Aerodynamic Interference Analysis between Propeller/Wing for High Performance Electric Aircraft Using FaSTAR-move

〇Shota Taniguchi (ISAS/JAXA),
Kanako Yasue (JAXA), Ryota Fukuchi (SUBARU),
Atsushi Shinozuka, Akira Oyama (ISAS/JAXA)

Electric aircraft

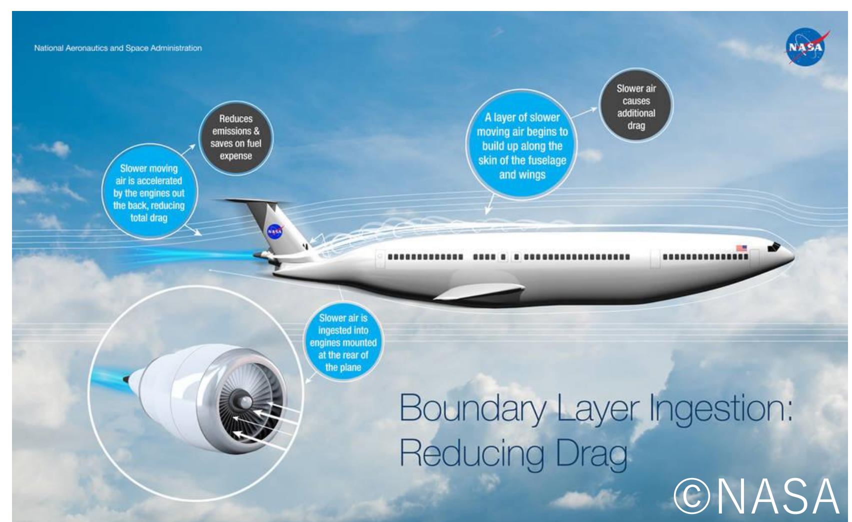
Alternative means of transportation

- eVTOL aircraft

Eco-friendly airplane

- Airplane with DEP

- Airplane with BLI



Propeller layout for electric aircraft

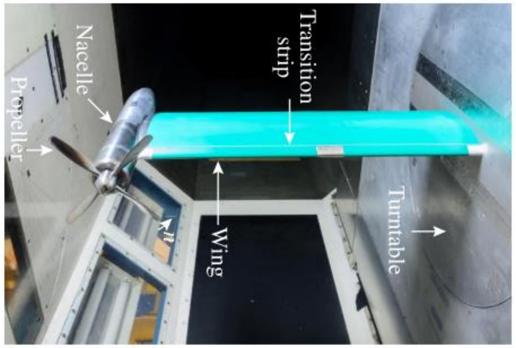
Propeller layout taking advantage of
aerodynamic interference between propeller/wing

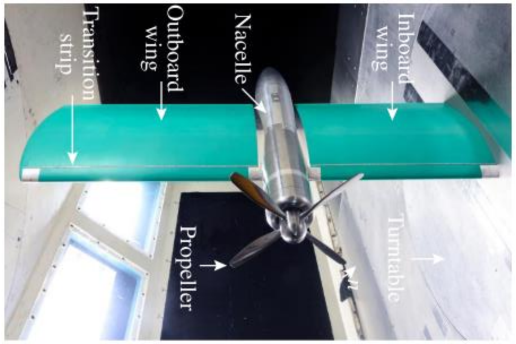
- **Wingtip mounted propeller**
- **Distributed electric propulsion (DEP)**

Research on aerodynamic interference

Wingtip mounted propeller

Experiments show smaller drag than mid-span mounted configuration.





[Sinnige et al., 2019]

eVTOL with distributed electric propulsion (DEP)

Experiments show complex aerodynamics due to propeller.

