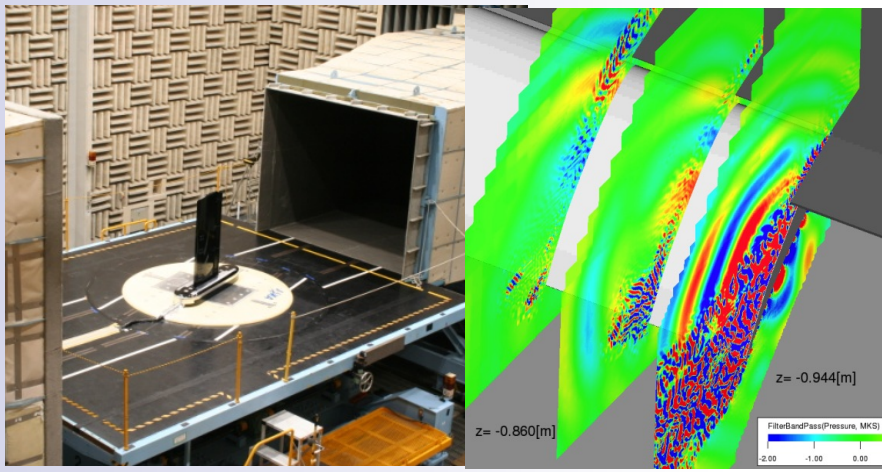
Investigation on Airframe Noise due to Flap Side Edge and its Reduction

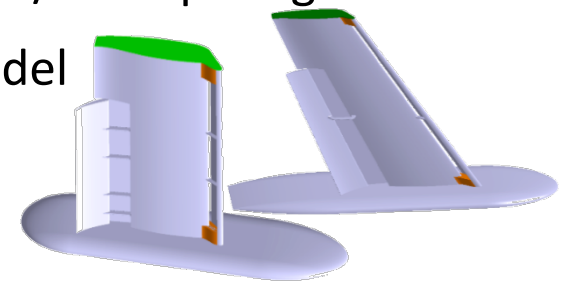


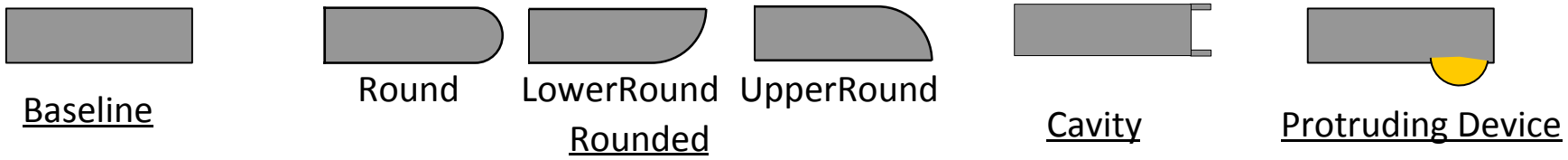
Mitsuhiro Murayama,
Yuzuru Yokokawa, Kazuomi Yamamoto,
Yasushi Ito, Takehisa Takaishi
FQUROH Project Team
Aeronautical Technology Directorate
Japan Aerospace Exploration Agency

Advanced Modeling & Simulation (AMS) Seminar Series, 16 March, 2016

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  - JAXA FQUROH project
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  - Investigation using simplified high-lift wing model w/o swept angle
  - Investigation using more realistic high-lift wing model
- Concluding Remarks

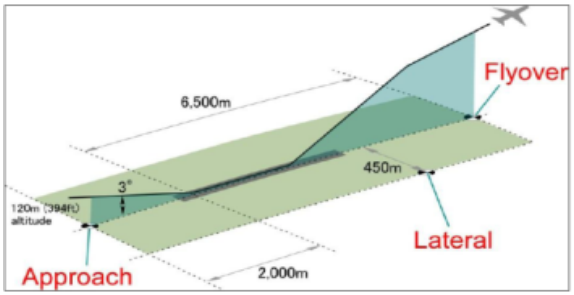




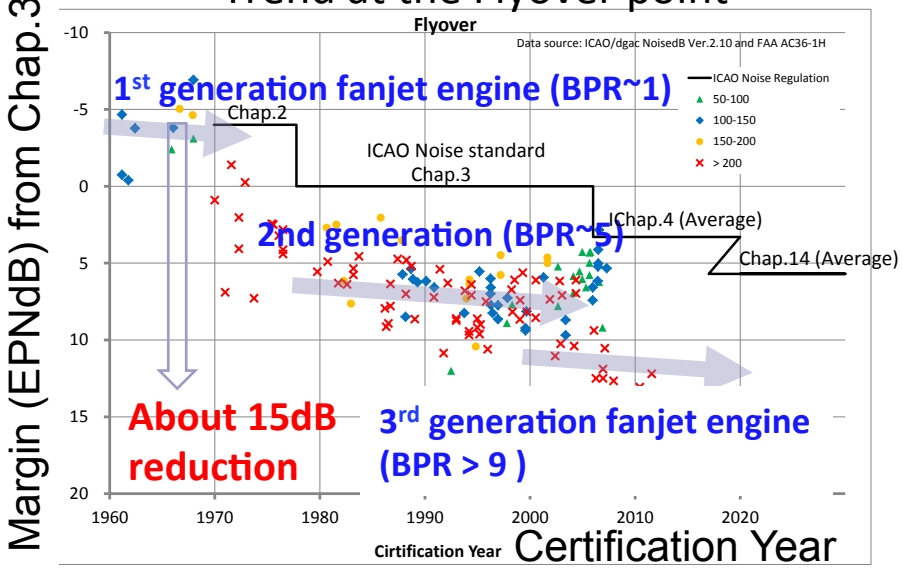
50 years trend of aircraft noise reduction

- ICAO and FAA Data show how noise has been reduced in 50 years
  - Stepwise changes have been mainly obtained by increasing BPR
  - At approach condition, the reduction has been saturated after 1990

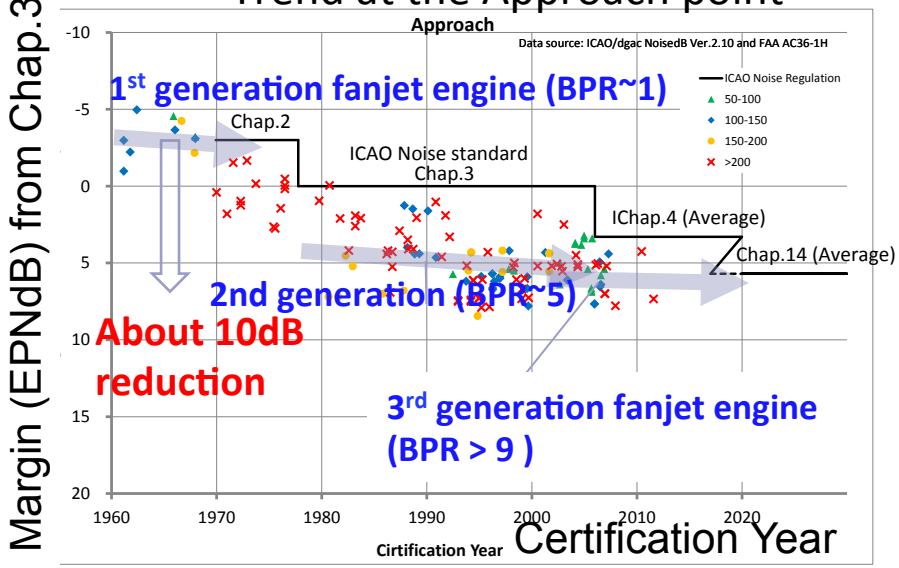
Noise reduction at the approach condition is a bottleneck to make aircraft further quieter.



Trend at the Flyover point



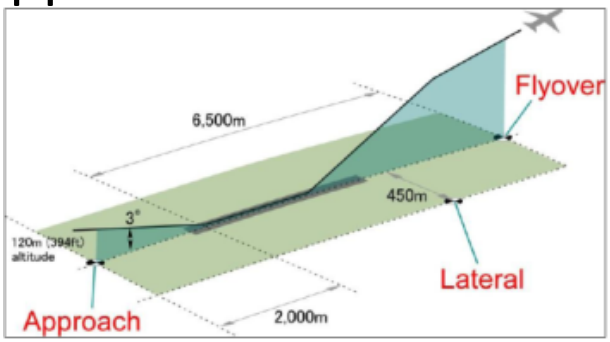
Trend at the Approach point

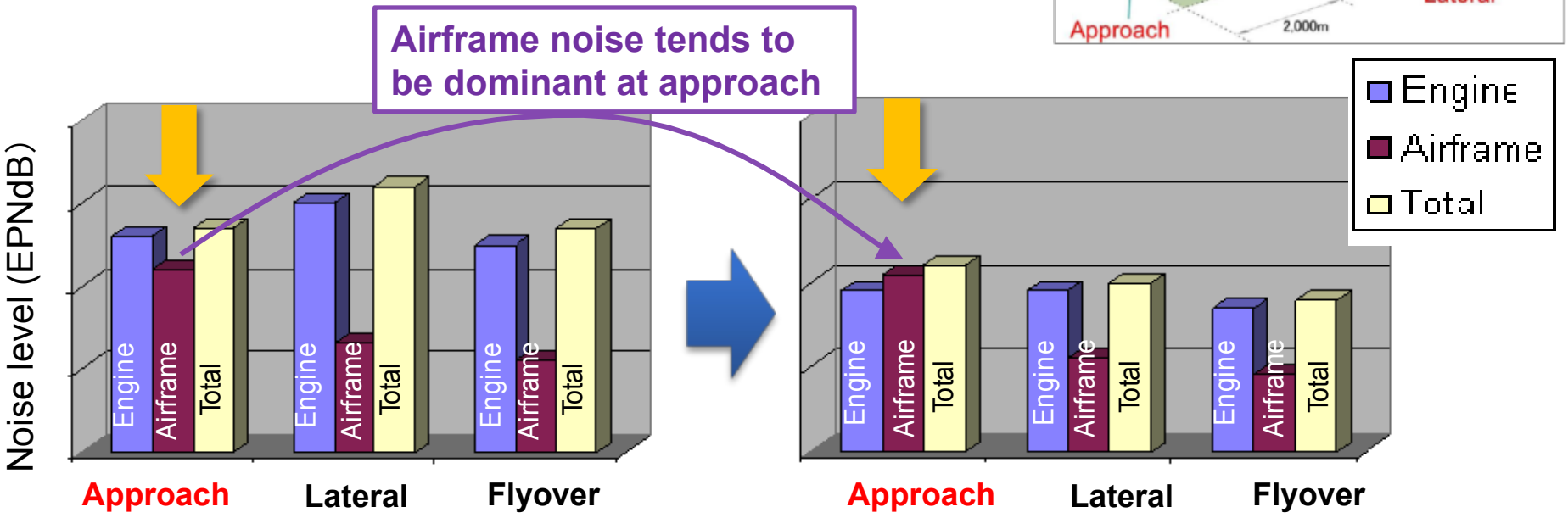


Importance of airframe noise reduction at approach

- Higher BPR of engine can reduce the engine noise level further.
- Airframe noise tends to be dominated at approach.

Airframe noise is an important technical issue for quiet aircraft in the future.

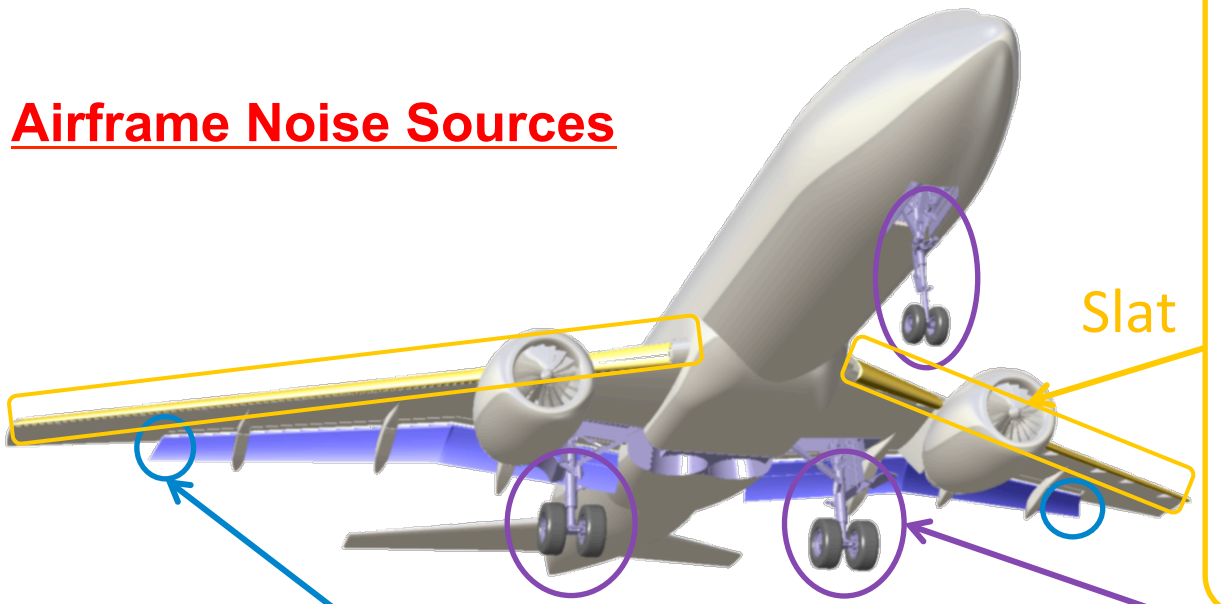




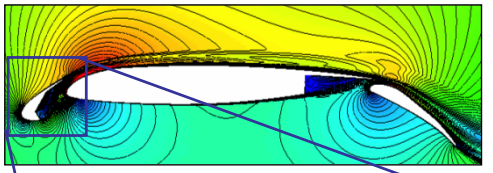
Noise level change at ICAO noise evaluation points

