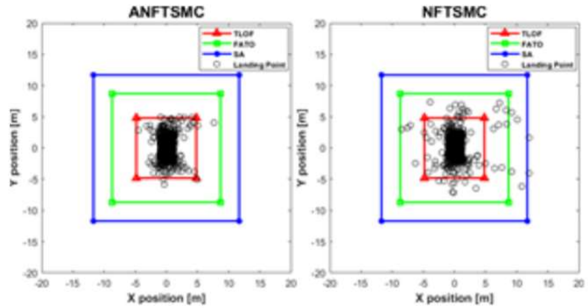
Vision-Based Automatic Landing System for UAM Considering Building Wind



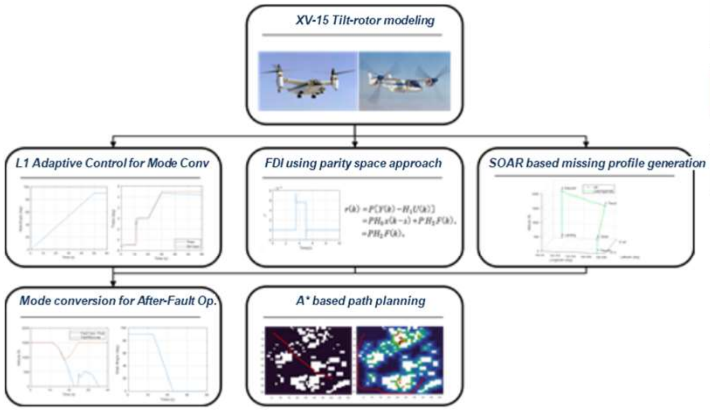


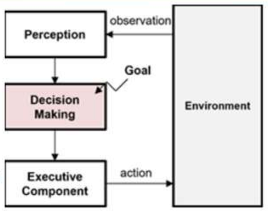


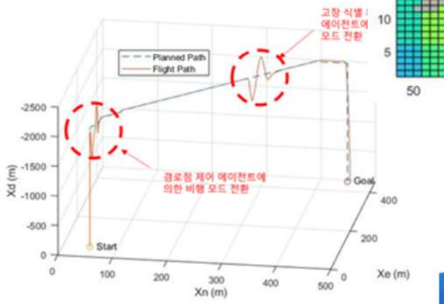


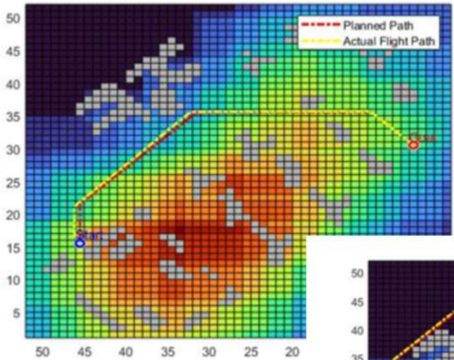


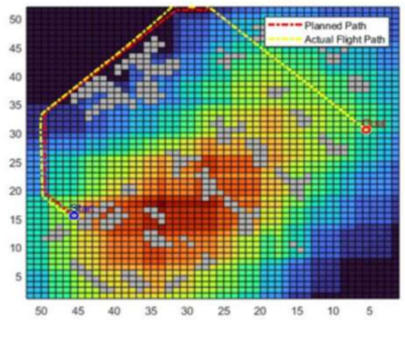
Autonomous System with Cognitive Architecture











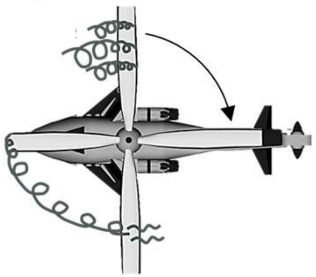
$\alpha_d = 1, \alpha_r = 5$

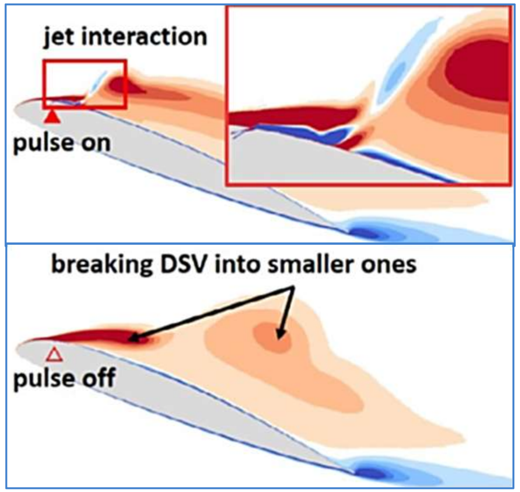
GIST (Gwangju Institute of Science and Technology)

Dynamic Stall Control

- **Dynamic stall control with impulsive jets**
- **Impulsive jet**
  - Sonic jet for 1 msec
  - Generated from combustion-powered actuation
  - Breaking DSV into smaller vortices
- **Control benefits**
  - Moment peak (negative) reduction by 70%
  - Lift enhancement by 20%

Dynamic Stall in Retreating Blades

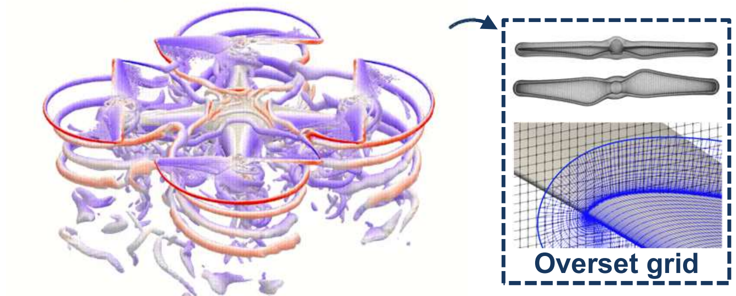




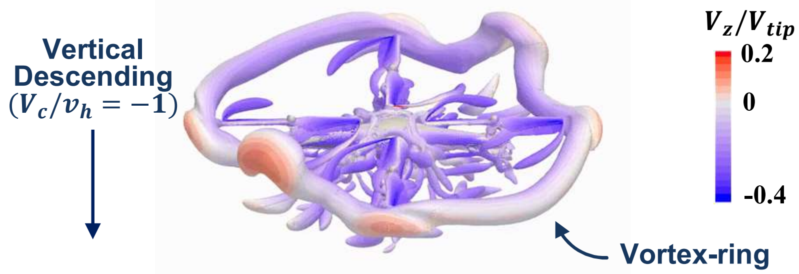
[Kim, T. and Jee, S., 2023, Comp & Fluids]

Multi-Copter Aerodynamics

- **Full Navier-Stokes Solver with overset grid**
  - OpenFOAM with SA-RC RANS
  - CFD is validated for a hovering quadcopter
- **VRS : vortex-ring state**
  - Must-to-avoid condition in descending
  - Well captured in current CFD