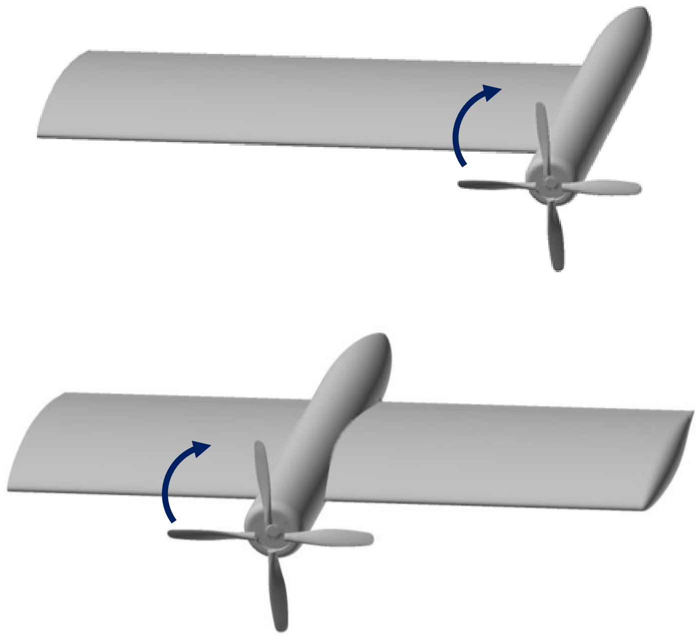
[Geuther et al., 2020]

Lack of understanding of how propellers change the aerodynamic characteristics of the fixed-wing.

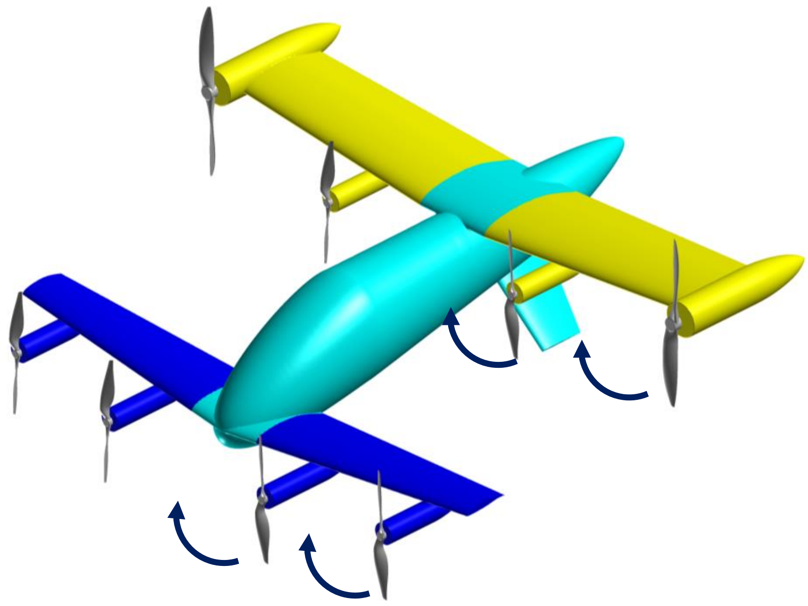
Objective

- Clarify the mechanism by which propellers change the aerodynamic characteristics of a wing.
- Verify the URANS accuracy of predicting aerodynamic characteristics of propeller and fixed-wing .