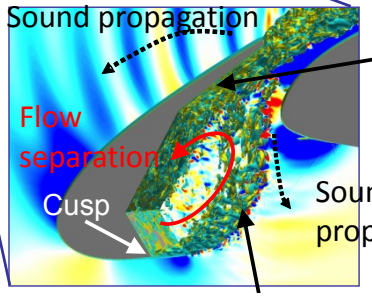
Main airframe noise sources

Airframe Noise Sources



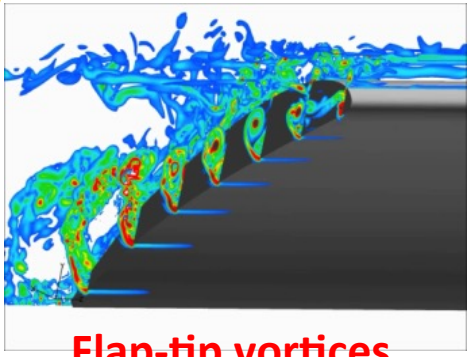
Slat



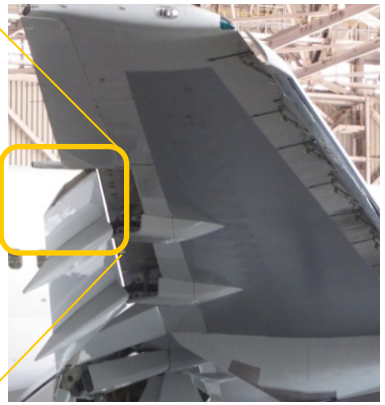


Flow separation around slat cove

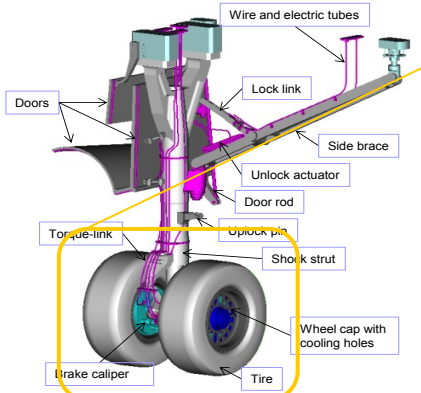
Flap

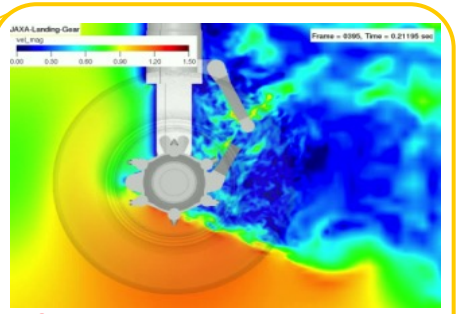


Flap-tip vortices



Landing Gear



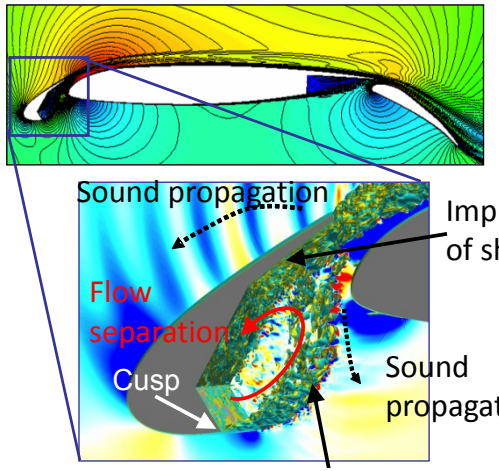


Flow separation around landing gear

Main airframe noise sources

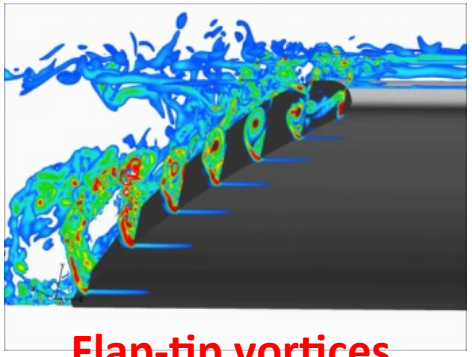
Basic physics of airframe noise

- Broadband aerodynamic noise due to turbulent shear-layer in flow separations at high-lift devices and landing-gears
  - Noise reduction is possible by suppression and control of flow separation and/or acoustic absorption.

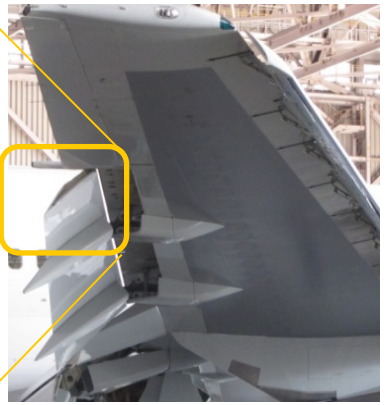


Flow separation around slat cove

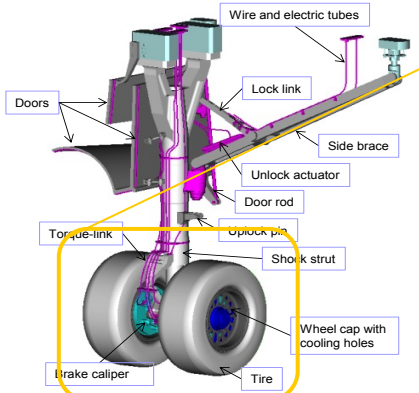
Flap

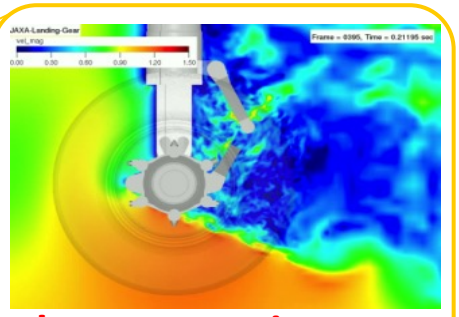


Flap-tip vortices



Landing Gear





Flow separation around landing gear

Noise generation mechanism and technical issues

Basic physics of airframe noise

- Broadband aerodynamic noise due to turbulent shear-layer in flow separations at high-lift devices and landing-gears
  - Noise reduction is possible by suppression and control of flow separation and/or acoustic absorption.

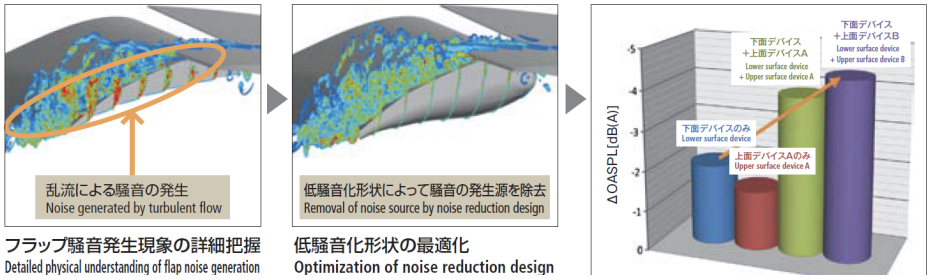
Technical issues in application to actual aircraft design

- Interaction with aerodynamic performance, weight, retractable functions, brake cooling, etc.
- Prediction of complicated turbulent flow and noise level
- Scale (Reynolds No.) effect / installation effect

FQUROH project

Flight Demonstration of Quiet Technology to Reduce Noise from High-lift Configurations

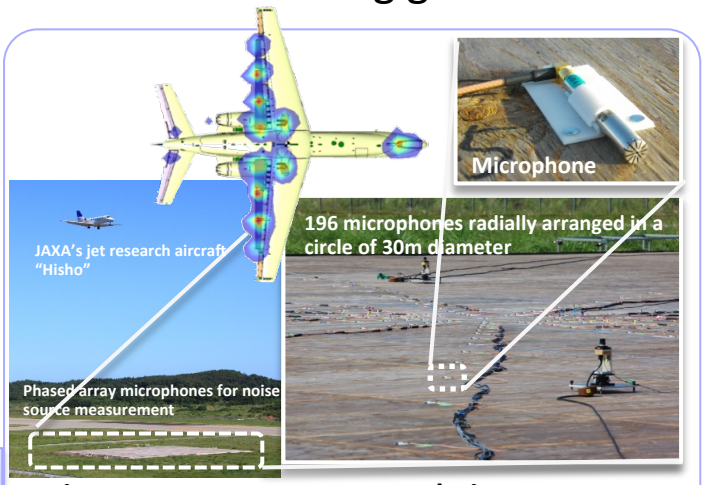
- To verify the feasibility of practical noise reduction concepts for airframe noise and design methods based on advanced computational simulations.
- To demonstrate noise reduction technologies for the airframe noise through flight tests using aircraft with modified high-lift devices and modified landing gear.



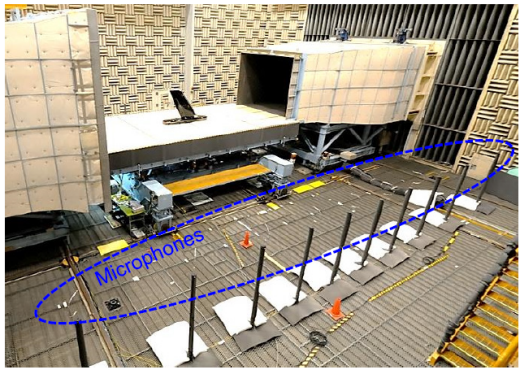
フラップ騒音発生現象の詳細把握
Detailed physical understanding of flap noise generation

低騒音化形状の最適化
Optimization of noise reduction design

Physic-based noise reduction design using advanced numerical simulations

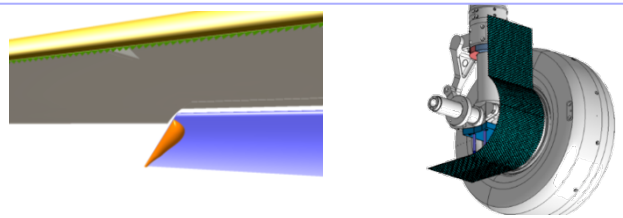


Noise source measurement techniques to capture noise sources and their frequency characteristics



Detailed evaluation of noise reduction design using Wind Tunnel

Flight demonstration using JAXA's jet research aircraft "Hisho" and a commercial aircraft



Application of practical noise reduction concepts

- **Acceleration of the development of noise reduction design methods using advanced numerical simulations**
- **Demonstration of the feasibility of airframe noise reduction concepts**

On the project name “FQUROH”

Flight Demonstration of Quiet Technology to Reduce Noise from High-lift Configurations

- The name of FQUROH comes from the Japanese word for a silently-flying bird, an “owl”
  - Owl is a symbol of silent flight. “Fukuroh” is its Japanese name.
  - “Fukuroh” is also good name for happiness in Japanese
    - “Fuku” and “roh” can mean “Happiness” and “is coming”
    - “Fu” and “kuroh” can mean “No” and “hardship”

Owls hunt their prey without making a sound

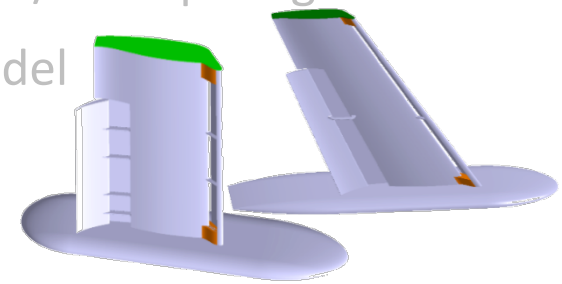
Unique features of owl wings

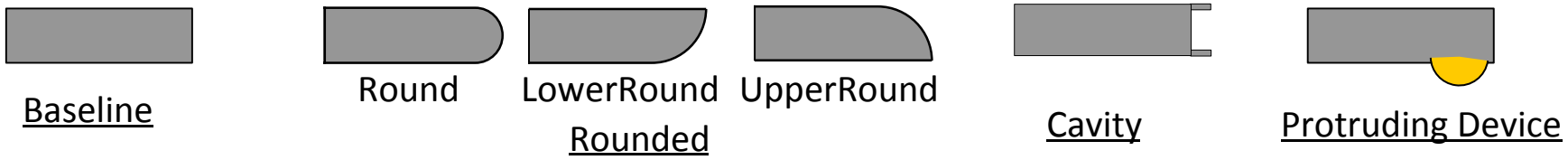
- Comb-like serrated leading edge
- Fluffy feathers
- Trailing fringe



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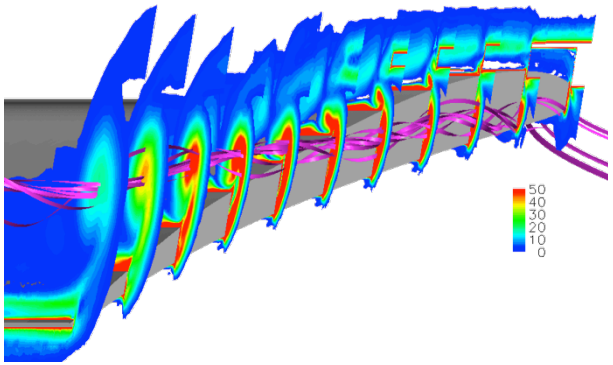
Flap noise

- A trailing-edge device deployed to increase lift during landing and take-off

- Flap-edge is dominant noise source
  - Vortex instability
    - Around flap-trailing edge
  - Shear-layer instability
    - Side-edge
    - Gap between main wing and flap

Streett et al, AIAA 2003-979
Choudhari et al, NASA TM-2002-211432

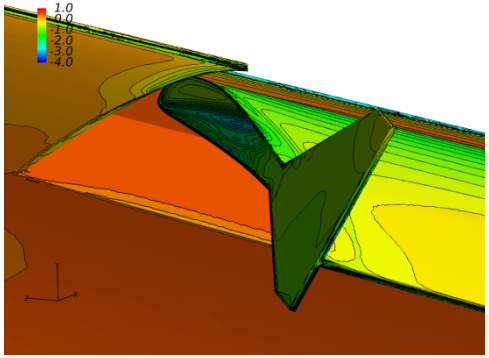




To develop efficient noise reduction techniques, better understanding of noise characteristics and noise generation and reduction physics is important

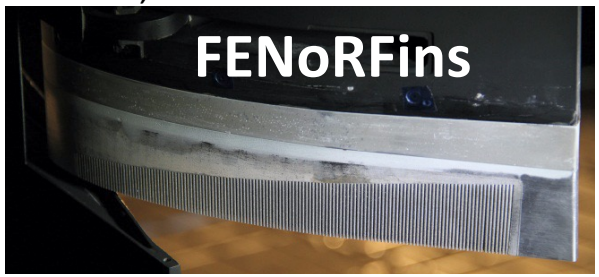
Flap noise reduction concepts

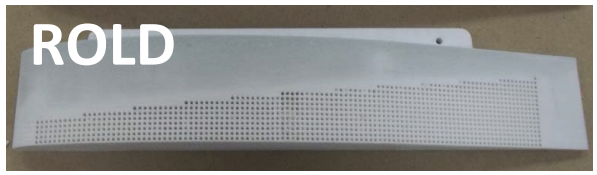
- Change of the flap side-edge vortices
  - To change the flap side-edge geometry
    - Rounding the side-edge: Choudhari, M. M., et. al, NASA TM-2002-211432, 2002.
    - Flap side-edge fences: Koop, L., et. al, AIAA2004-2803, 2004.
  - To remove gap between flap and main wing
    - Flexible side-edge link: Khorrami, M. et. al, AIAA2014-2478
  - To change the side-edge surface structures
    - Porous materials, Flap Edge Noise Reduction Fins, Reactive Orthotropic Lattice Diffuser etc.
      - Choudhari, M. M., et. al, AIAA 2003-3113 , Khorrami, M. et. al, AIAA2014-2478



Flap side-edge fences







AIAA2014-2478, Khorrami

Rounding the side-edge

Choudhari, M. M., et. al, NASA TM-2002-211432, 2002

- The change of the flap side-edge shape was mainly investigated by wind tunnel test



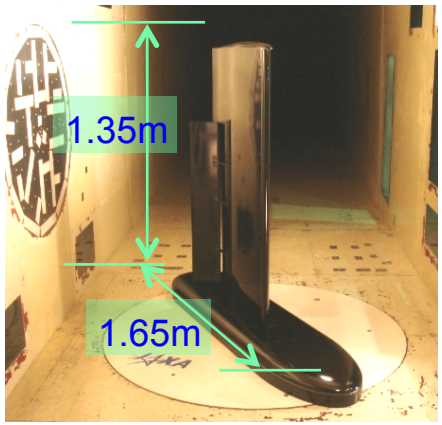
Baseline Round LowerRound UpperRound

Revealing the details of the underlying unsteady flow field and the resulting noise characteristics can greatly aid the understanding of the noise generation mechanisms and help low noise design.