▲ Quadcopter in Hover
$V_{tip} = 63$ m/s

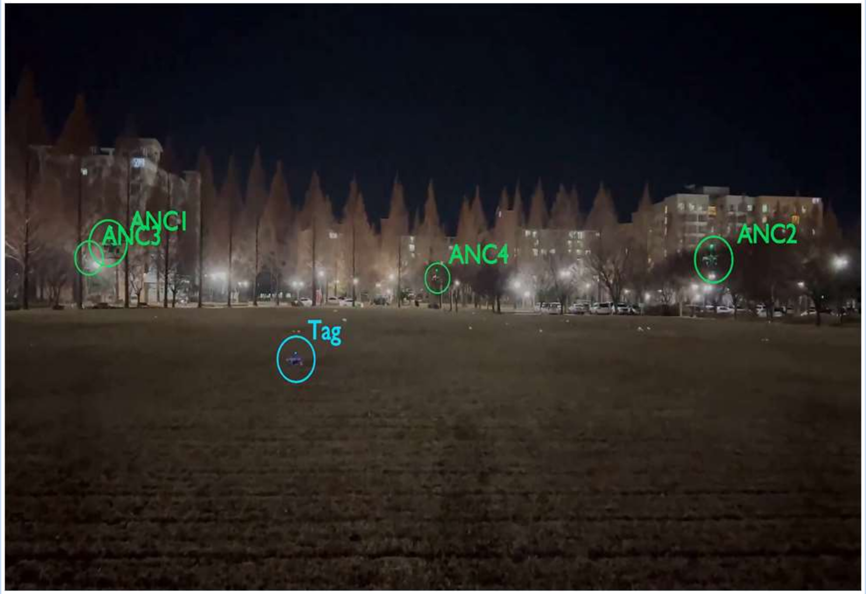


▲ Quadcopter in VRS (vortex-ring state)
Descending velocity $V_c = -5.5$ m/s $= -0.09\, V_{tip}$

[Park, Y. M. and Jee, S., 2023, AIAA Aviation]

GIST (Gwangju Institute of Science and Technology)

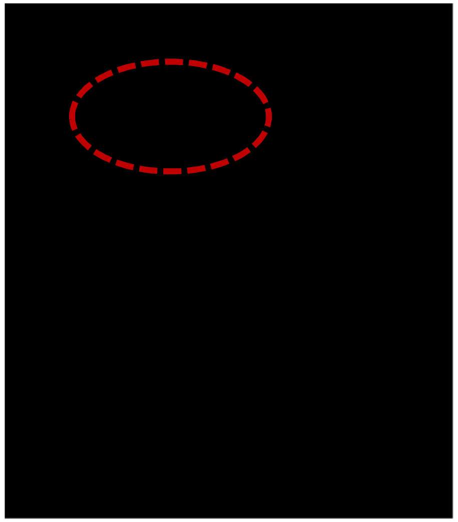
Multi-UAV Control

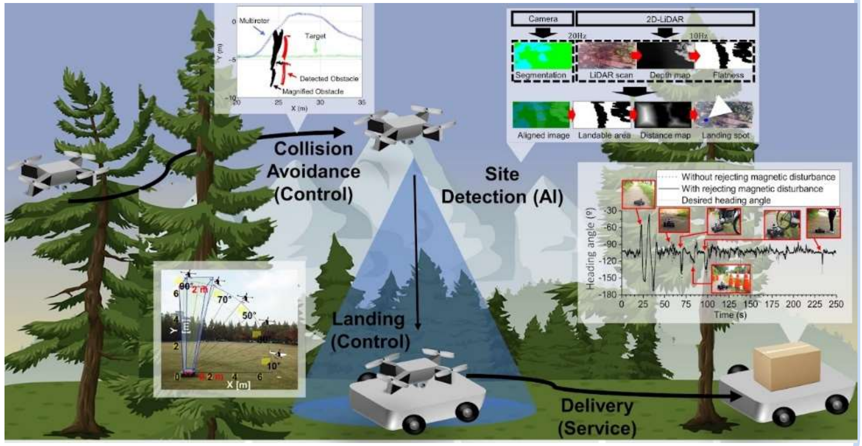


▲ Multi-UAV Control with UWB

- NO GPS for tagged UAV
- Positioning through RF-based UWB (ultra-wide band) with autonomous anchored UAVs
- Decentralized position control with stable inter-vehicle communication

Collision Avoidance Control





Gyeongsang National University (1 / 2)

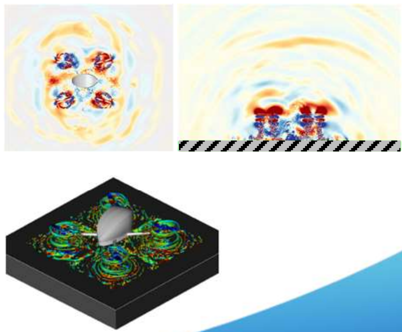
❖ Biography

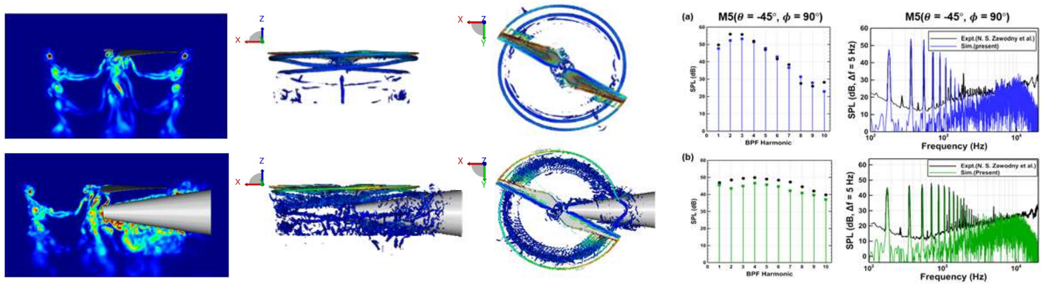
- **Hakjin Lee, Ph.D.** (hlee@gnu.ac.kr)
  - Assistant Professor, School of Mechanical and Aerospace Engineering, Gyeongsang National University
  - Director, **Rotorcraft Aerodynamics and Noise Simulation (RANS)** Lab.
- **Education**
  - Ph.D. in Aerospace Engineering, Korea Advanced Institute of Science and Technology (KAIST), 2019
  - M.S. in Aerospace Engineering, Korea Advanced Institute of Science and Technology (KAIST), 2014
  - B.S. in Aerospace Engineering, Korea Aerospace University, 2012
- **Research Interests**
  - **Rotor Aerodynamic, Aeroacousitcs**
  - Computational Fluid Dynamics (CFD), Computational Aeroacoustics (CAA), Vortex Methods
  - Rotorcraft, Helicopter, Urban Air Mobility (UAM), Drone, Wind Turbine

❖ Research topic I

- **Aeroacoustic analysis of urban air mobility**
  - Investigate the interactional aerodynamics and aeroacoustics of UAM
  - Simulate the co-axial multi-rotor eVTOL vehicle in ground effects