1. Tip-mounted propeller

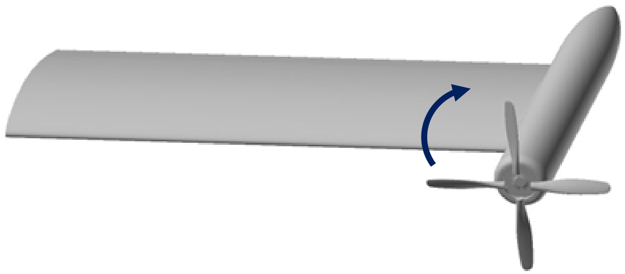


2. eVTOL with DEP



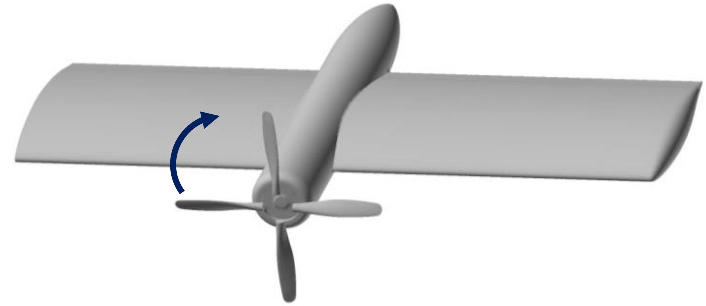
Tip-mounted propeller Analytical model

Tip-mounted

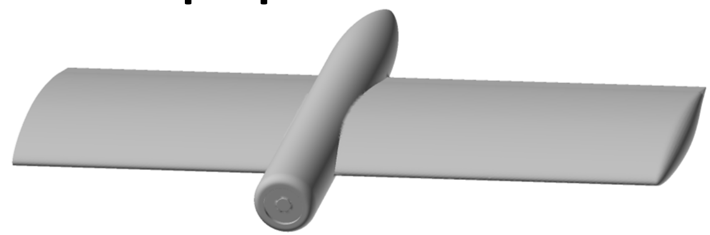


- without propeller

Mid-span mounted



- without propeller



Flow conditions

※Same as Sinnige et al., 2019

Reynolds number	Re_c [-]	640,000
Mach number	M [-]	0.11
Angle of attack	α [deg]	2.0, 6.0
Propeller advance ratio	J [-]	0.7