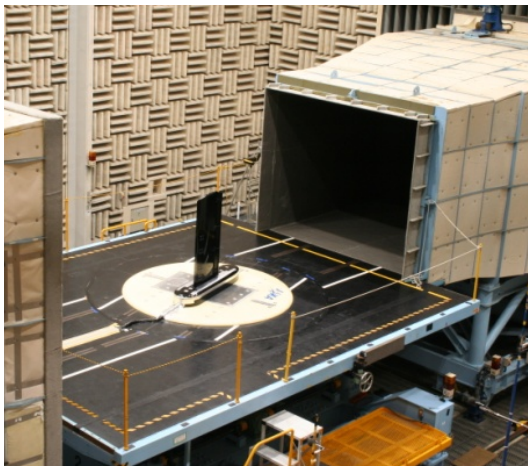
Synergistic combination of computational methods and wind tunnel tests greatly aid the purpose

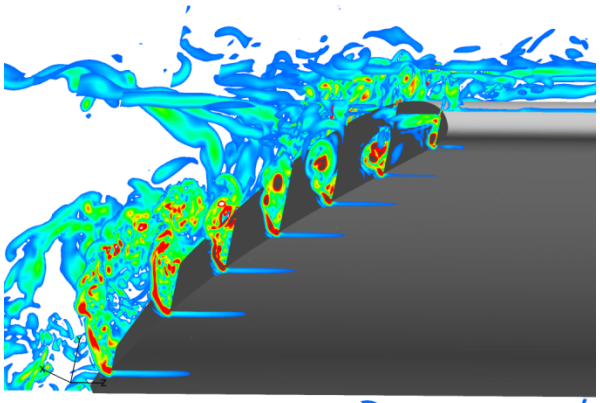
Objectives

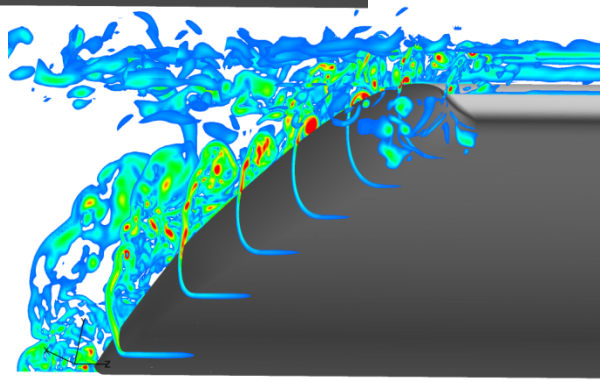
- To clarify the noise generation and reduction mechanism by investigation of flow fields and far-field noise related to the flap side-edge shape using combination of wind tunnel tests and numerical simulations

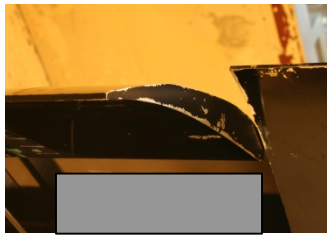


OTOMO w/o taper & sweep angle

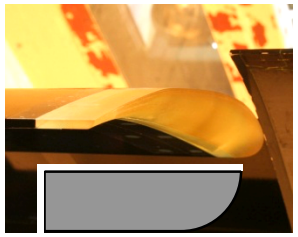








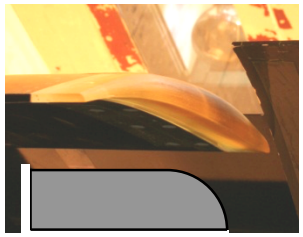
Baseline



LowerRound



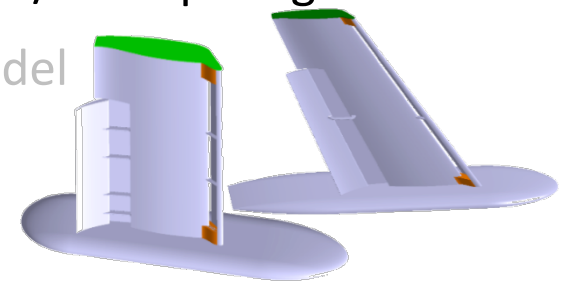
Round

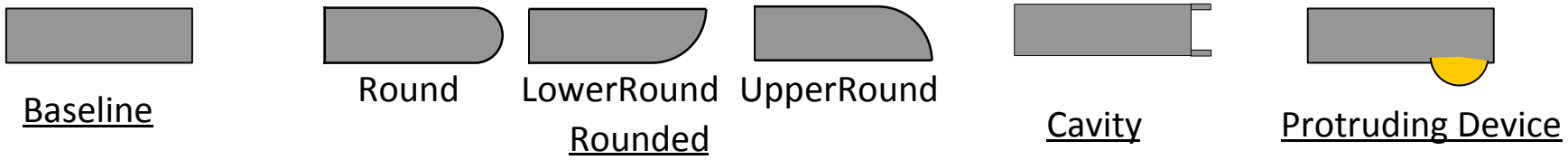


UpperRound

Outline

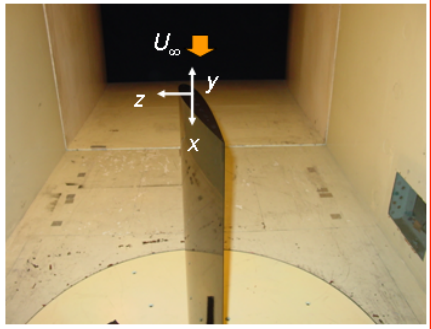
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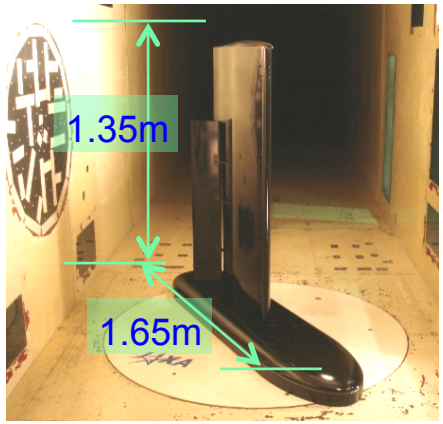


JAXA high-lift device noise research model

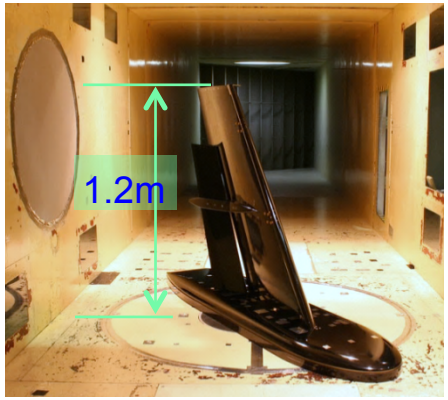
- Noise generation and reduction mechanisms using wind tunnel tests and CFD/CAA
  - Models used for High-Lift Device (HLD) noise research
    - NACA0012 single-element wing with bluff wing-tip
    - Three-element HLD model, “OTOMO”
      - w/o taper and sweep
      - w/ taper and sweep
    - Realistic HLD configuration model, “JSM”



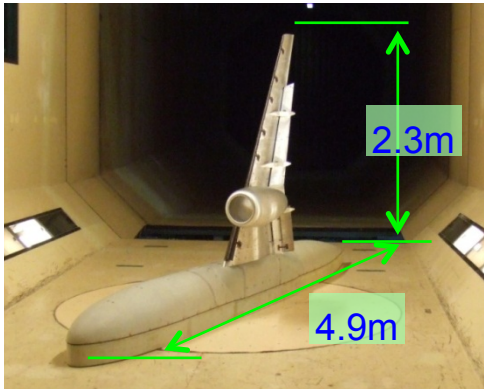
NACA0012 Wing-tip



OTOMO
w/o taper & sweep angle



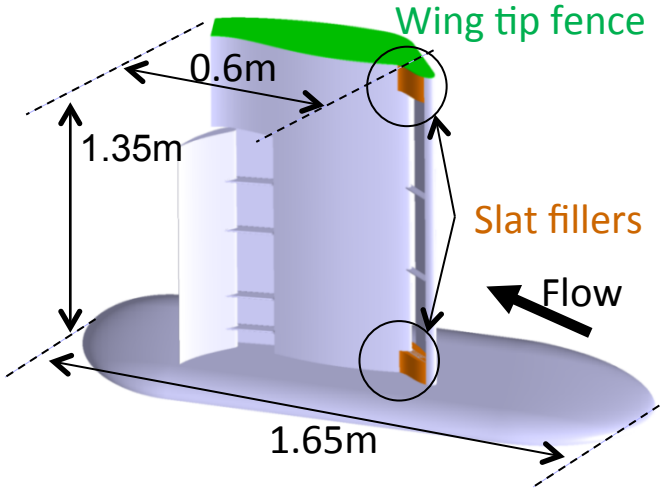
OTOMO2
w/ taper & sweep angle

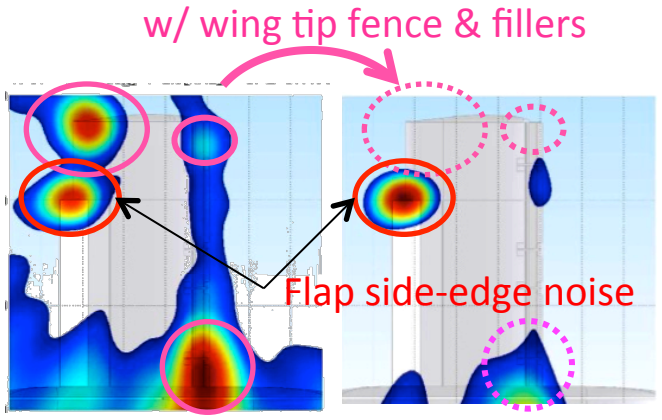


JAXA High-lift Standard Model

JAXA High-lift Device Noise Research Model, “OTOMO”

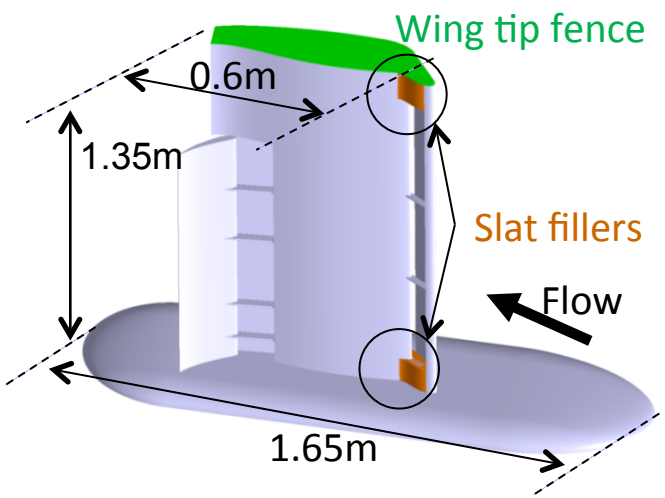
- Generic three-element HLD model with a body pod
  - Not 2D, but no sweep angle, no taper, and no dihedral angle
    - To investigate flowfield and noise characteristics on larger scale model
    - To easily understand the phenomena and develop low-noise concept
  - Chord=0.6m, half wing span=1.35m (AR=4.5)
  - Full-span slat and part-span single slotted flap
  - Wing tip fence and slat-slot fillers at the root and tip to eliminate undesirable excessive noise sources

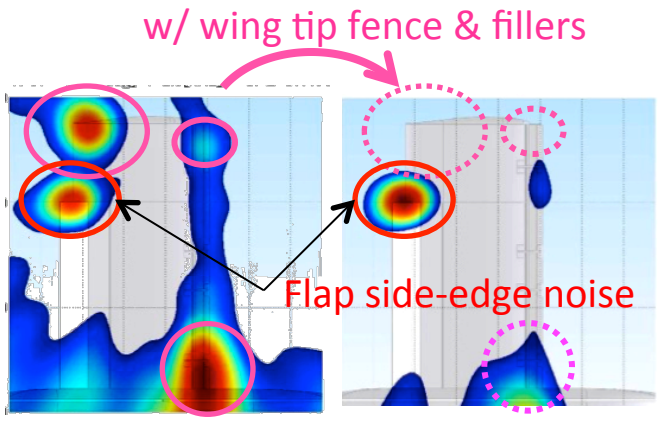




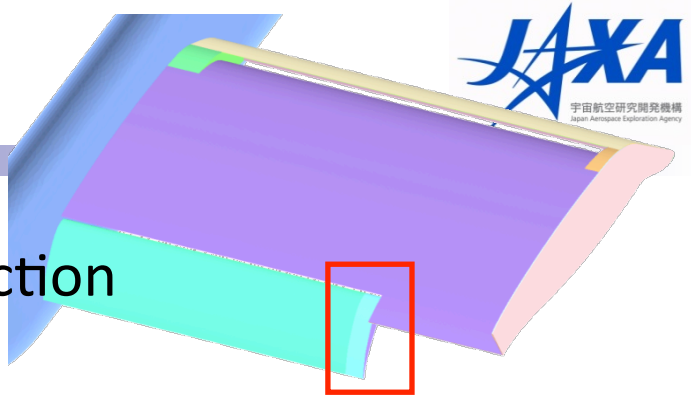
JAXA High-lift Device Noise Research Model, "OTOMO"

- Typical test conditions discussed in this presentation
  - U_{inf} = 50m/s, Re= 2 million
  - No roughness to trip boundary-layer to turbulent





Baseline flap side-edge

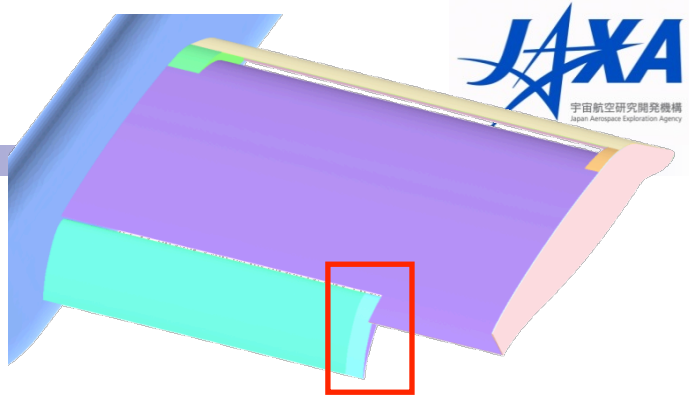


- Bluff flap tip with a rectangular cross section

Baseline



Rounded flap side-edge



- Three rounded flap side-edge shapes



Baseline





Round



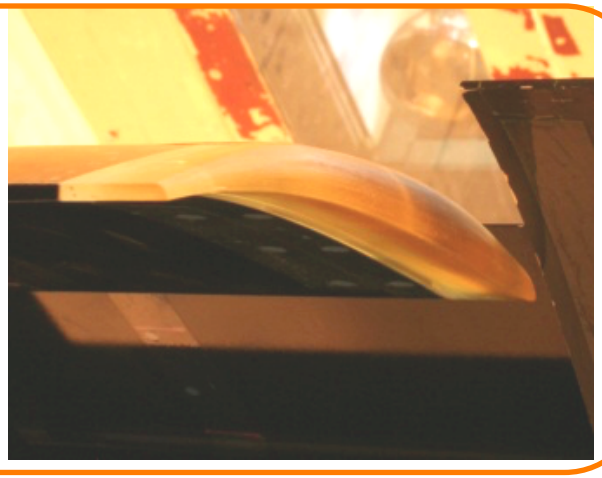


LowerRound





UpperRound

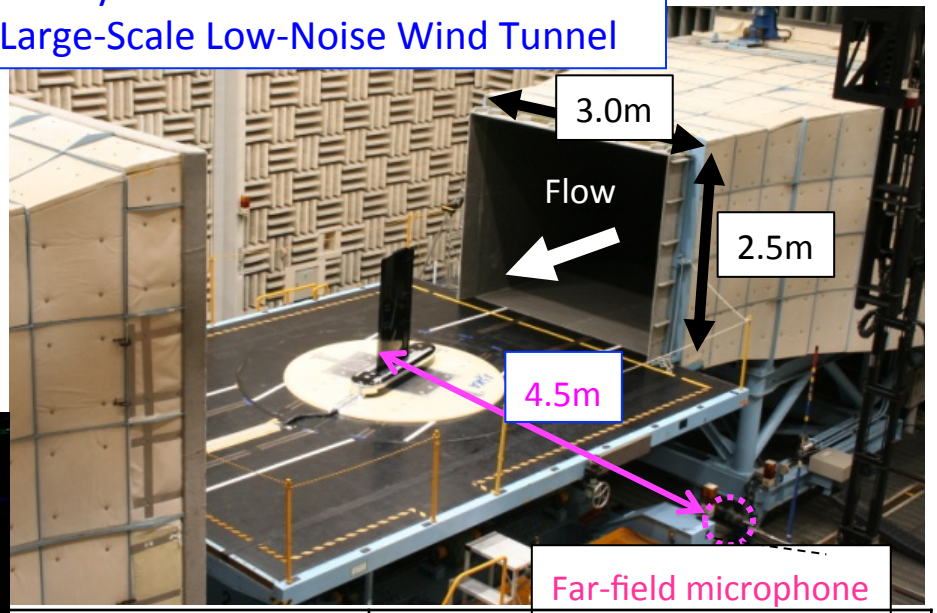


Experimental facilities

JAXA-LWT2



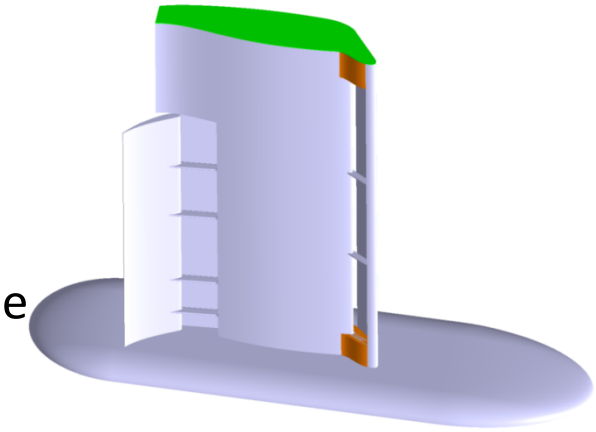
Railway Technical Research Institute's
Large-Scale Low-Noise Wind Tunnel