Acoustic dilatation field of co-axial eVTOL





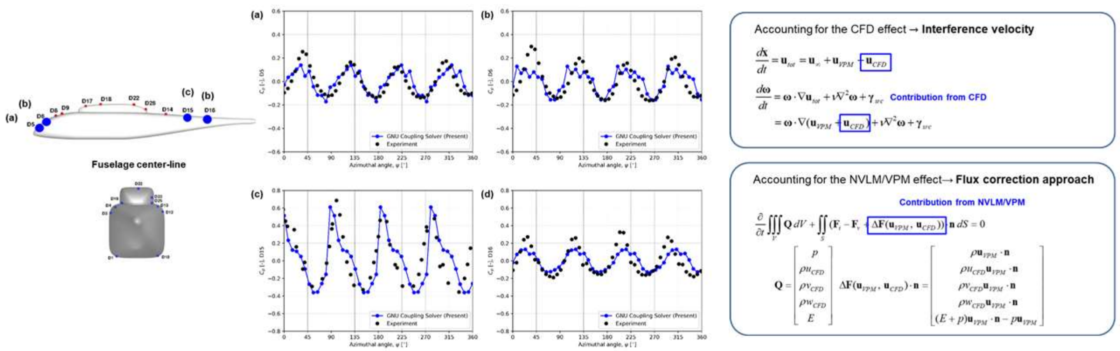
Comparison of Isolated rotor and rotor-conical airframe

Gyeongsang National University (2 / 2)

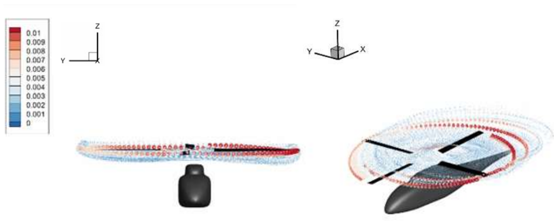
❖ Research topic II

➢ Comprehensive analysis of rotorcraft

- Hybrid Lagrangian-Eulerian approach for simulating the complex rotorcraft
- Provide an efficient and accurate aerodynamic analysis solution, which supports the aeroacoustic design of rotorcraft



Fundamental formulation and validation results of NVLM/VPM/CFD simulation



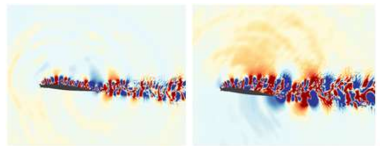
NVLM/VPM/CFD simulation of complete rotorcraft

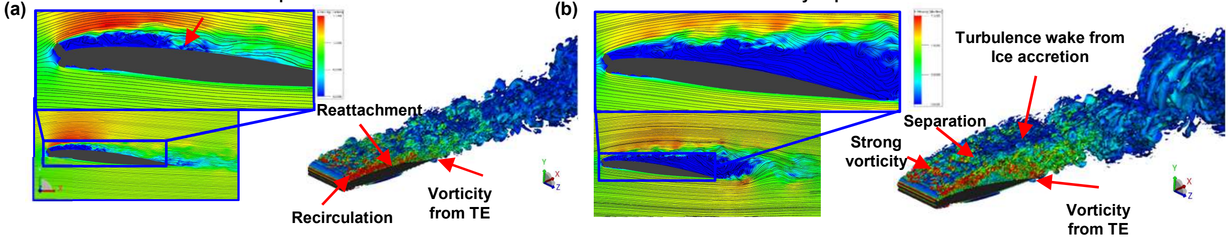
❖ Research topic III

➢ Flow physics and aeroacoustics of iced airfoil and rotor blade

- Analyze the expanding process of separation bubble and noise generation of an iced airfoil

Acoustic dilatation field of iced airfoil



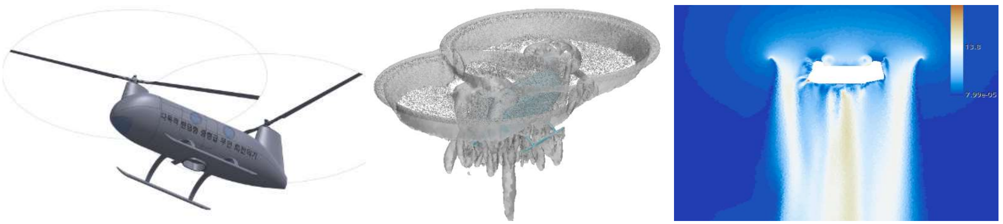


Instantaneous x-velocity contour and λ_2 iso-surface: (a) 6 deg. (b) 8 deg.

Hanseo University

- **Research Area: Aerodynamics**
  - Development of a mid-fidelity aerodynamic solver based on vortex methods
  - High-fidelity CFD computation for rotorcrafts

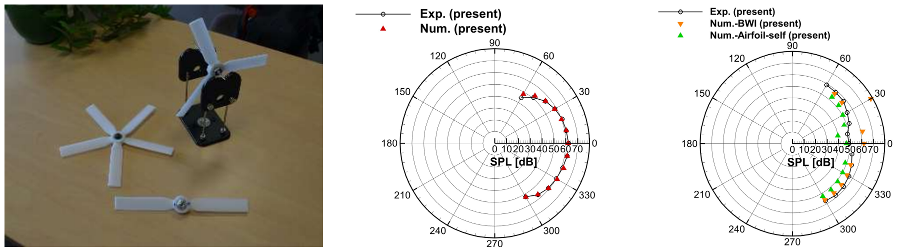
[redacted]



CFD computation for a tandem UAM helicopter

- **Research Area: Aeroacoustics**
  - Development of a noise-prediction code for rotorcrafts (tonal/broadband/body-scattering)
  - Development of a community noise assessment code

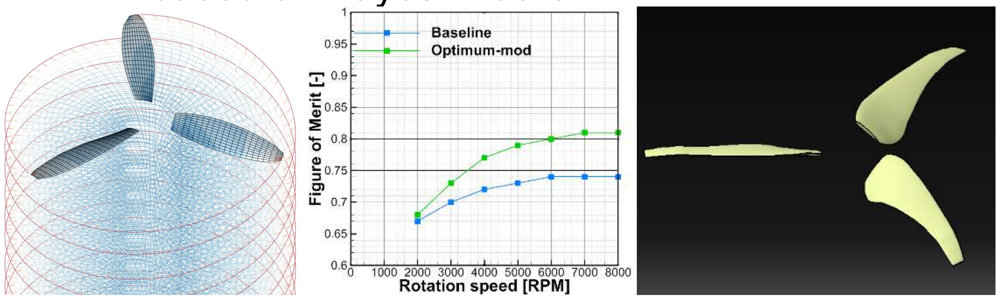
[redacted]



Rotor noise prediction for a 3-bladed UAV rotor

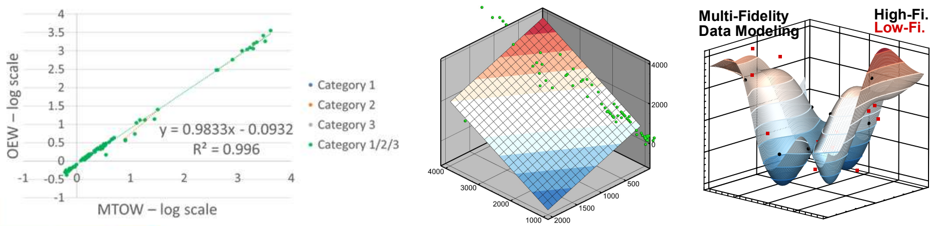
Hanseo University

- **Research Area: Design Optimization**
  - Development of machine-/deep-learning based surrogate models
  - Aleatory/epistemic uncertainty quantification based on Bayes' theorem