Computational settings

Numerical methods

Unsteady RANS using overset mesh

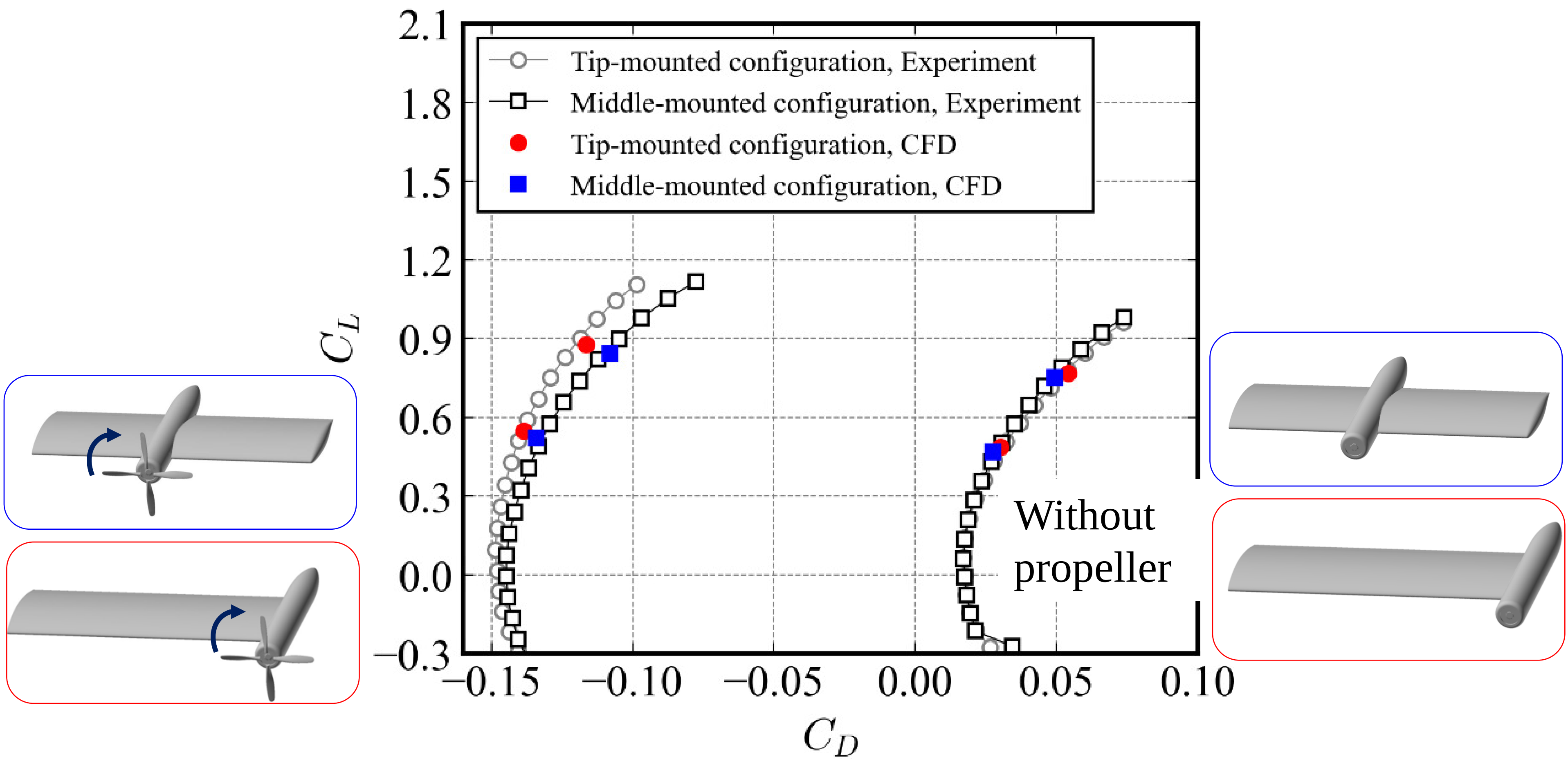
solver : FaSTAR MOVE

Governing equations	3D compressible Navier-Stokes equations
Time integration	LU-SGS
Convection terms	SLAU
Reconstruction	MUSCL
Turbulence model	SA-noft2