	2m x 2m JAXA-LWT2 (Hard wall or Kevlar wall)	3m x 2.5m RTRI (Open-cart and Anechoic)
Force and moment	O	
Static pressure	O	O
Unsteady pressure		O
Far-field sound		O
Acoustic map by phased-array	48mic. D=0.25m & 1m	66mic. D=1m & 4m
Surface flow viz. & PIV	O	

Computational method and conditions

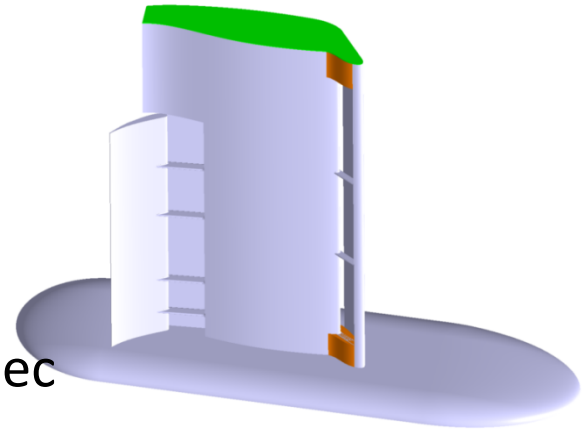
- Steady RANS computations
  - TAS code for mixed-element (Tet, Prism, Hex, Pyramid) unstructured mesh
    - Commonly-used CFD codes for unstructured grids in JAXA
    - SA-noft2-R (Cvor=1) is typically used as the turbulence model



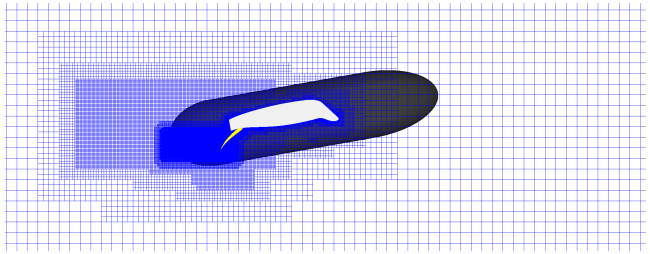
- Unsteady computations
  - PowerFLOW
    - Commercial Lattice Boltzmann Method Code
    - Cartesian grid with an extended wall model
    - A RNG-based, VLES two-equation turbulence model
  - Ffowcs Williams and Hawkings (FW-H) solver applied to solid surface

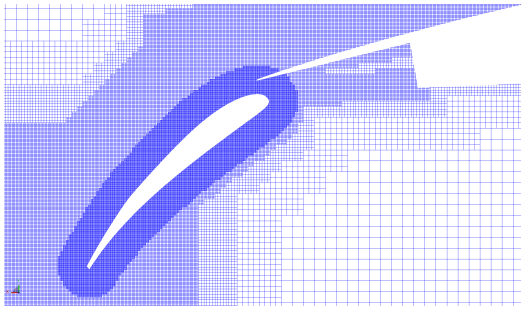
Computational method and conditions

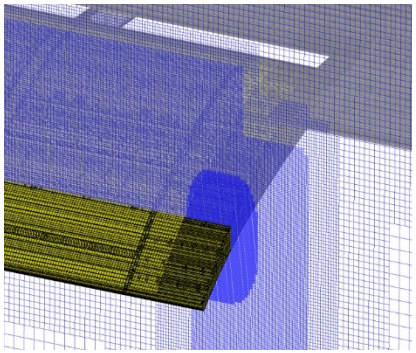
- Computational conditions
  - U_{inf} = 50m/s, Re = 2 million
  - Fully turbulent computation (WTT: Natural transition)
- Computational grid and physical computational time for unsteady simulation
  - Configuration with slat and flap supports
  - 86 million voxels , 0.25mm min. spacing
  - $t=4.2\times10^{-7}$sec x 1,200,000 timestep => t=0.5sec



Target frequency range: 0.7kHz~7kHz

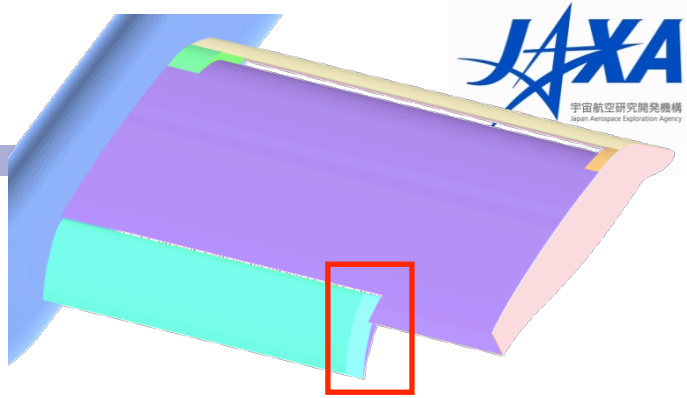






Results

- Baseline and rounded flap side-edge





Baseline



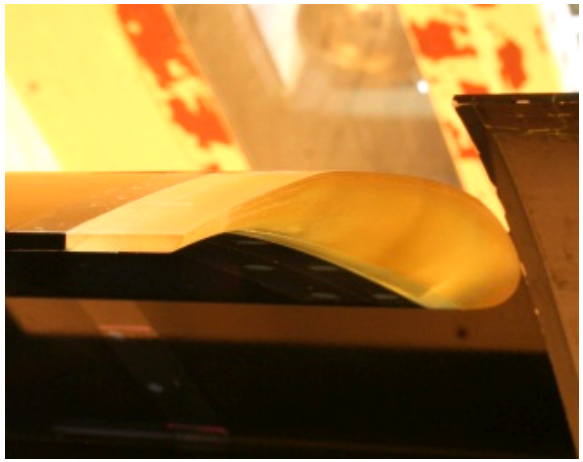


Round





LowerRound



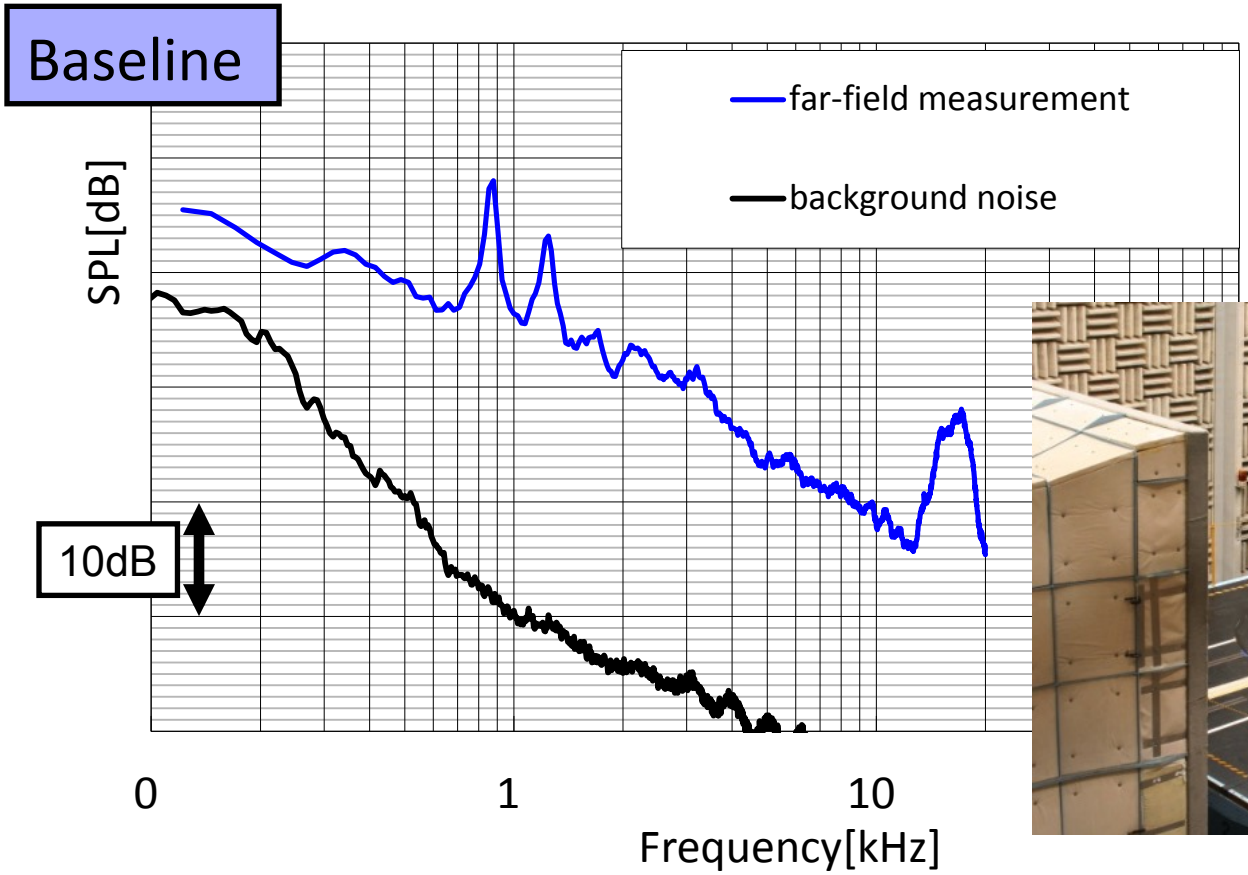


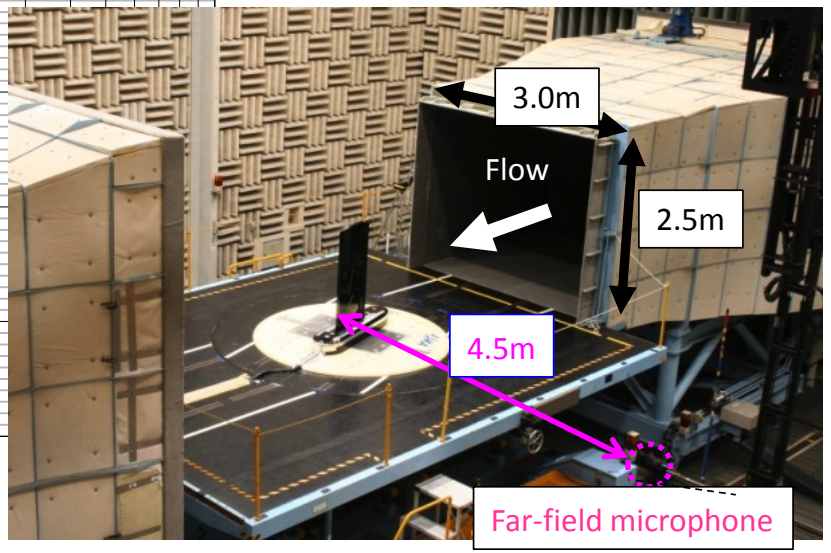
UpperRound



Measured SPL spectra in WTT ($\alpha_{corrected} \approx 10deg$)

- Slat and flap deployed configuration with the baseline flap side-edge shape
- $\alpha_{RTRI_opencart}$=12deg => $\alpha_{corrected}$≈10deg