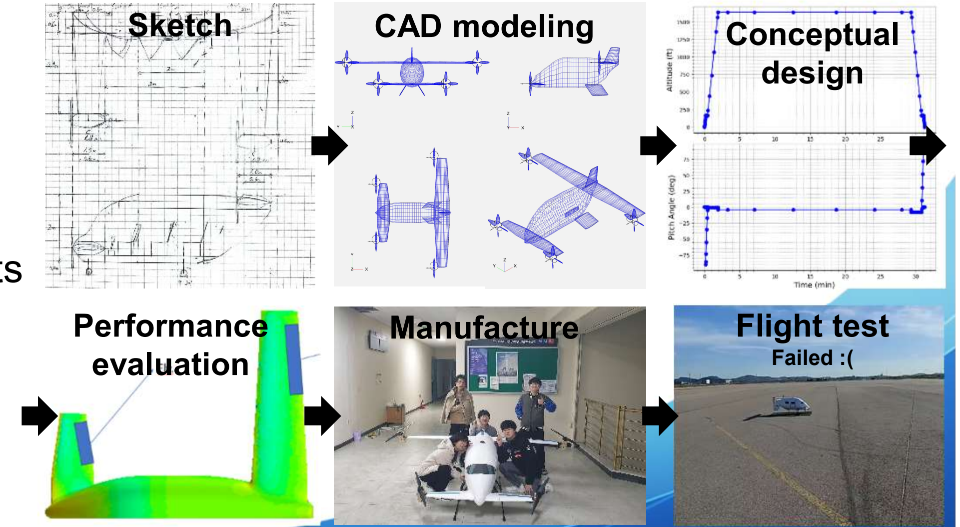


Design optimization of a sUAS rotor

- **Research Area: System Design**
  - Data modelling of aircraft performances for conceptual designs
  - Conceptual design of aircrafts
  - Manufacture and flight test of designed aircrafts



Data modelling for small-scale UAM vehicles



Design, manufacture, and flight test of a tilt-rotor UAM vehicle

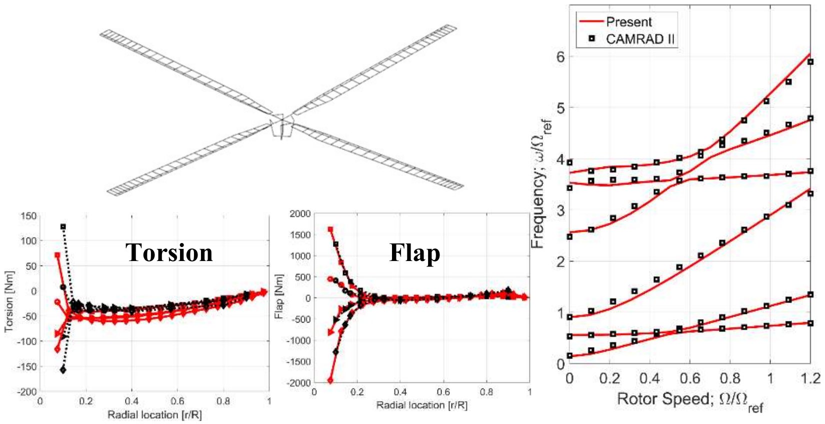
Jeonbuk National University

❖ **Development of Vibration Source Active Control Device SW for Medium Helicopter Vibration Reduction (2022~2024)**

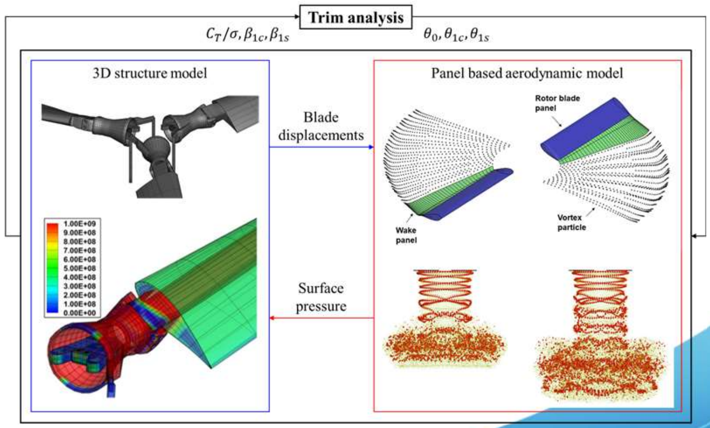
- Nonlinear beam analysis coupled with aerodynamic model
- Load analysis and verification with CAMRAD II

❖ **Development of rigid coaxial rotor system design/manufacturing technology (2022~2026)**

- High-precision rotor structural dynamics via 3D FEM and coupling with aerodynamic model



<Verification of beam analysis with CAMRAD II for HHC application>



<Aeromechanical load/vibration analysis for coaxial rotor system>

III. Industries

Korea Aerospace Industries

A Professional Integrated Development for Rotary Wing

KUH-1

Military Helicopter

"The Excellent Mission Profiler"

- Specification
  - Dimensions : 3.0m × 19.0m × 5.0m
  - Power Plant : 1,855 shp × 2
  - Max. Speed : 145 kt
  - 18 passengers
- State-of-the-art Equipment
- Excellent performance in various terrains, harsh conditions both day/night and any adverse weather conditions

KUH Variants

Police/Medical/Etc. Helicopter

"Contribution to Safety"

- Derivatives Expanding Domestic and International Civil and Parapublic based on KUH-1.
- Various missions like search and rescue, patient transportation and fire-fighting.

LAH / LCH

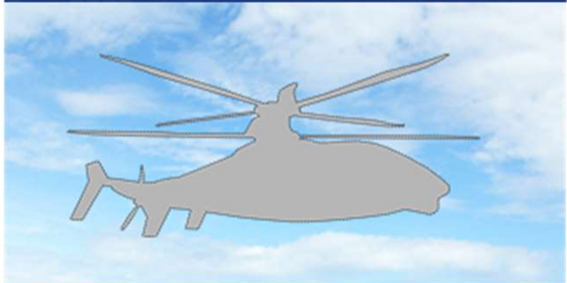
Light Armed/Civil Helicopter

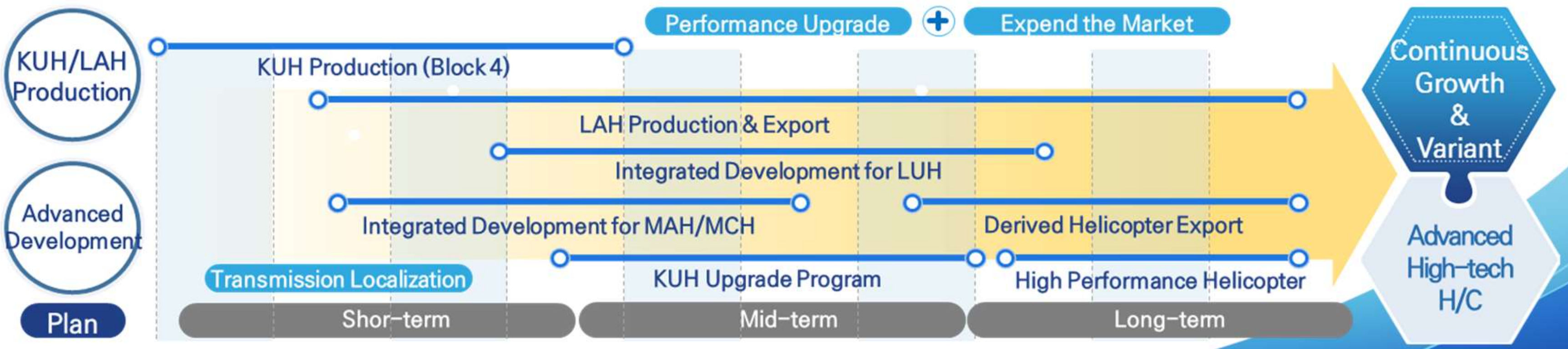
"Enhancement of the Armed Forces"

- Specification
  - Dimensions : 3.9m × 14.3m × 4.3m
  - Power Plant : 1,032 shp × 2
  - 2 passengers
- LAH aims to develop an advanced armed helicopter suitable for modern battlefields.
  - Equipped with modern avionics, weapons(Turret Gun, AGM, Rocket), fire-control systems.