Computational grid

Consists of fixed-wing grid and four propeller blade grids

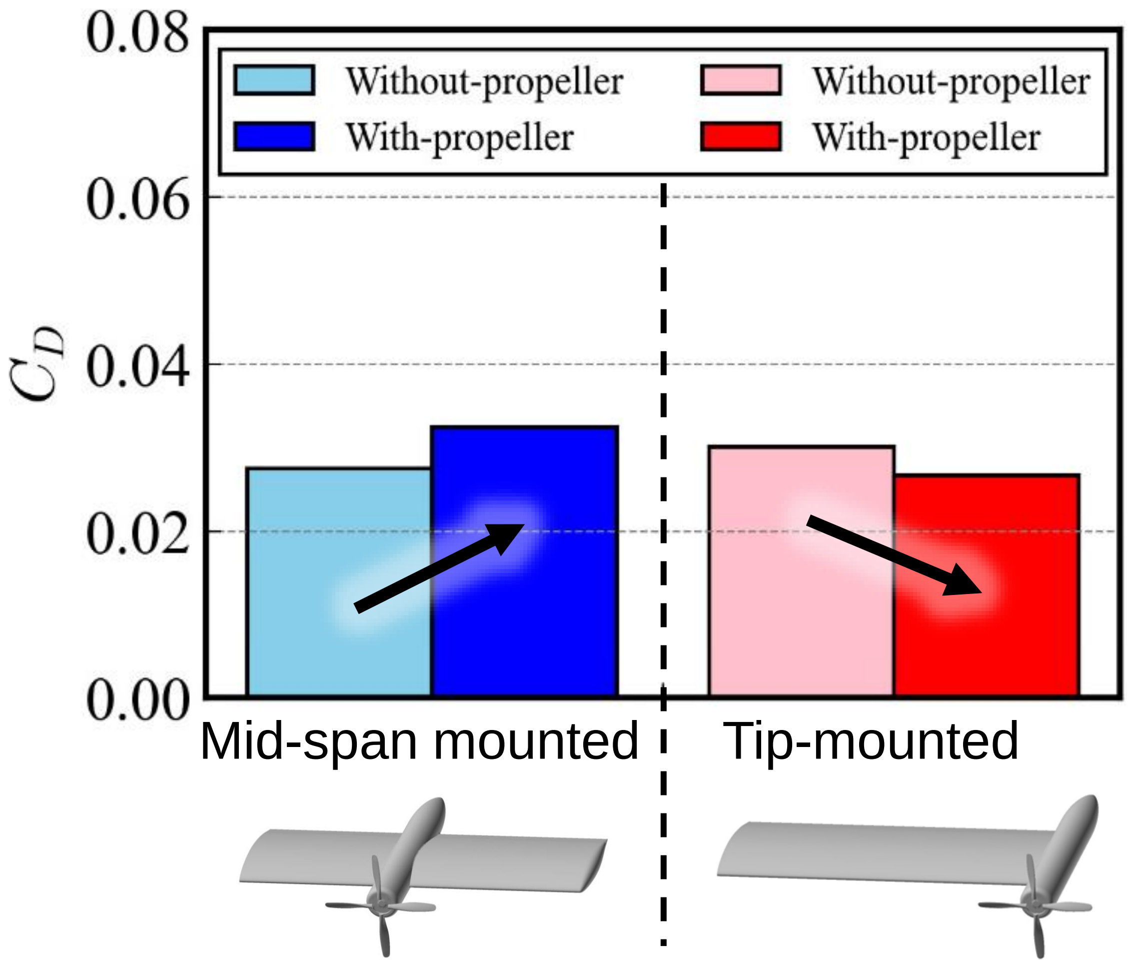
Comparison of URANS and experiment



The results of URANS and experimental results are in good agreement.

Propeller effect on drag coefficient of wing and nacelle

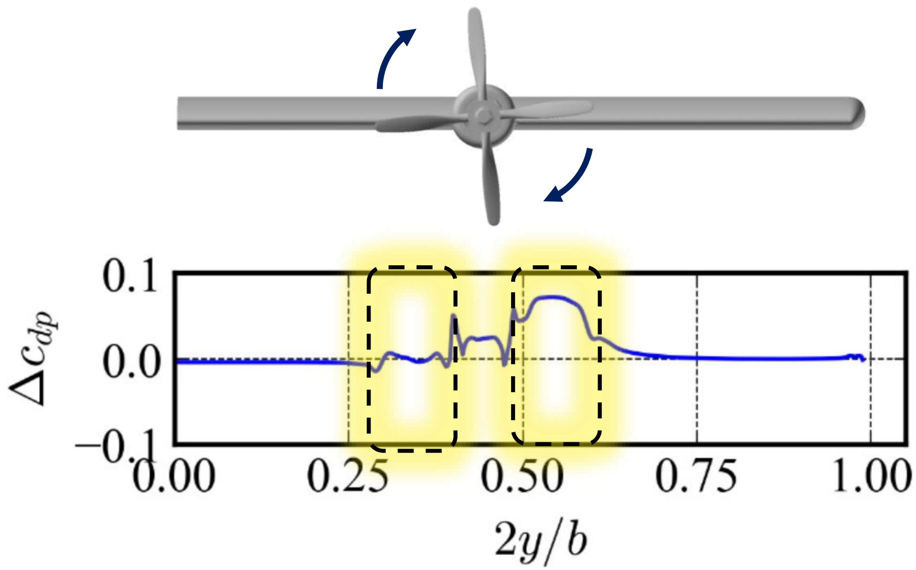
AOA=2 [degree]