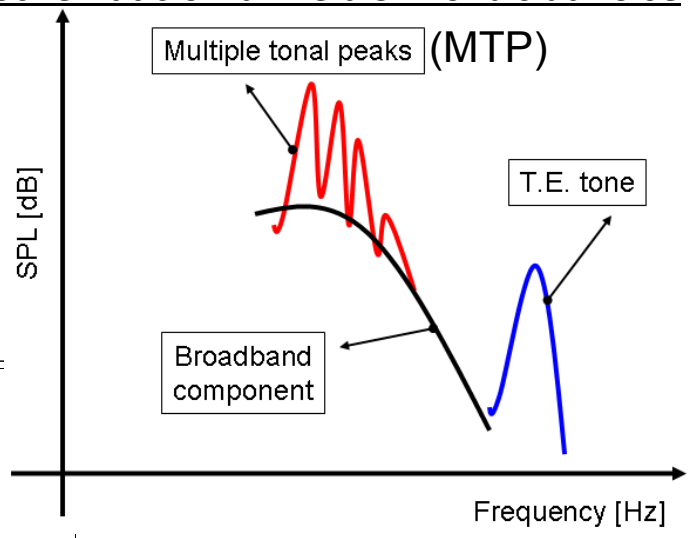


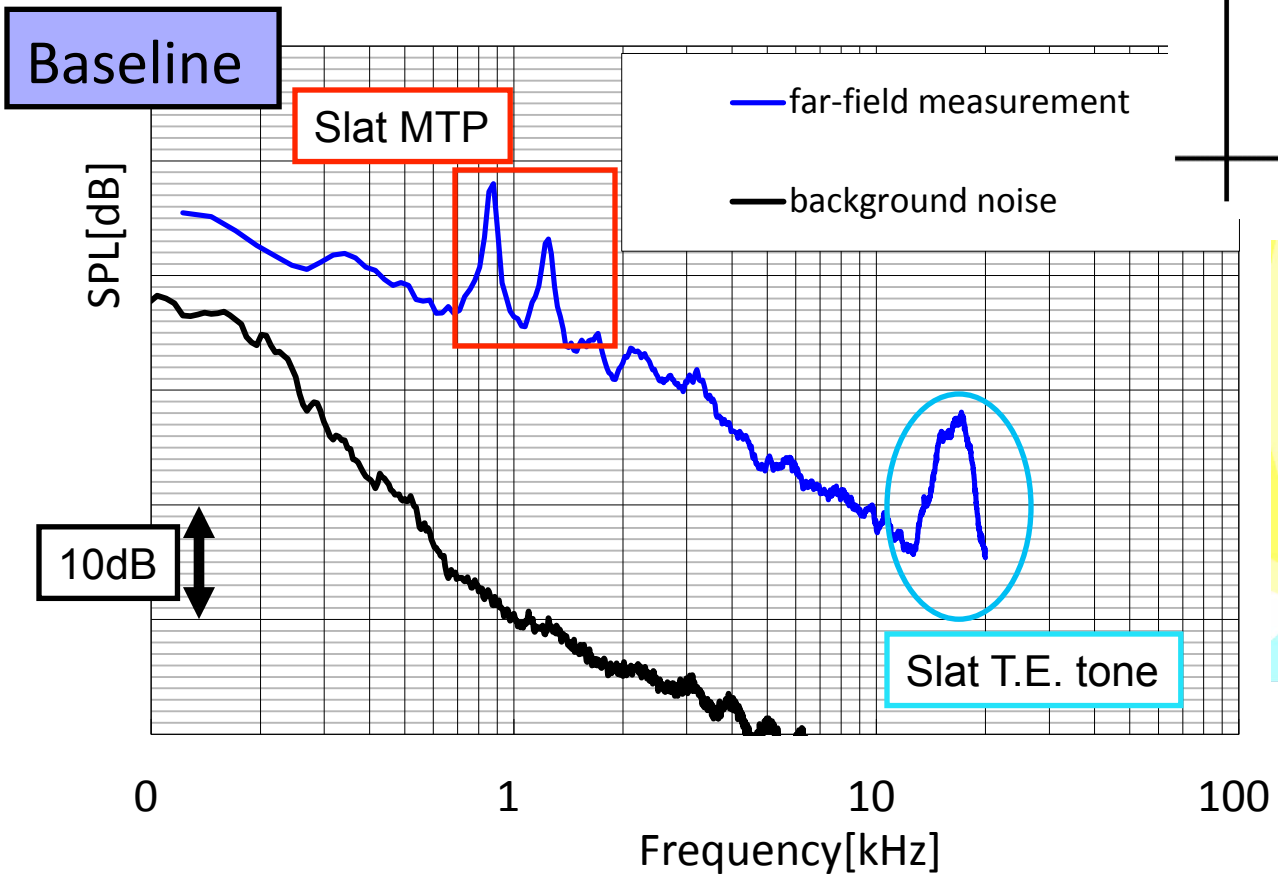


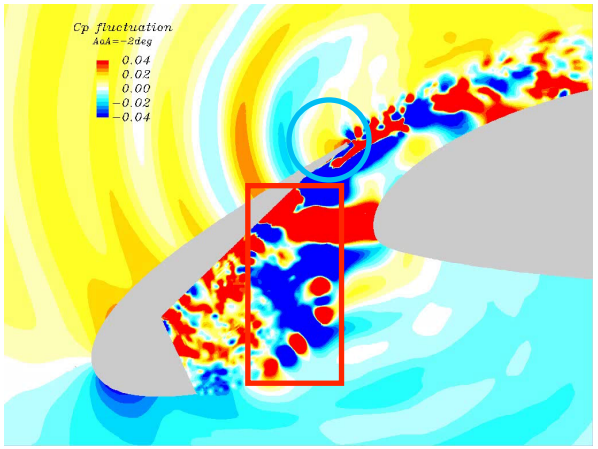
Measured SPL spectra in WTT ($\alpha_{corrected} \approx 10deg$)

- Slat and flap deployed configuration with the baseline flap side-edge shape
- $\alpha_{RTRI_opencart}$=12deg => $\alpha_{corrected}$≈10deg

Schematic of far-field SPL of a slat noise

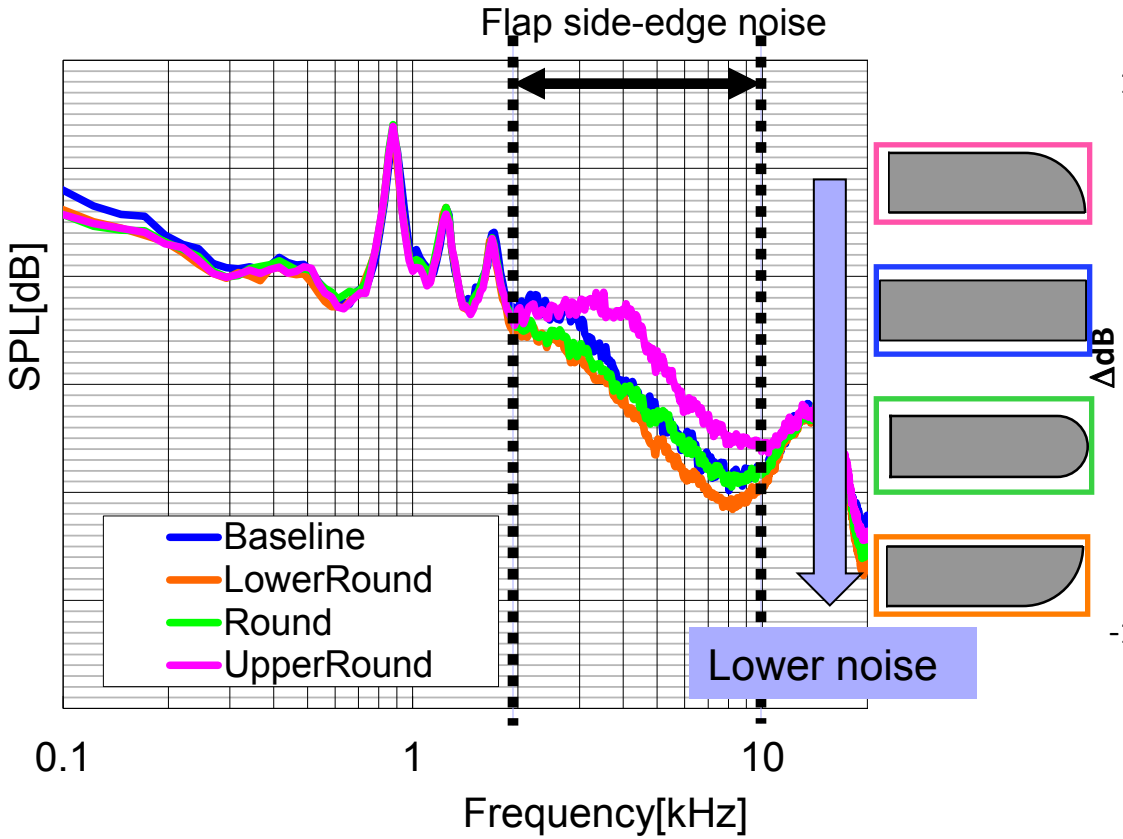


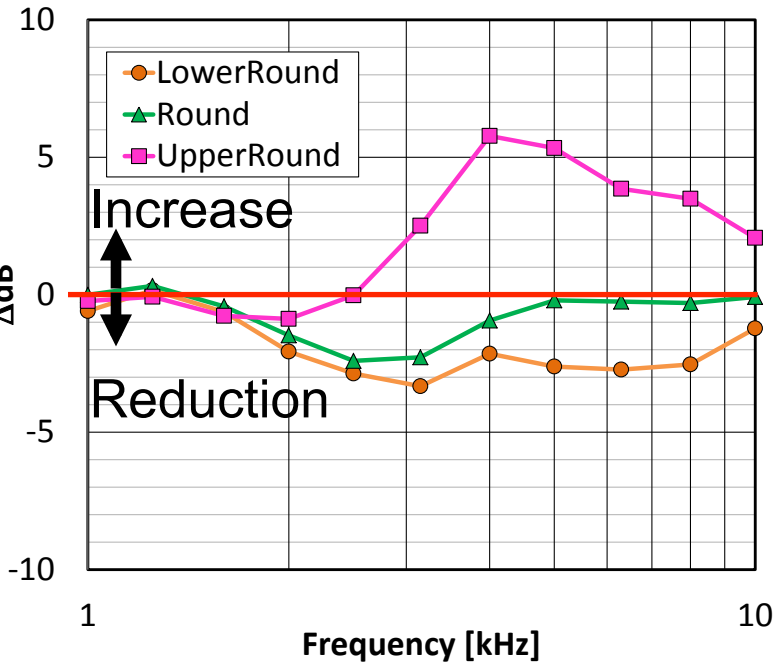




Measured noise change by flap side-edge shape

- Noise change at f=2kHz ~ 10kHz
- Noise level
  - UpperRound > Baseline > Round > LowerRound

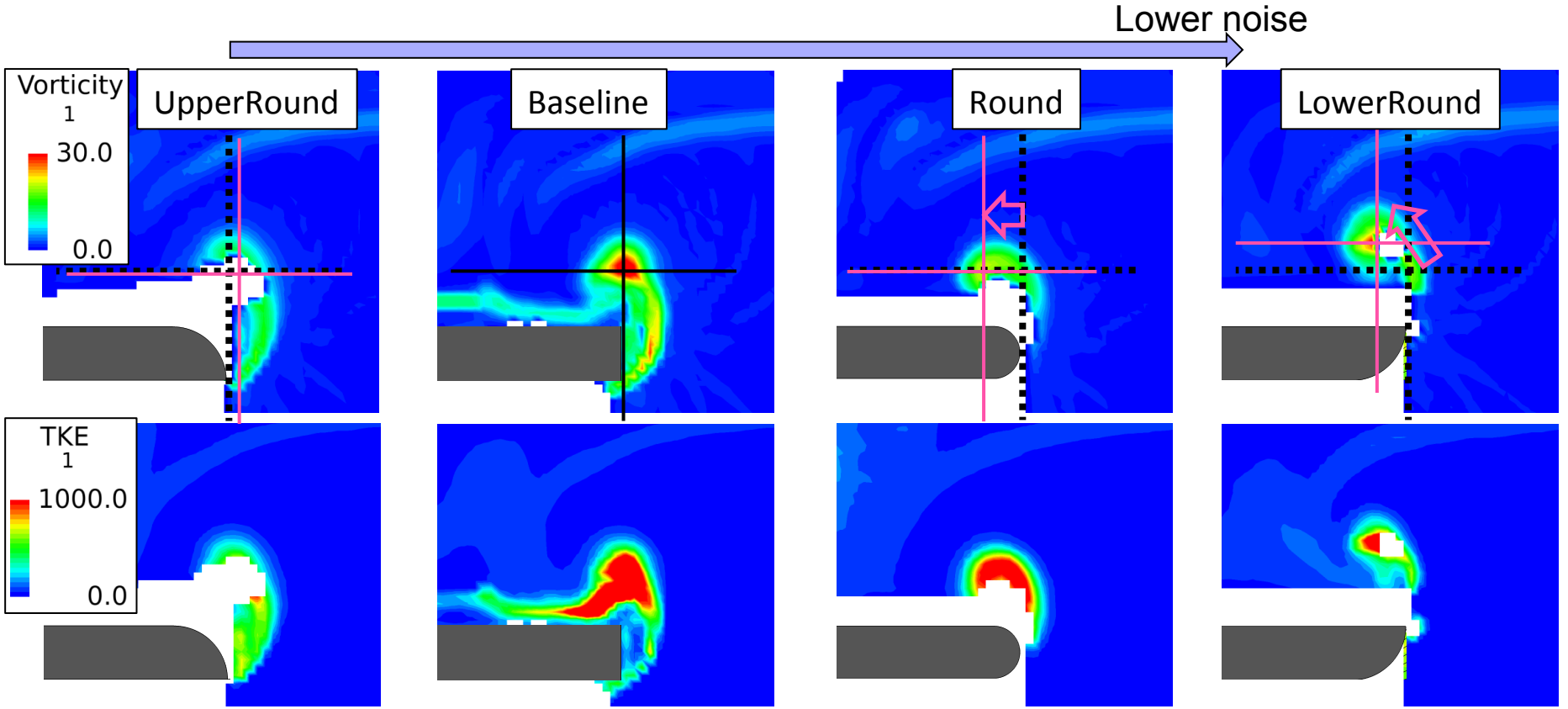




ΔdB from baseline flap side-edge

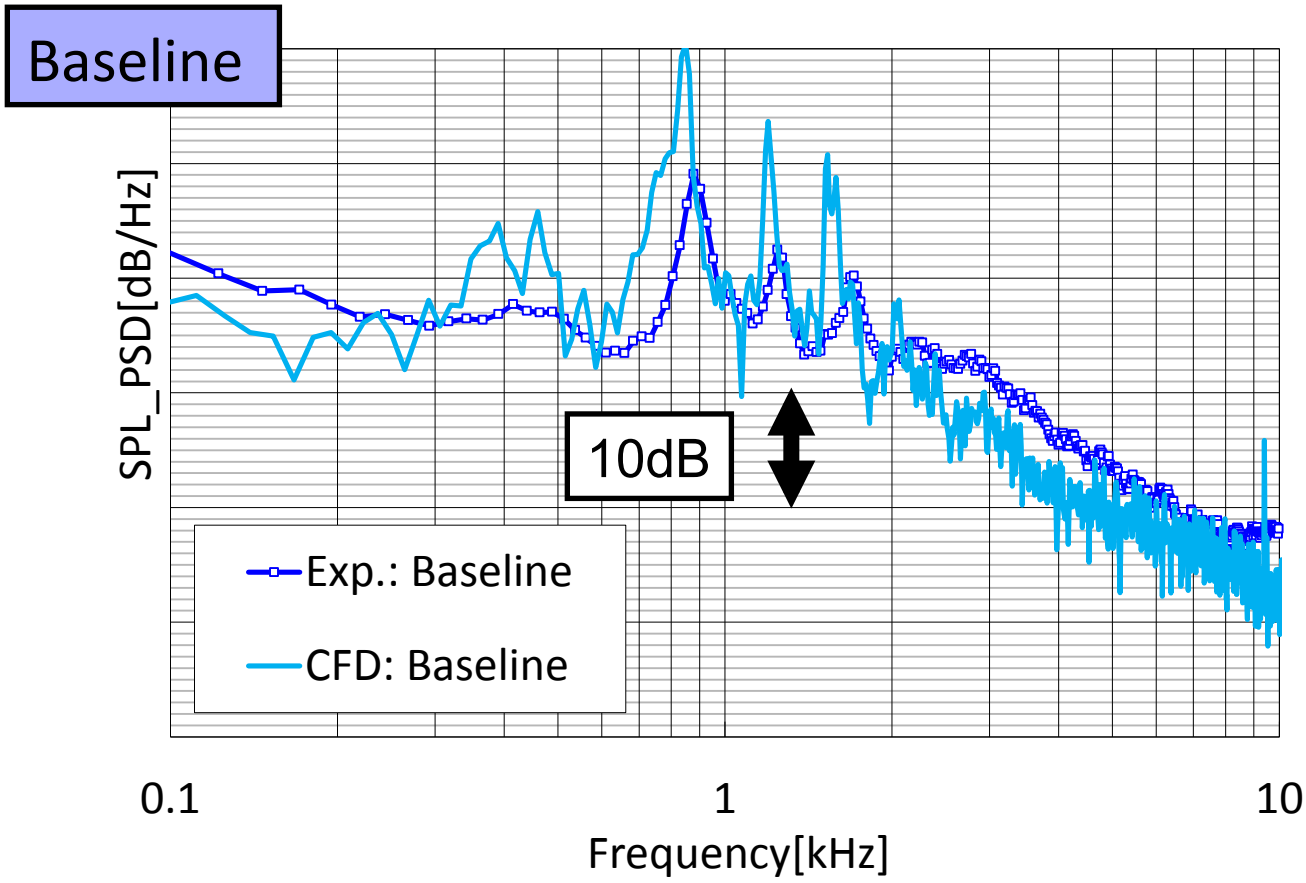
Vorticity and TKE at 75%c_{flap} by PIV ($\alpha_{corrected}$≈10deg)