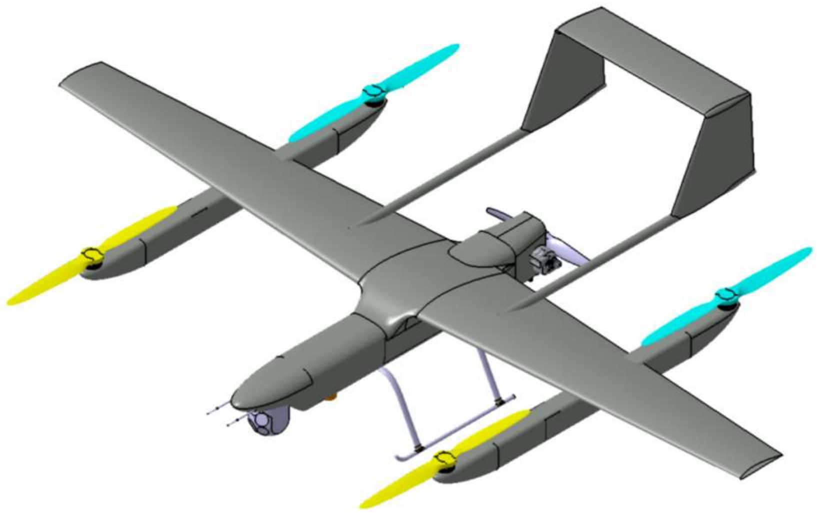
Korea Aerospace Industries

Focal Strategy Programs

MAH / MCH	LAH Variants	New Generation
		
Marine Attack Helicopter Mine Countermeasure Helicopter	MUMT(Man-Unmanned Teaming)	High Performance Helicopter



Korean Air



Target Gross Weight	000 kg
Target Payload	00 kg
Overall Length	4 m
Prop Radius	1.5 m
Endurance	0 hrs
Max Speed	190 km/h

❖ Program Overview

- KAL R&D program (Model Name : KUS-VS)
- 2021. 1 ~ 2023. 8 (32 months)

❖ KUS-VS Characteristics

- VTOL UAV for military propose
- Electric & ICE Hybrid propulsion system
- Long Range EO/IR/LRF Camera payload
- Rapid deploy and ground transportation
- STANAG 4586 Interoperability
- Military Airworthiness Ready

❖ Program Milestone

- '21.1Q : Scale model flight
- '21.2Q : Electric proplusion system test
- '22.4Q : New OML release
- '23.3Q : Design complete

Korean Air

Gross Weight	000 kg
Payload	00 kg
Overall Length	6.4 m
Main Rotor Diameter	7.2 m
Max Endurance	0 hrs
Cruise Speed	100 km/h

❖ Program Overview

- Government R&D program
  (Model Name : KUS-VM)
- 2023. 8 ~ 2028. 7 (60 months)

❖ KUS-VM Characteristics

- VTOL UAV for Navy and Marine Corps
- Long Range EO/IR and SAR/ISAR payload
- Autonomous take-off and landing on Destroyer class ship
- Military Airworthiness Ready

❖ Program Milestone

- '23.3Q : Program start
- '24.4Q : CDR
- '25.4Q : Aircraft Roll out
- '28.2Q : System development Complete

LIG Nex1

Overview

Development of MTOW 200kg Multi-purpose Unmanned Helicopter(Cargo/ISR)

Program Type	Civil-Military Technology Development	Period	’17.12 ~ ’21.11
Prime Company	Sung-woo Eng.	Budget	13,000,000 USD
Contractor	ADD ICMTC (Institute of Civil Military Technology Cooperation)		

Appearance

Progress

- ’17.12 : Agreement and Program Start
- ’18.04 : SRR (System Requirement Review)
- ’18.11 : PDR (Preliminary Design Review)
- ’19.02 : CDR (Critical Design Review)
- ’19.10 : TRR#1 (Test Readiness Review)
- ’20.02 : FFRR (First Flight Readiness Review)
- ’20.06 : TRR#2 (Test Readiness Review)
- ’21.11 : The program ends

Features

- MTOW : 200kg+ (Payload : Max. 60kg)
- Max. Speed : 150km/h+
- Operational Altitude : 3km+
- Endurance(Payload) : 6hrs(25kg) / 3hrs(60kg)
- Operational Range : 50km+
- Payload : EO/IR

LIG Nex1

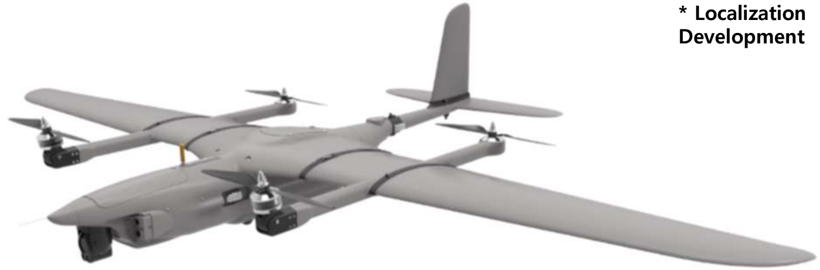
Overview

Development of a Army Small UAV System for Reconnaissance and Attack

Program Type	Rapid Demonstration Acquisition Project	**Period**	'20.12 ~ '22.09
Prime Company	LIGNex1	**Budget**	3,900,000 USD
Contractor	DAPA (Defense Acquisition Program Administration)		

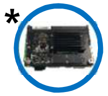
Appearance

* Localization Development

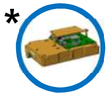


* 

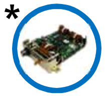
Ground Control System

*  Image Processing Unit

*  Motors

*  Datalink

*  EO/IR/LRF

*  Integrated Flight Computer

*  Warhead

Progress

- '20.12 : Contract
- '21.11 : Delivery Completed(ROKA, 18ea)
- '22.09 : ROKA Demonstration Support Report Submitted

Features

- Loitering munition for BN reconnaissance & attack missions
- Operational Range : 8km+, Altitude : 300m+, Time : 30min+
- Flight Speed : 90km/h, Impact Speed : 140km/h
- MTOW : 15.0kg
- IPX3 waterproof, Anti Jamming, KCMVP Communication Security