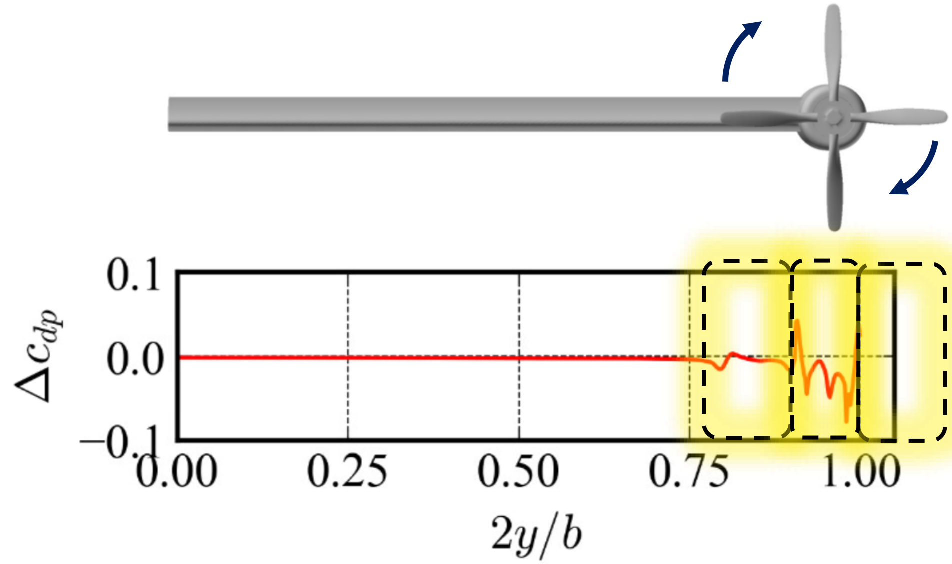
Mid-span mounted propeller increases C_D of wing and nacelle, while tip-mounted propeller decreases that.

Propeller effect on drag distribution

Mid-span mounted



Tip-mounted

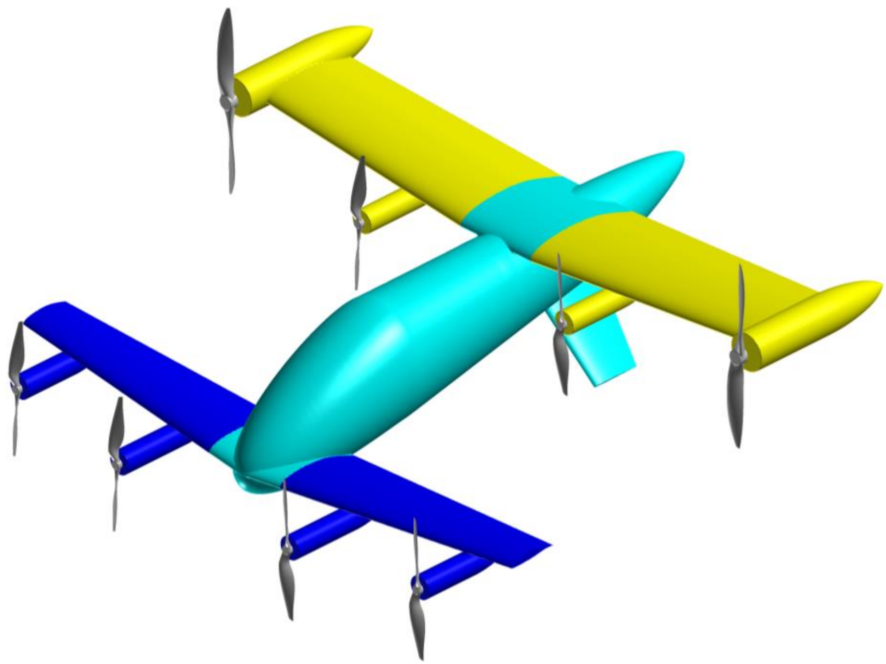


$$\Delta c_{dp} = c_{dp} - c_{dp\ without\ propeller}$$

- Propeller downwash increases c_{dp} .
  ➡Larger C_D for mid-span mounted configuration
- Tip-mounted propeller decrease c_{dp} of the nacelle.
  ➡Smaller C_D for tip-mounted configuration