- UpperRound: Vortex center remains unchanged
- Round: Vortex center moves inboard
- LowerRound: Vortex center moves inboard and away from the surface
  - TKE is smaller



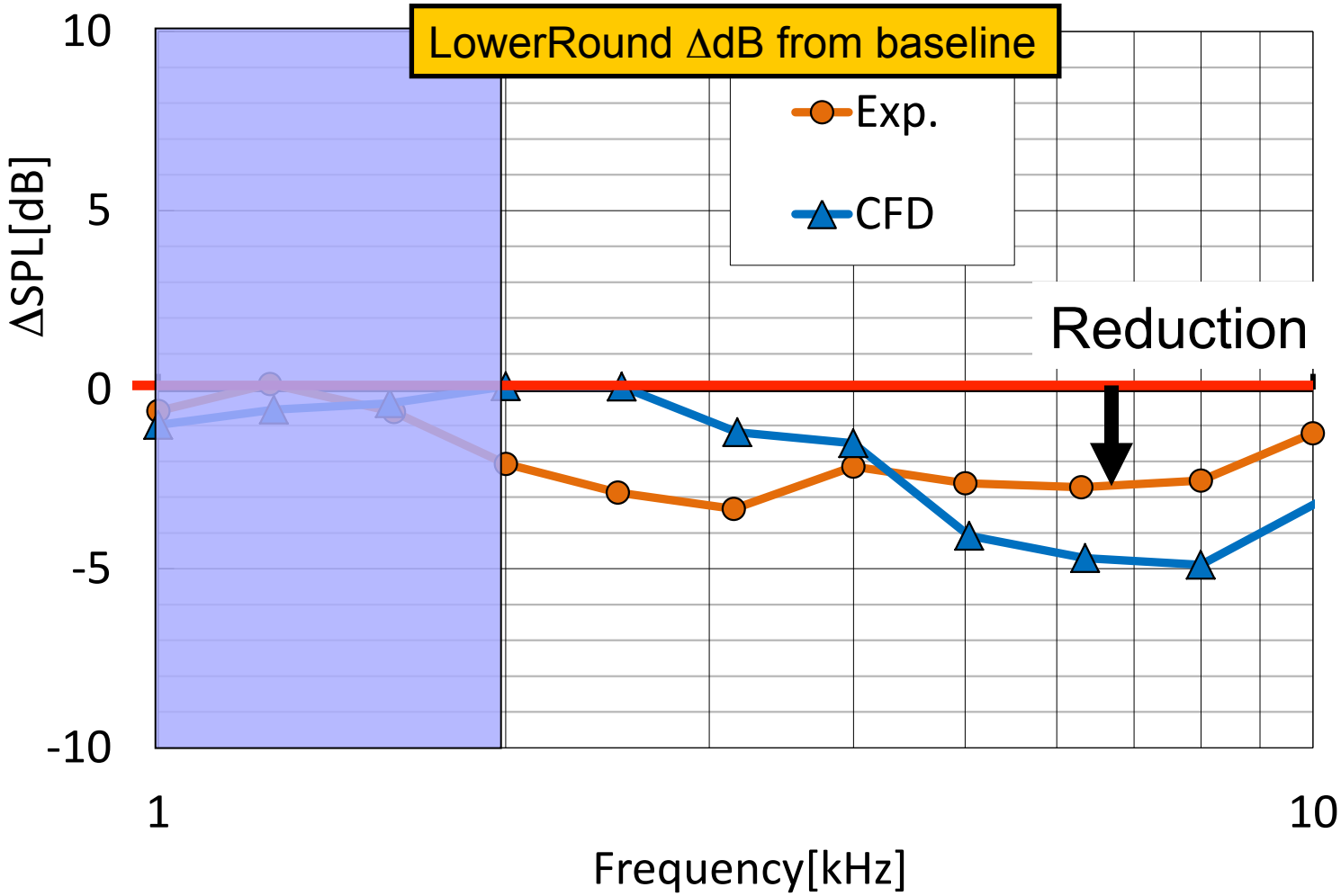
Comparison of SPL between WTT and CFD ($\alpha_{corrected}$≈10deg)

- Reasonable agreement with WTT
  - Slat MTP at f=0.9kHz ~ 2kHz are reproduced but overestimated
    - Coarse grid resolution around slat may artificially generate excessive 2D vortex structures and result in higher level of Slat MTP



Comparison of SPL between WTT and CFD ($\alpha_{corrected}$≈10deg)

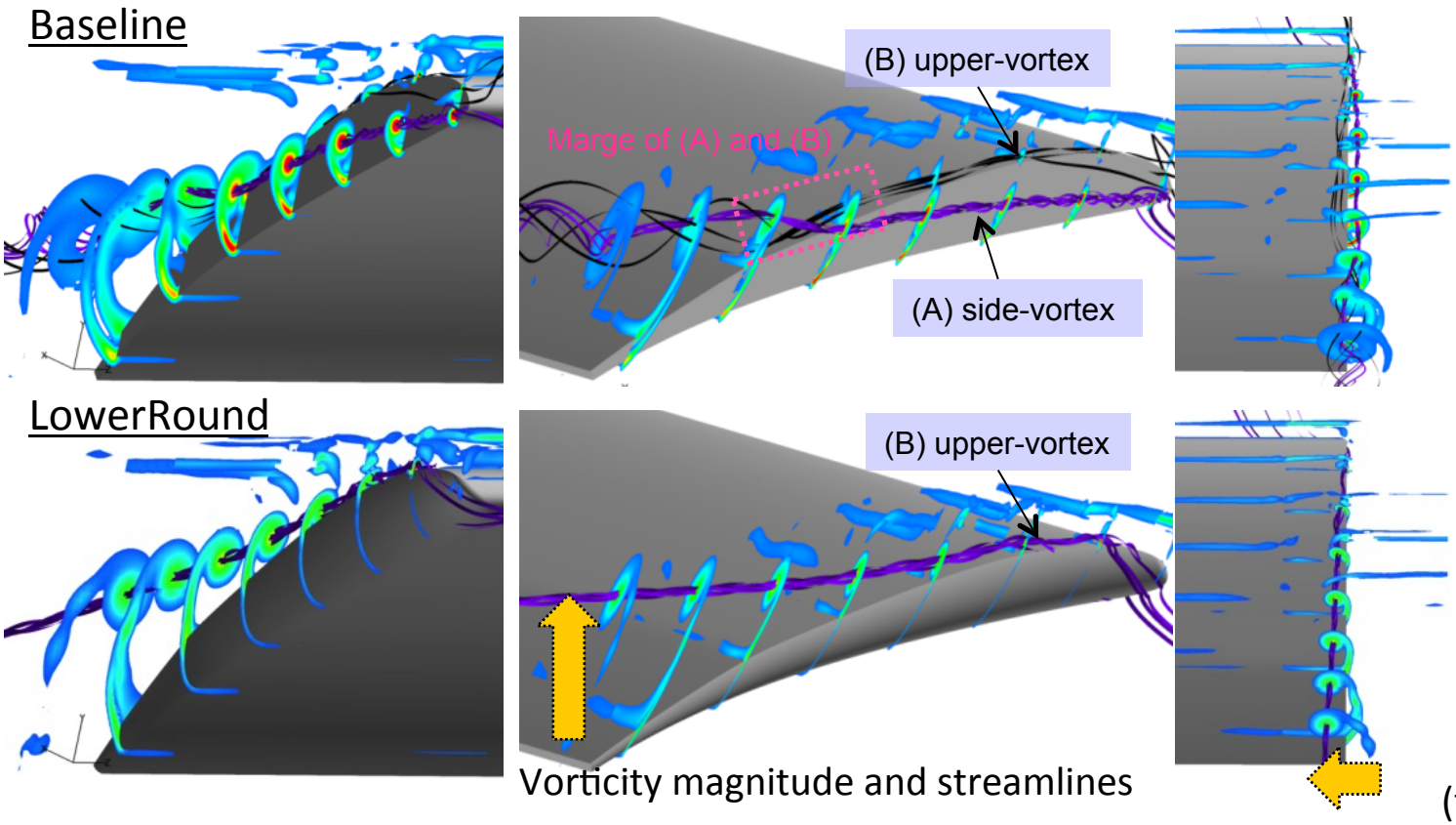
- LowerRound Effect is fairly predicted



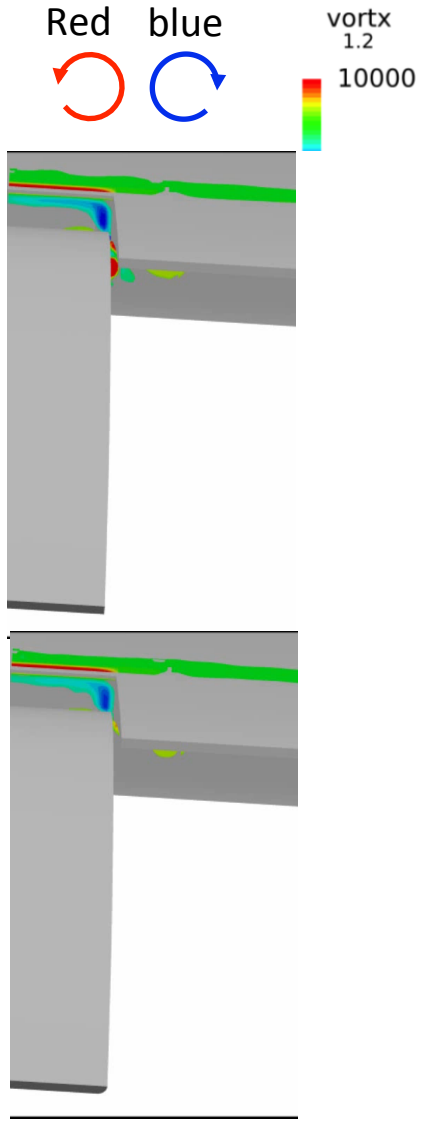
ΔdB from baseline flap side-edge

Time averaged flowfield: Vorticity

- Baseline: Two major vortex structures
  - (A) Side-vortex rolled-up from lower-edge near the leading-edge
  - (B) Upper-vortex rolled-up from upper-edge near the leading-edge
    - Vorticity of (A) is much higher
  - (A) and (B) marge at upper surface near 60% flap-chord
- LowerRound: Only (B) Upper-vortex
  - Upper-vortex moves inboard and away from surface earlier

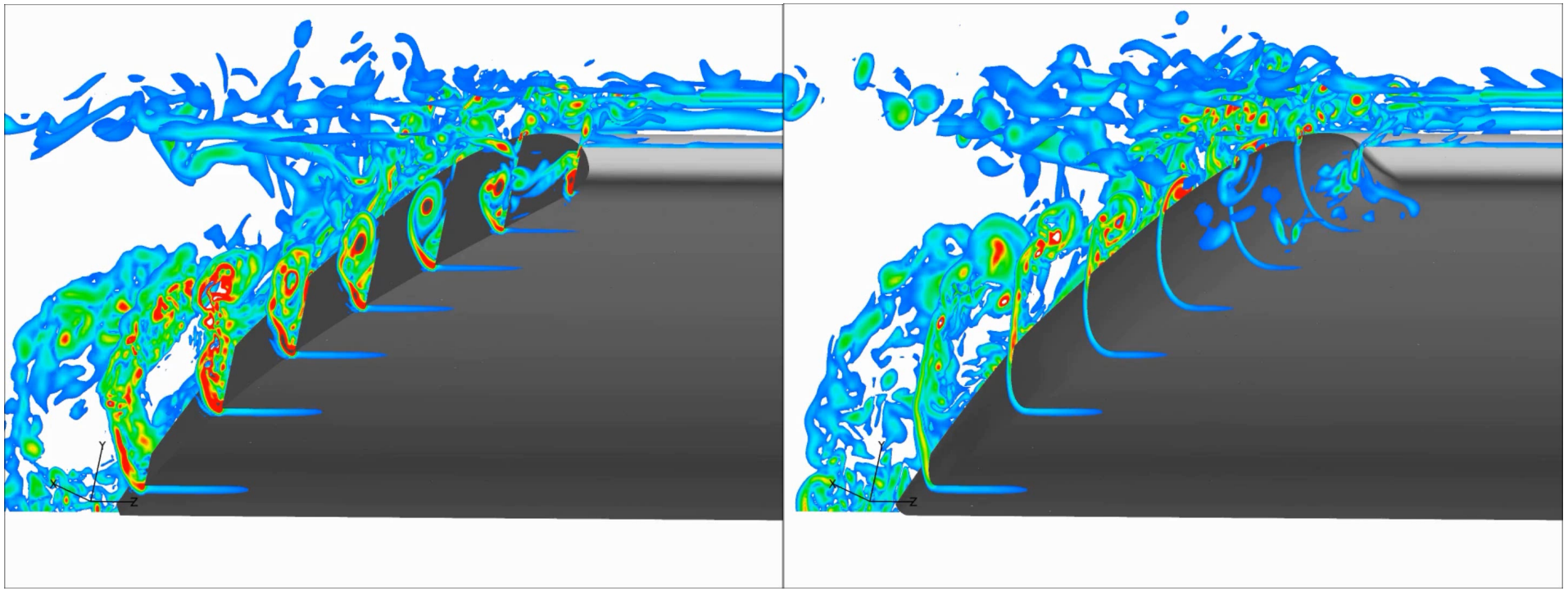


Vorticity magnitude and streamlines



X-vorticity
(free-stream direction)