LIG Nex1

Overview

Hybrid Engine based Payload 40kg Multi-copter Cargo Drone Development for Civil-Military dual use

Program Type	Civil-Military Dual-use Technology Development	Period	’20.11 ~ ’23.11
Prime Company	LIGNex1	Budget	4,600,000 USD
Contractor	ADD ICMTC (Institute of Civil Military Technology Cooperation)		

Appearance

Progress

- ’20.11 : Commencement of the agreement
- ’20.12 : Kick-Off Meeting
- ’21.09 : PDR(Preliminary Design Review)
- ’22.05 : CDR(Critical Design Review)
- ’23.04 : TRR(Test Readiness Review)
- ’23.06 : FFRR(First Flight Readiness Review)
- ’23.10 : Final Evaluation
- ’23.11 : The program ends

Features

- Maximum Payload Weight : 40kg+
- Operational Range : 10km+
- Operational Time : 60min+
- Operational Altitude : 400m+
- Maximum Flight Speed : 50km/h+
- Powertrain : Engine Battery Hybrid

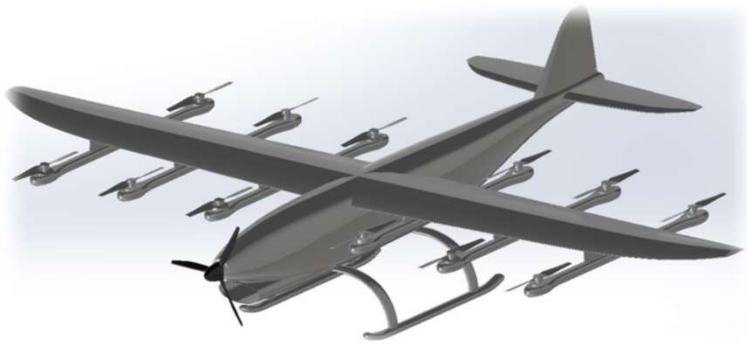
LIG Nex1

Overview

Payload 200kg Cargo Drone Technology Development based on Hydrogen Fuel Cells

Program Type	National R&D Program (MOTIE)	Period	'21.06 ~ '25.12
Prime Company	LIGNex1	Budget	36,000,000 USD
Contractor	Korea Evaluation Institute of Industrial Technology(KEIT)		

Appearance



Progress

- '21.06 : Agreement
- '21.07 : Kick Off Meeting
- '21.10 : SRR/SFR(System Requirement/Functional Review)
- '22.11 : PDR(Preliminary Design Review)
- '23.09 : CDR(Critical Design Review)
- '23.12 : Mid-Term Evaluation
- '25.01 : FFRR(First Flight Readiness Review)
- '25.09 : Final Evaluation
- '25.12 : The program ends

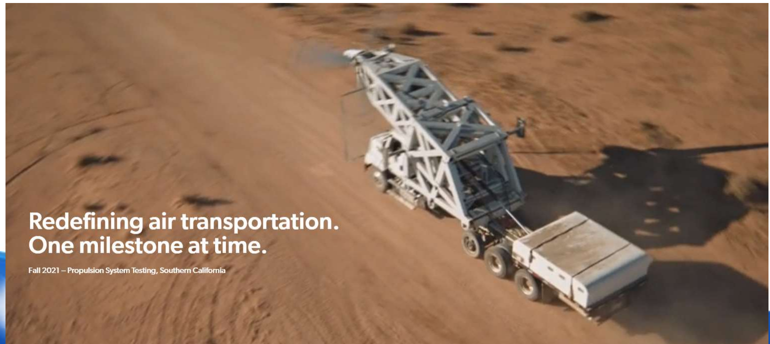
Features

- Maximum Payload Weight : 200kg+
- Operational Range : 50km+
- Operational Time : 1hrs+
- Maximum Flight Speed : 100km/h+
- Powertrain: "Hydrogen fuel + Battery" Hybrid

Hanwha Systems

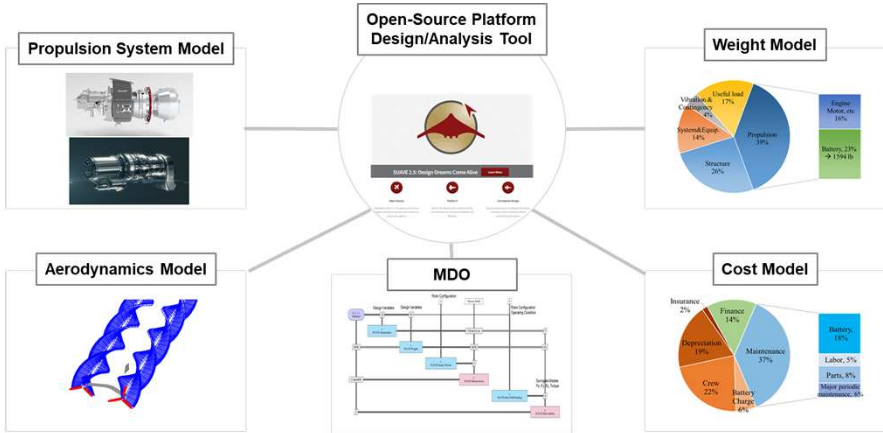
❖ Overair Butterfly

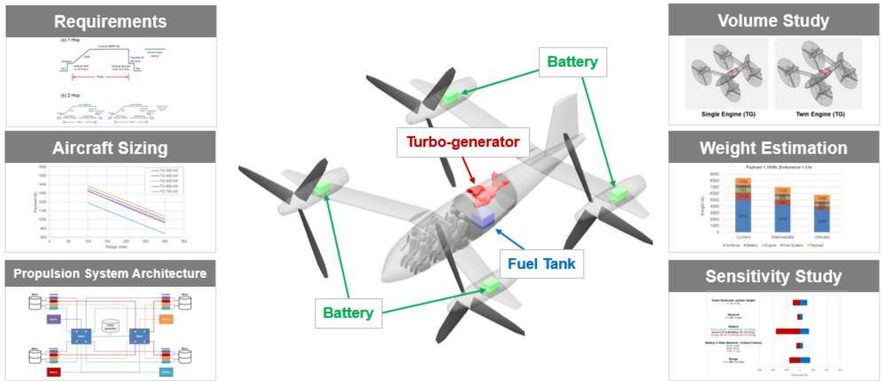
- Capacity: 1 pilot + 5 pax
- Rotor system: 4 tilt rotors with individual blade control (IBC) system
- Full-scale propulsion system test program completed in Fall 2022