eVTOL with DEP analytical model

Tandem tilt-wing aircraft model

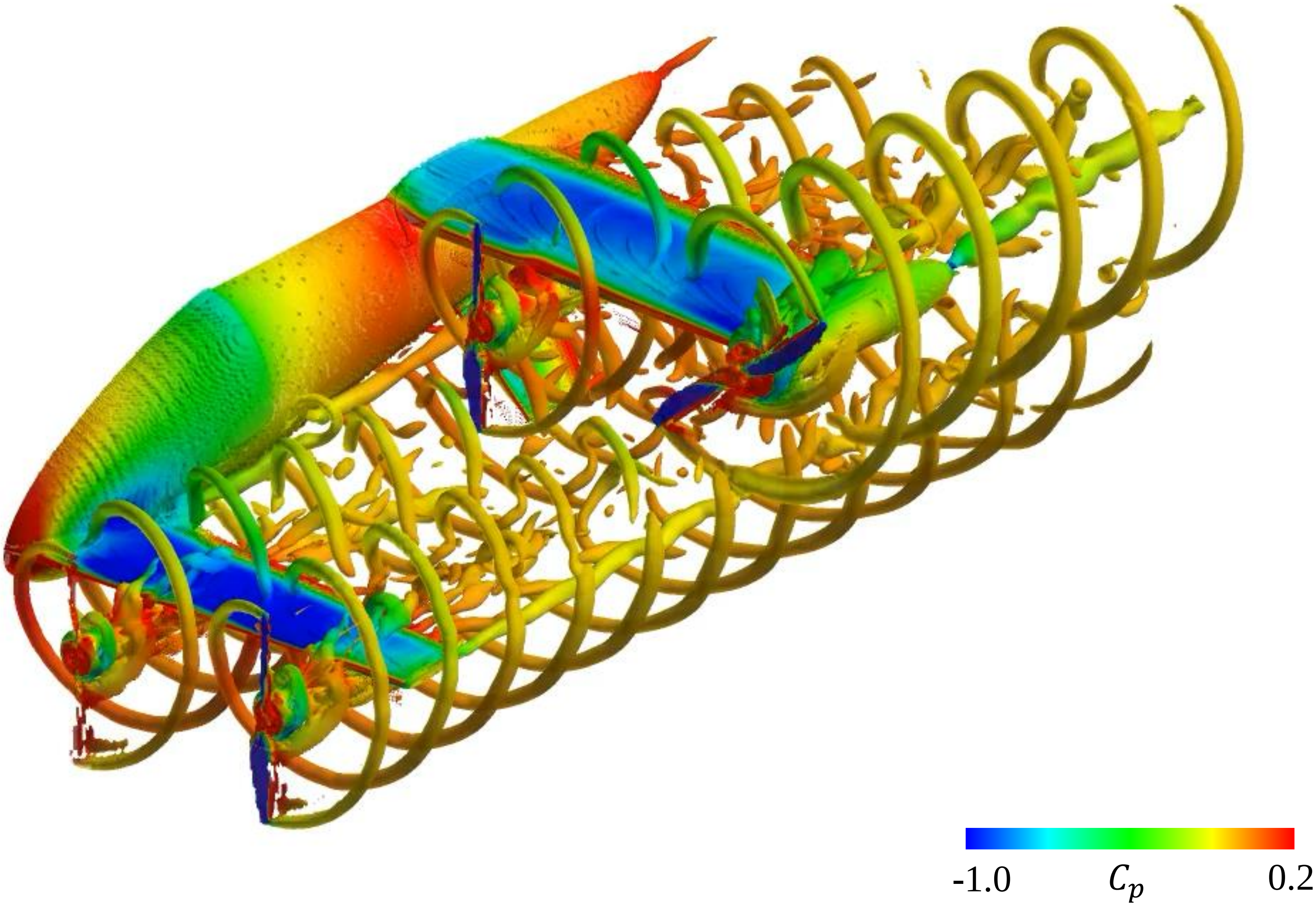


	AR [-]
後翼	5.45
前翼	7.96

Reynolds number	Re_{MAC} [-]	260,000
Mach number	M [-]	0.044

Flow field obtained by URANS

Angle of attack is 4 degree



Summary

We conducted URANS for the wingtip-mounted propeller and eVTOL with DEP to clarify the propeller effect and validate prediction accuracy.

<u>Wingtip-mounted propeller</u>

- There was a good agreement in C_L, C_D with the experiment.
- URANS confirmed drag reduction of the wing.

<u>eVTOL with DEP</u>

- With respect to C_L, there was qualitative agreement on the propeller effect on the stall with experiment.
- There was a quantitative agreement on the pressure coefficient with experiment.