Unsteady flowfield: Vorticity magnitude



Baseline

View from lower-side

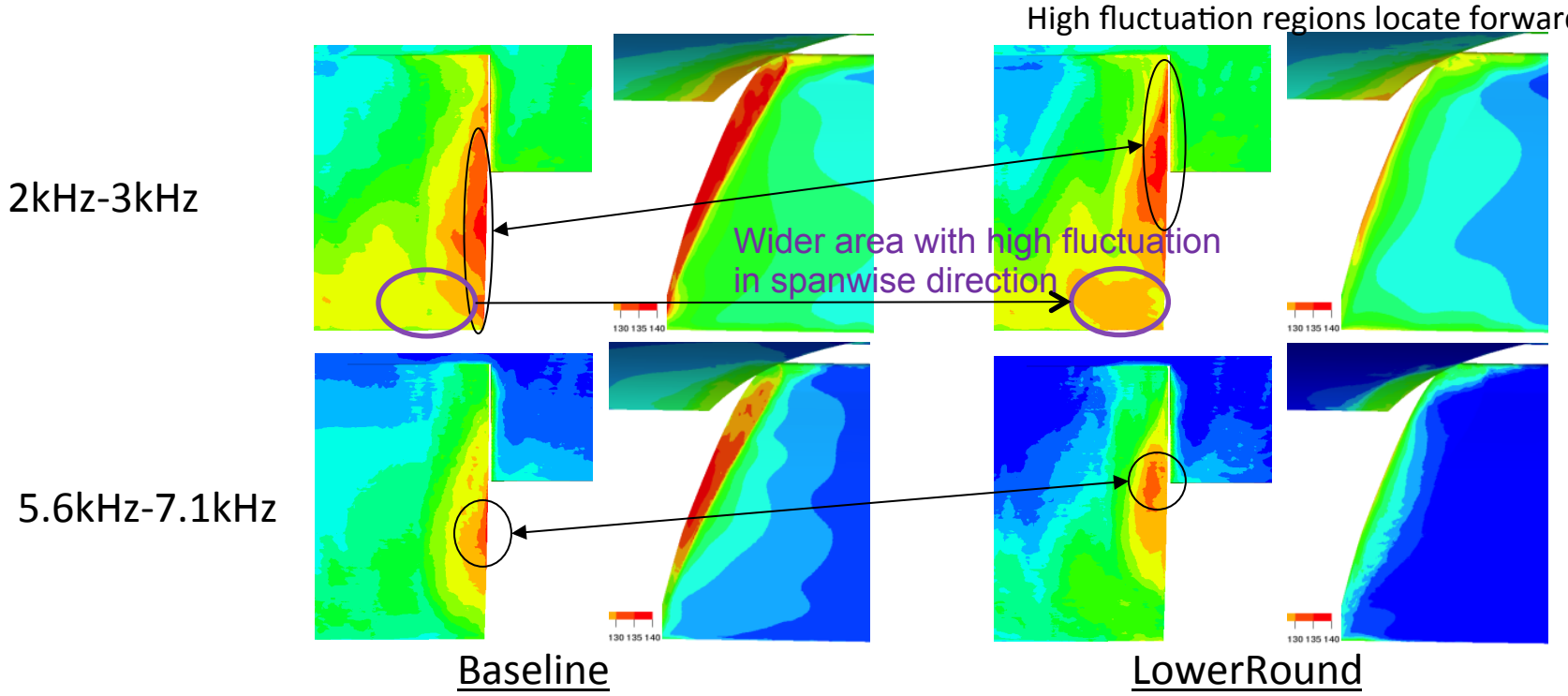
LowerRound





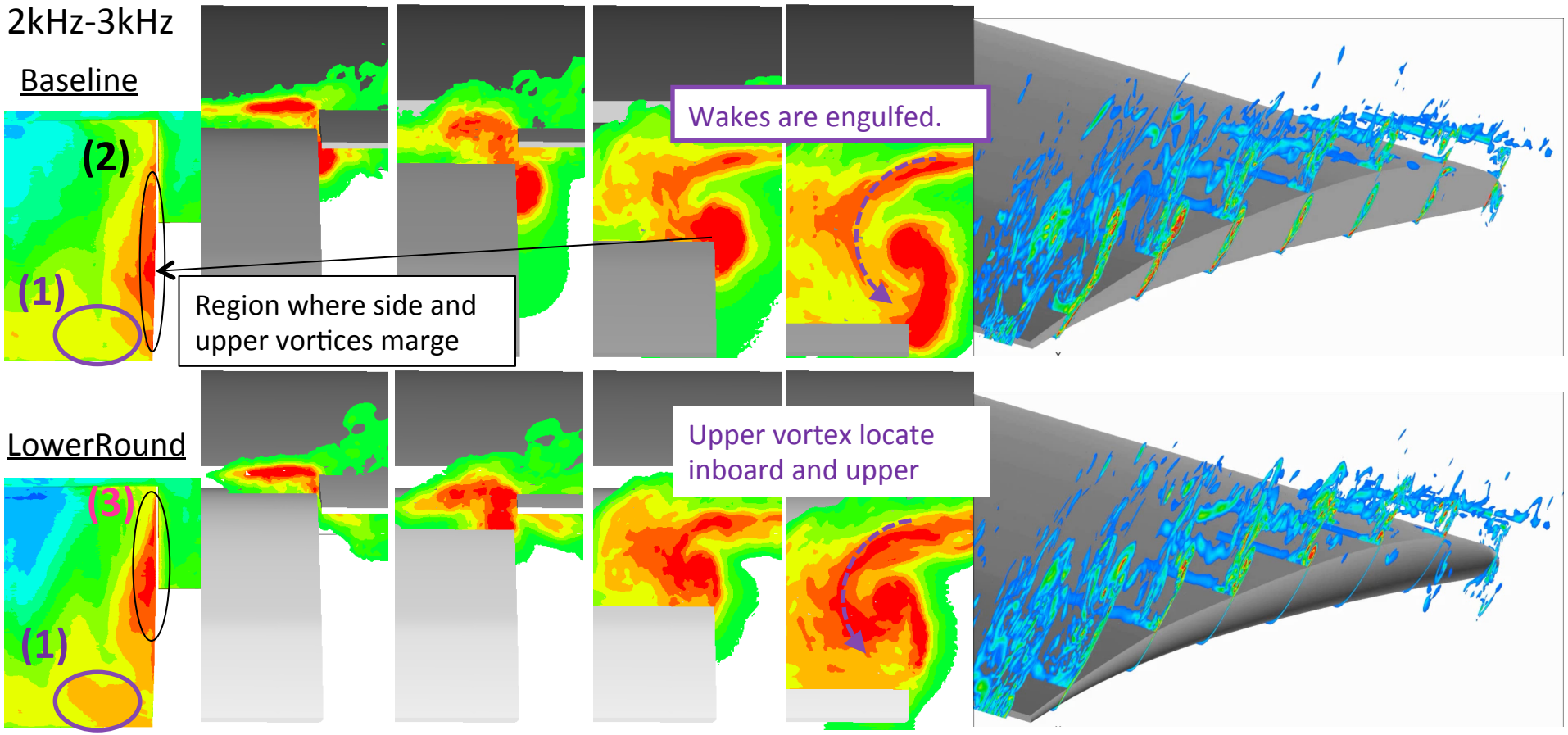
Comparison of high pressure fluctuation region

- Baseline
  - High pressure fluctuation along the paths of upper and side vortices
  - Max:60%c_{flap} where side and upper vortices marge
- LowerRound
  - Max: 40~50%c_{flap} and 5~25%c_{flap}
  - Wider area with high fluctuation in spanwise direction near flap trailing-edge



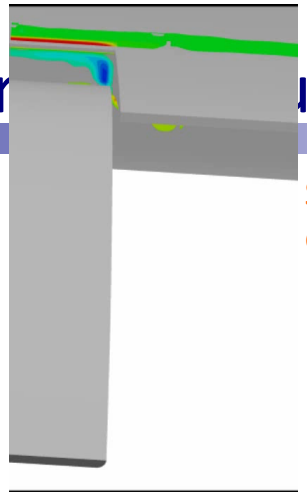
Comparison of high pressure fluctuation region

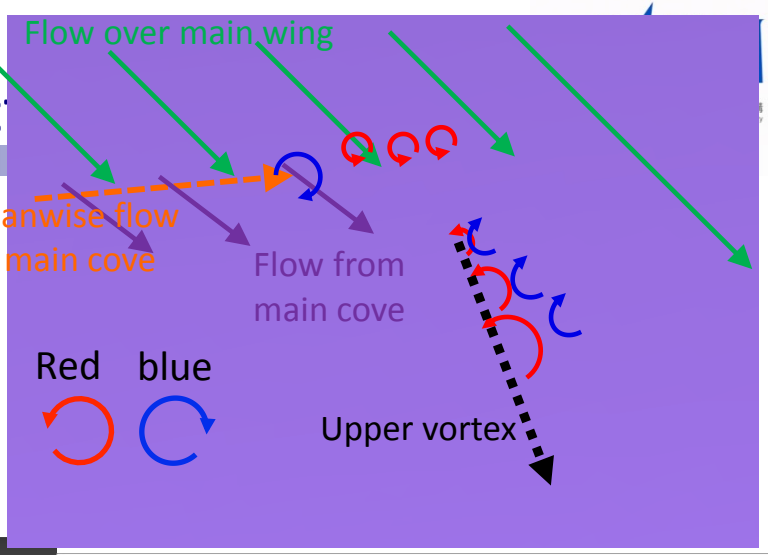
- (1) High area in the spanwise direction near flap trailing-edge
  - Interaction of upper-vortex and wake from main wing
- (2) High area at 60%c_{flap} for Baseline
  - Location where side and upper vortices marge near the upper-edge



Comparison of high pr…uc…

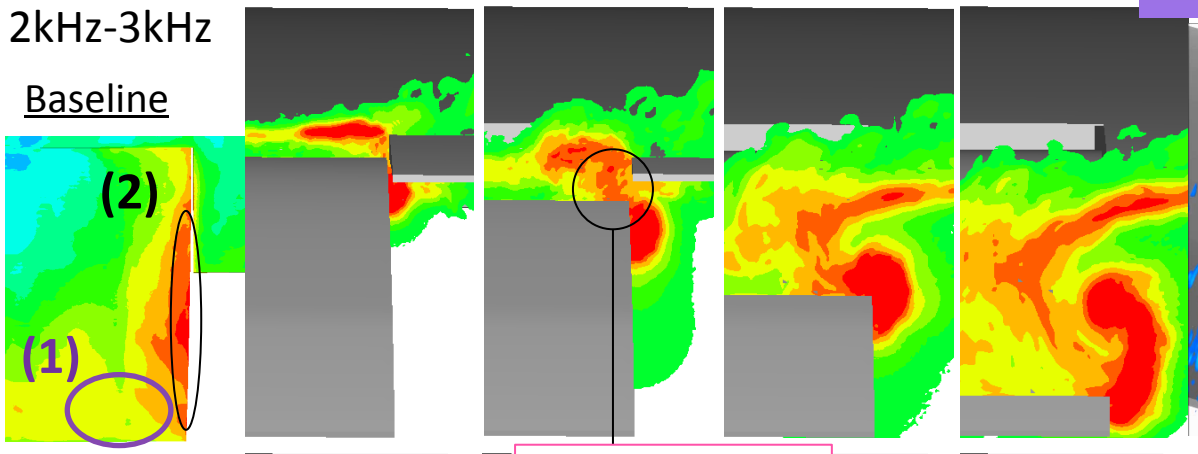
- (3)High area at 5~40%c_{flap}
  - Interaction of upper-vortex, wake from main wing, flows from cove and gap with main and flap

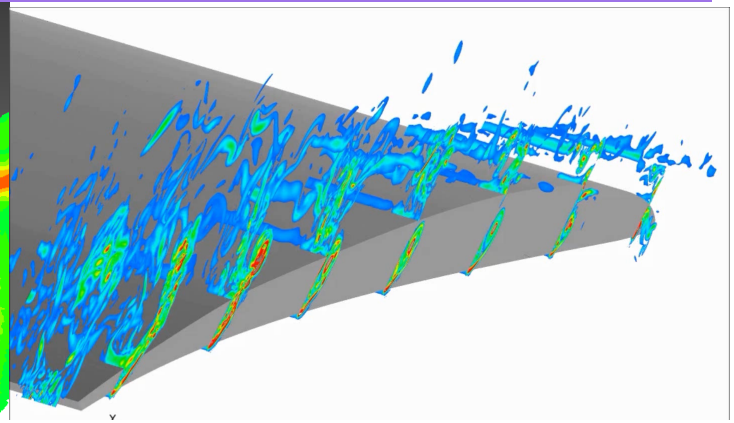




2kHz-3kHz

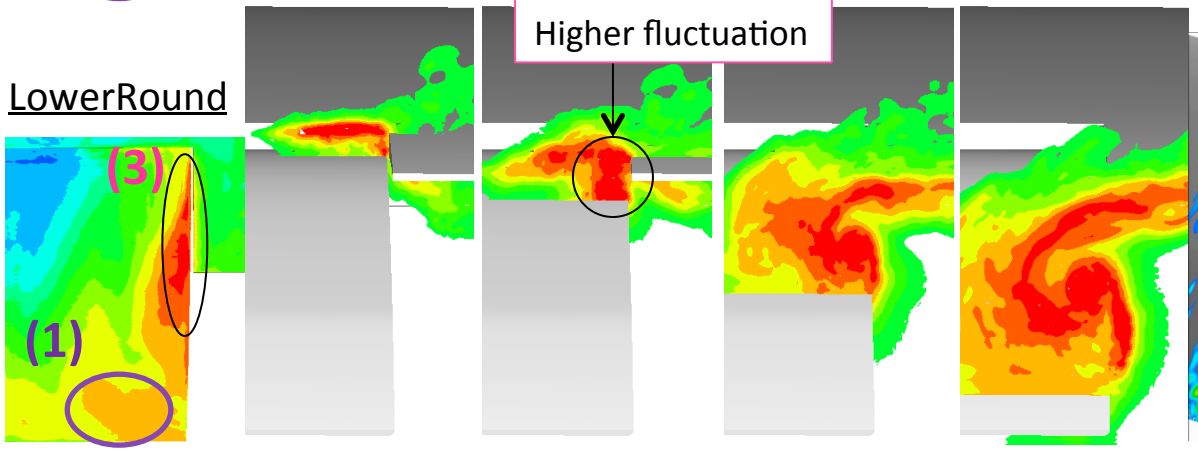
Baseline

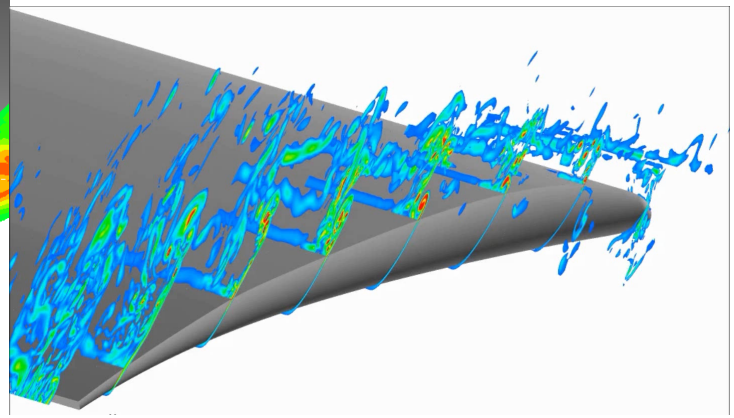




Higher fluctuation

LowerRound

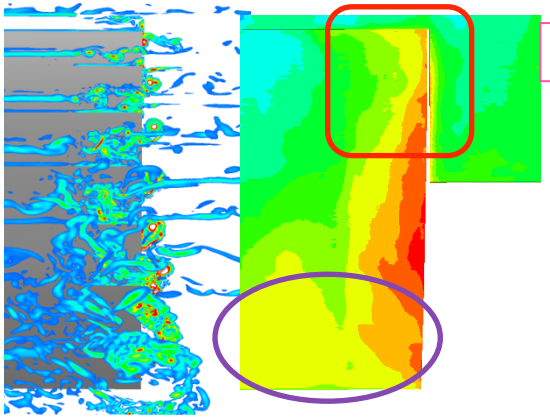




Ref. Comparison of OTOMO FlapTip & NACA0012 WingTip

OTOMO FlapTip

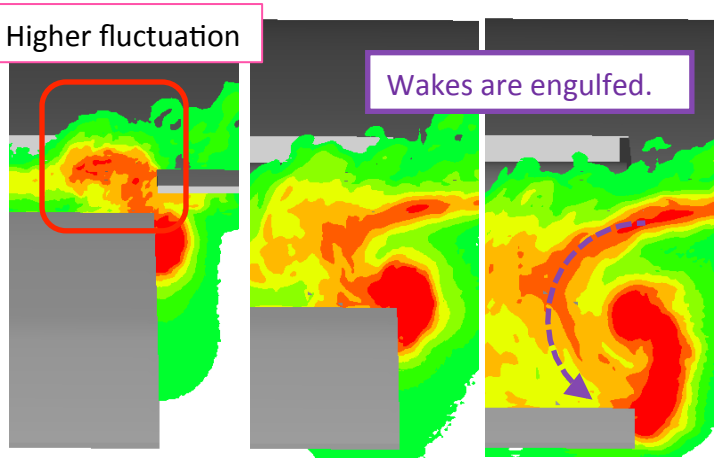




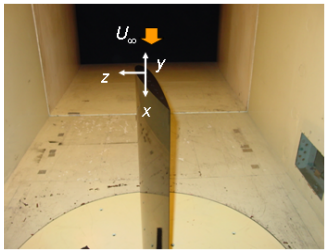
2kHz-3kHz

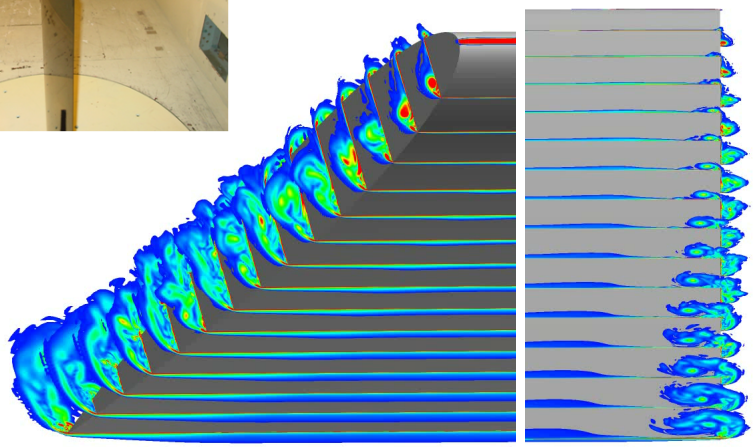
Higher fluctuation

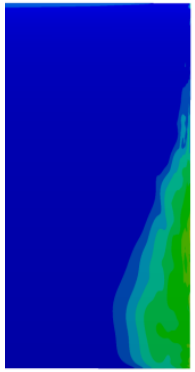
Wakes are engulfed.