❖ Advanced Research on Hybrid-Electric VTOL Aircraft

- Feasibility study on gas turbine hybrid-electric VTOL aircraft

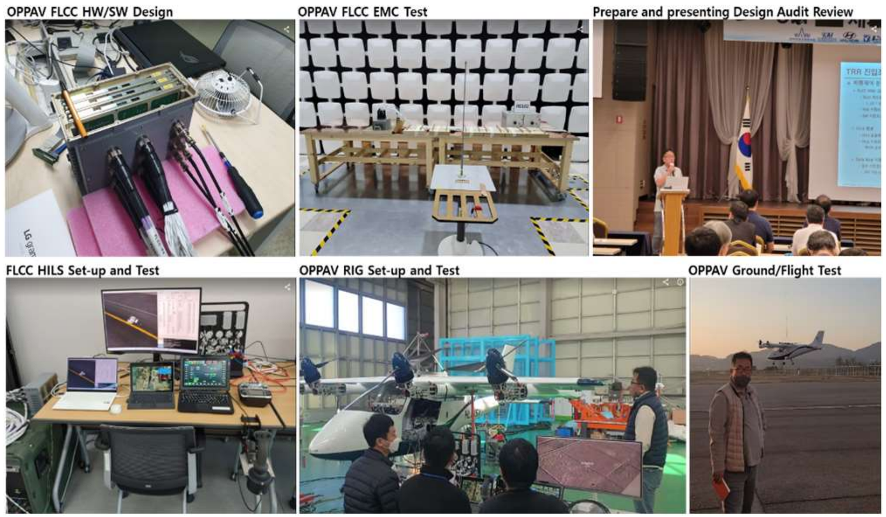




Hanwha Systems

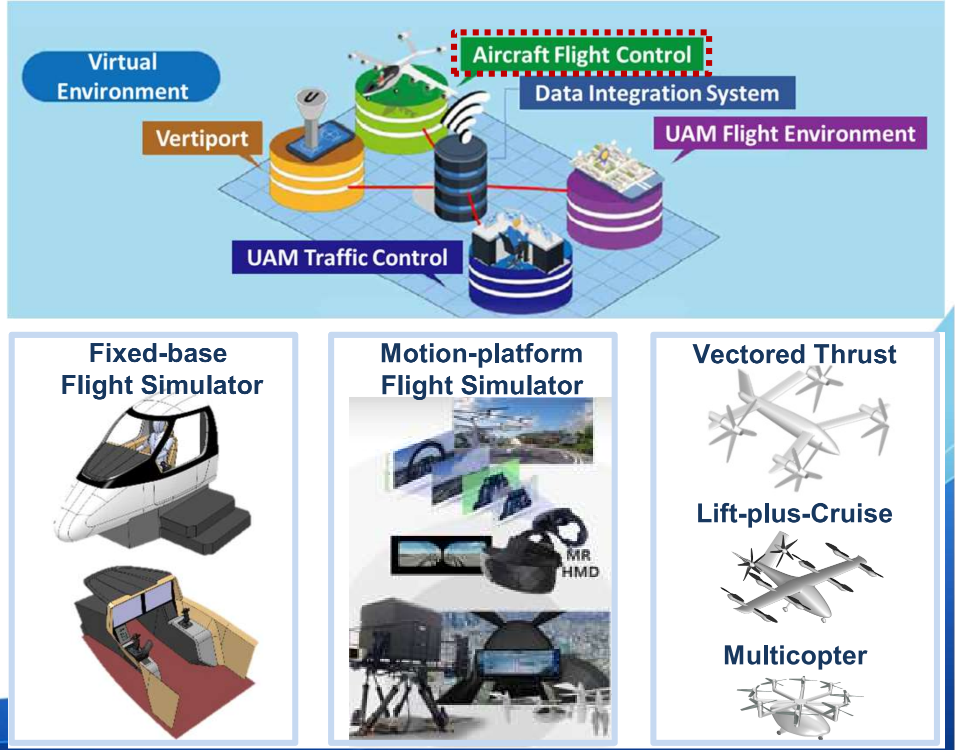
❖ Flight Control System of Optionally Piloted PAV (OPPAV)

- OPPAV Flight Control System Dev. Project (Apr. 2019 – Dec. 2023)
- Work scope:
  - FLCC SW(OFP) Design and Implementation
  - OPPAV HILS Configuration Setup
  - FCS System Integration Test (HILS & RIG)
  - OPPAV Ground/Flight Test



❖ eVTOL Aircraft Flight Simulator

- UAM VIPP (Virtual Integrated Operation Platform) Project (Apr. 2022 – Dec. 2025)
- Work scope:
  - Development of fixed-base and motion-platform flight training devices for three different types of eVTOL aircrafts



IV. Institutes

Korea Aerospace Research Institute

1.OPPAV

2.High-Speed Rotor System

3.30kW-H_2 Fuel Cell Unmanned Helicopter

4.Low Noise Prop-Rotor for UAM eVTOL

1. OPPAV(Optionally Piloted Personal Air Vehicle) eVTOL

- Optionally piloted eVTOL technology demonstrator is being developed (2019~2023)
  - One seater class. (Vc > 200kph, Range > 60km)
  - 8 electric motors, full electric using Li-Ion, 4 tilt props and 4 fixed lift props
  - Airworthiness standard draft is being developed in parallel
  - Wind tunnel testing is completed, the first flight is planned in Jan-2023

<Wind Tunnel Test of OPPAV Scaled Powered Model in KARI-LSWT>


<KARI OPPAV Concept>

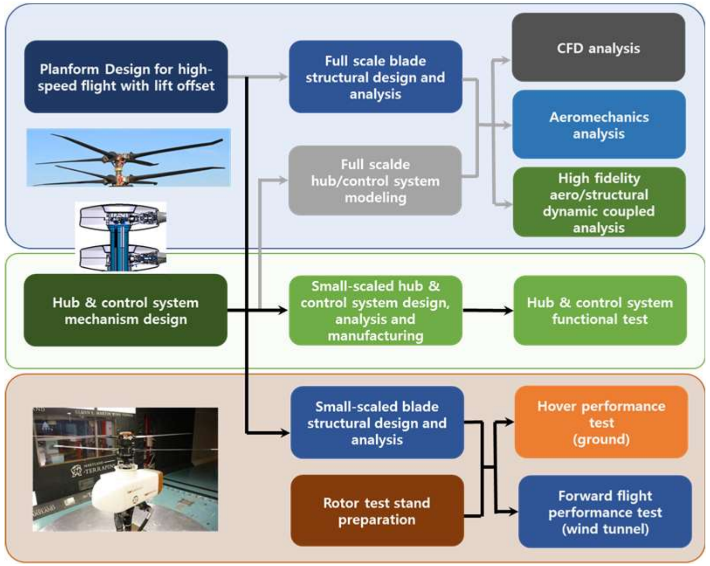
2. Rotor System for High-Speed Forward Flight

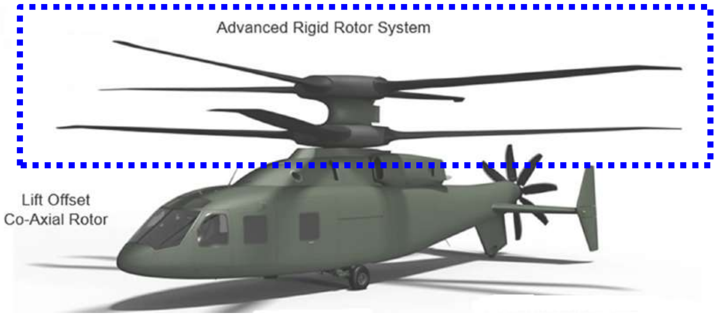
❖ Rigid Coaxial Rotor System Development for High Speed Long Range Utility Helicopter

. 2022. 12. ~ 2026.12 (Defense Acquisition Program Administration)

. Airspeed > 000 knot, High efficiency (FM > 0.00, L/D_e > 00)

- Design and analysis of low drag rigid coaxial rotor planform with lift offset
- Rigid composite blade design and analysis
- Efficient hub control system design and analysis
- Small-scaled model design, analysis, fabrication and ground & wind tunnel test



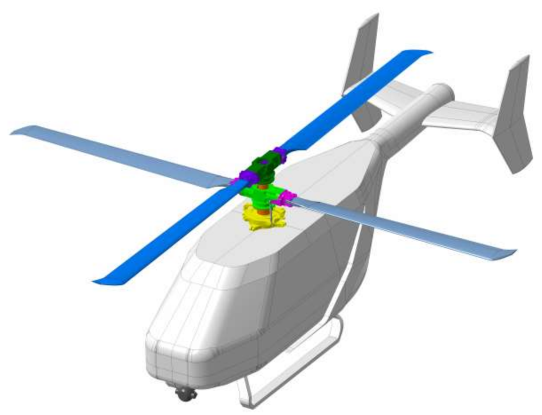


Reference model

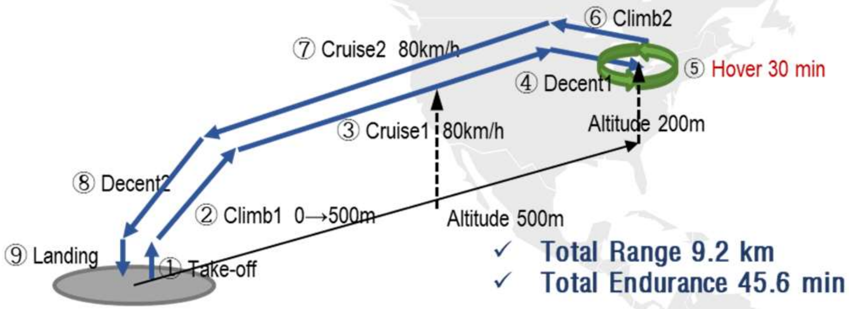
3. 30kW-H_2 Fuel Cell Unmanned Helicopter

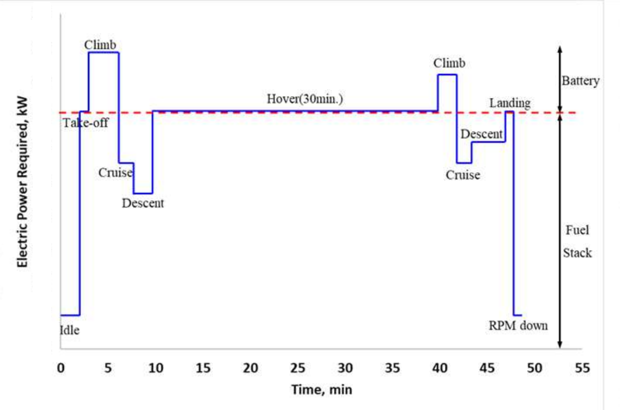
❖ **Net power 30kW class fuel cell power pack system for a unmanned helicopter with 200kg class maximum takeoff weight (2021~2025)**

- Rotor type : 2 bladed-coaxial rotors with 2.18m of rotor radius
- Rotor RPM : 580RPM
- Weight : 250kg
- Propulsion system : Electric motor powered by primary fuel cell and battery



<Coaxial rotor with fuel cell>



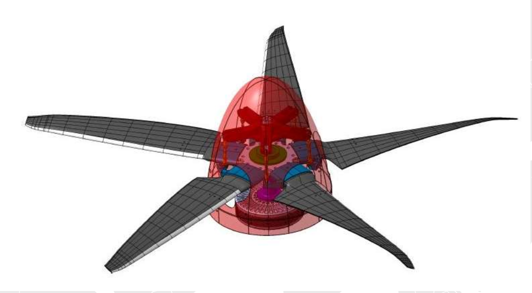


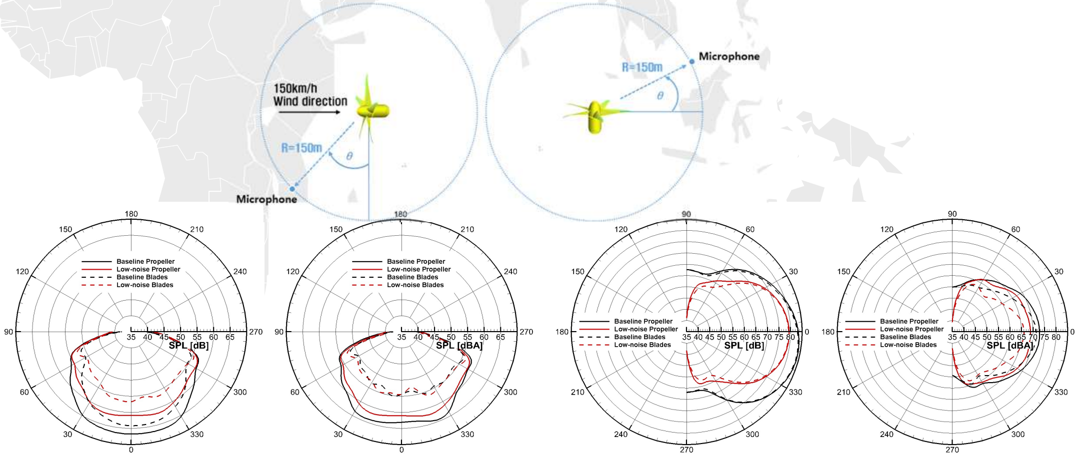
<Mission profile and power sharing>

4. Low Noise Prop-Rotor for UAM eVTOL

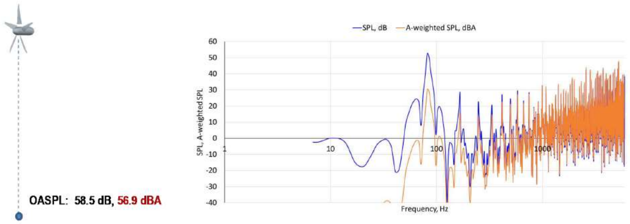
❖ Low noise prop rotor (2020~2023)

- Five bladed prop rotor with 1.3 meter of radius
- Maximum thrust 500kgf per prop rotor for Five seater class UAM
- Noise level 64dBA away from 150meter in forward flight
- Figure of Merit 0.7 above





<Analysis of noise level in forward flight and hover>



<Noise level measurement of prop rotor>

V. Conclusion

V. Conclusion

❖ **In Civil Side, eVTOL Aircraft System Technologies were focused on AAM(UAM, RAM) Application**

- Passenger Drone, Parcel Delivery Service, etc
- KARI, Hanwha Systems, Hyundai Motors, KAI, Vessel Aerospace, etc.

❖ **In Military Side(Manned) VTOL System Technologies have been focused on Army' s Light Armed Helicopter and Marine Attack Helicopter**

- LAH Helicopter Production Start(2023~)
- Marine Attack Helicopter Development Start (2022~)
- KAI

❖ **In Military Side(Unmanned) VTOL System Technologies have been focused on Army' s Observation and Scout, Delivery Service**

- KAI, KAL, LIG Nex1,Hanwha Systems, Vessel Aerospace

Thank you!