NACA0012 WingTip

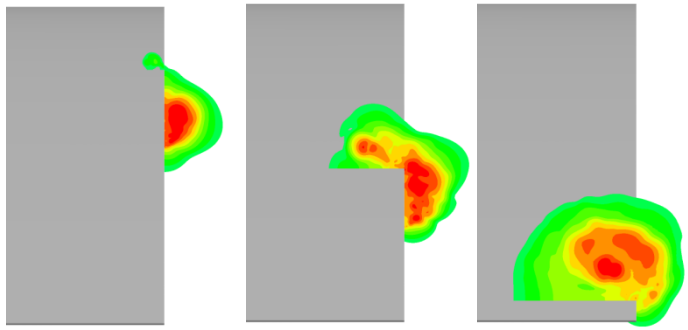








2kHz-3kHz



Variations of flap side-edge shape of real airplanes

- Flap side-edge with cavity

  Photos of real airplanes





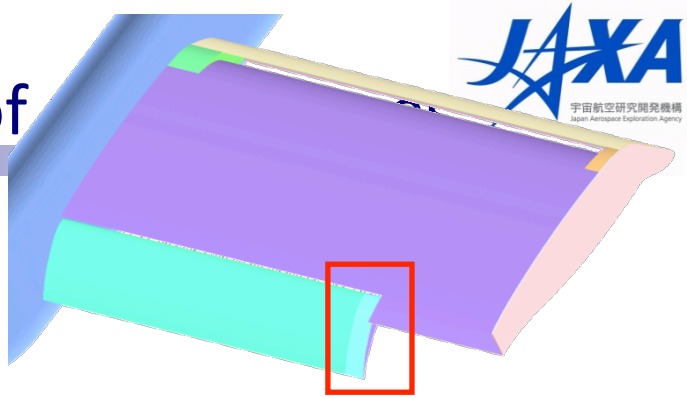


Bluff flap tip



Cavity

Variations of flap side-edge shape of



- Flap side-edge with cavity

Photos of real airplanes





Model for OTOMO

5mm depth cavity

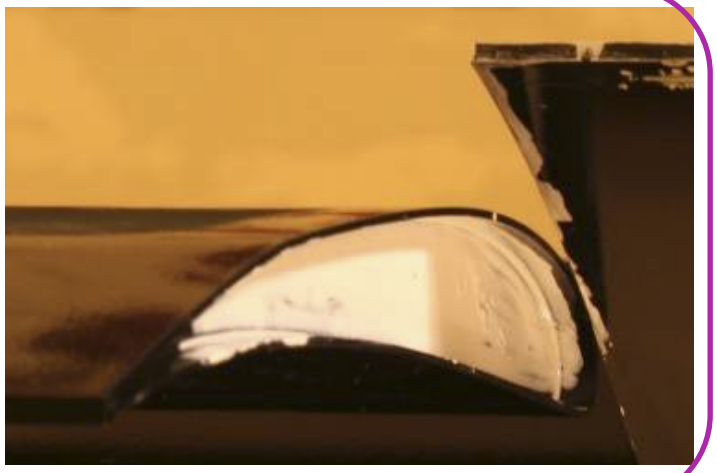


Baseline



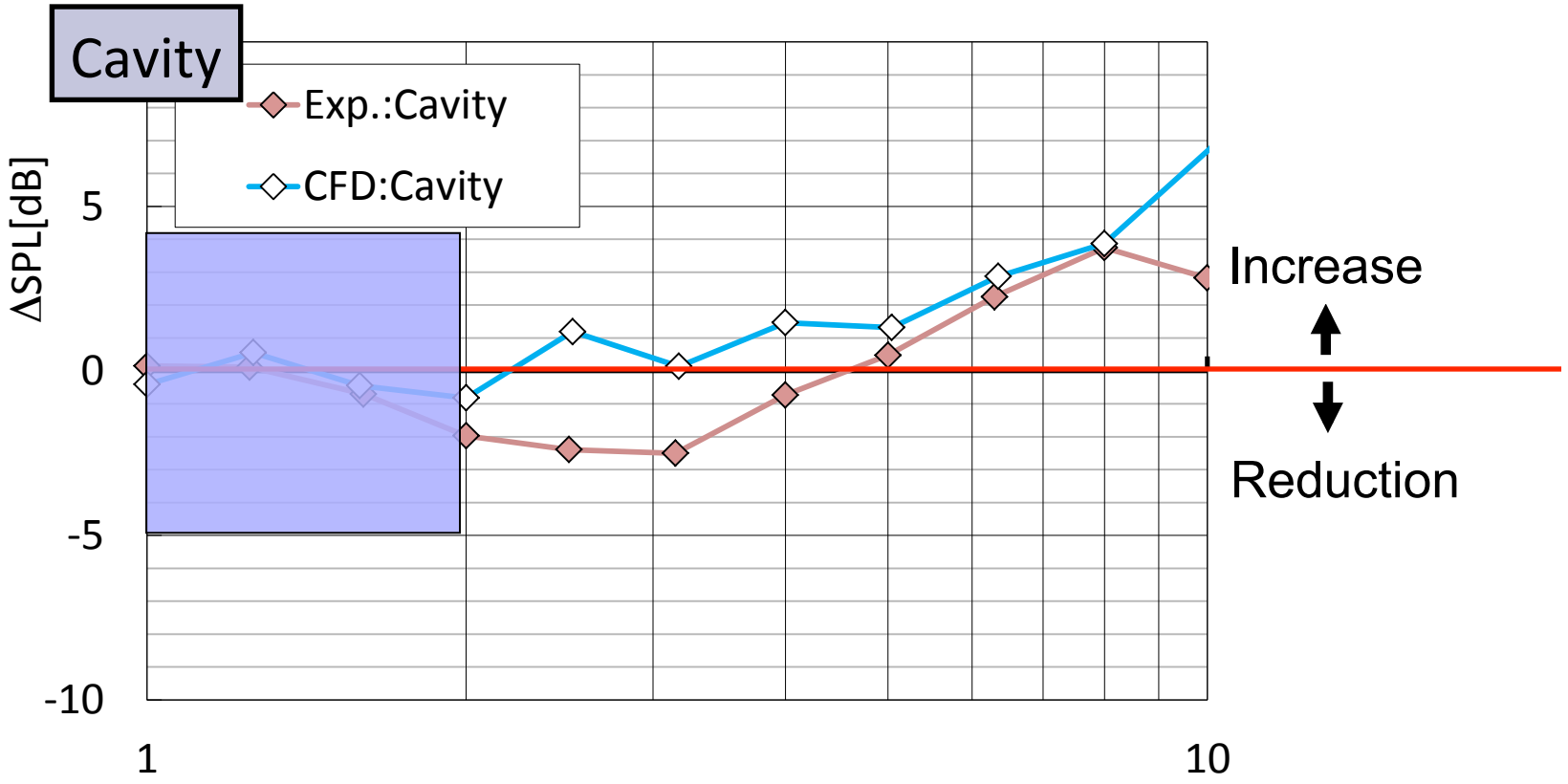


Cavity



Comparison of SPL between WTT and CFD ($\alpha_{corrected}$≈10deg)

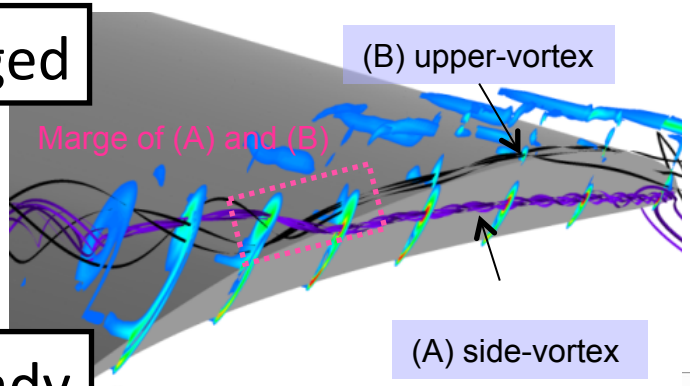
- Trend to increase noise with cavity at high frequency range
- Cavity effect is fairly predicted by CFD

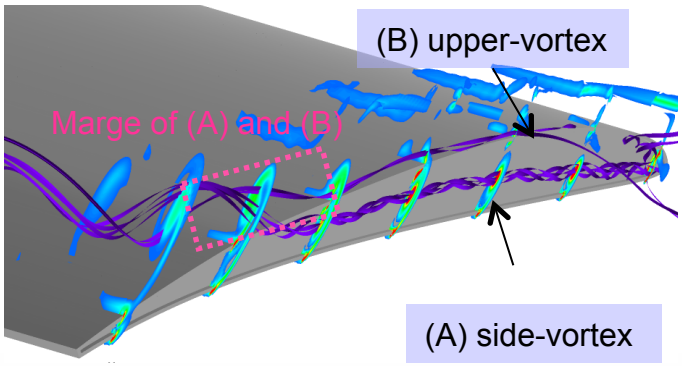


Vorticity magnitude

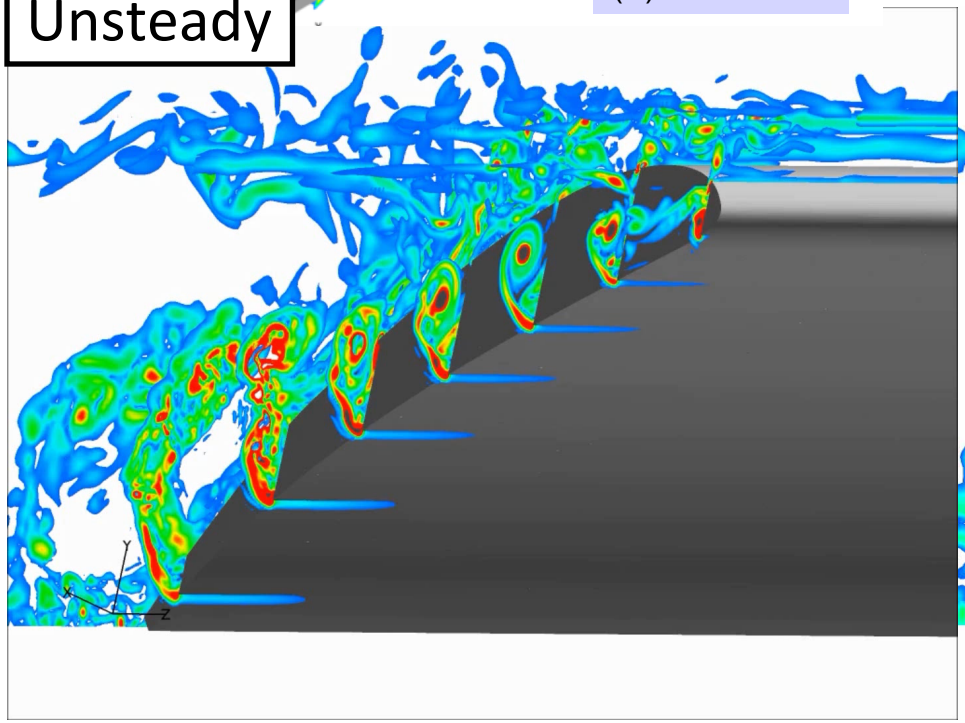
- Similar to baseline result
- Smaller vortex structures by edges of cavity

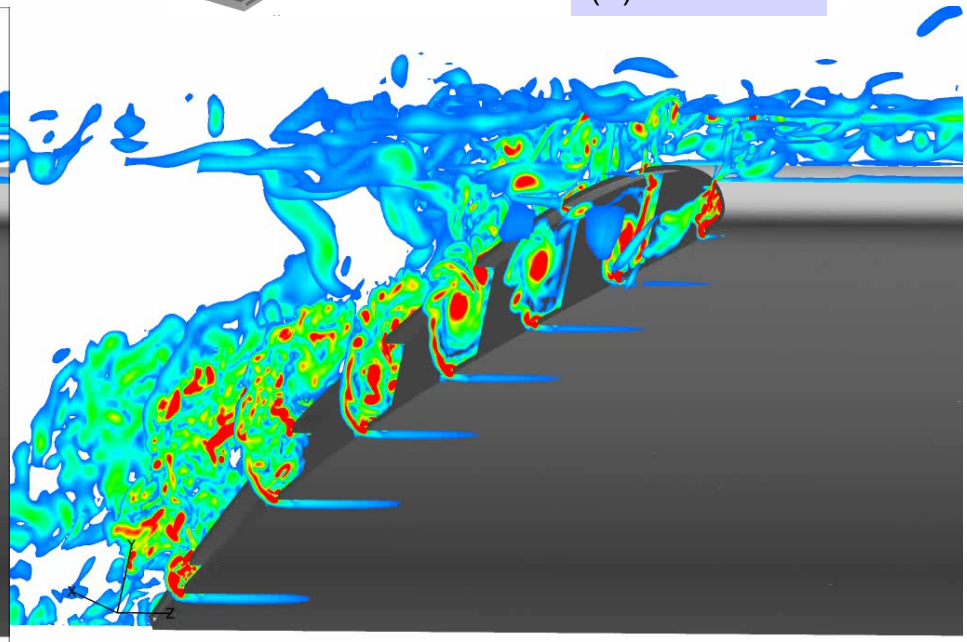
Averaged





Unsteady





Baseline

View from lower-side

Cavity



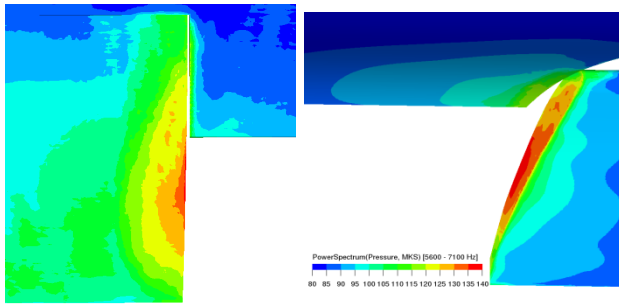


Change of high pressure fluctuation region by cavity

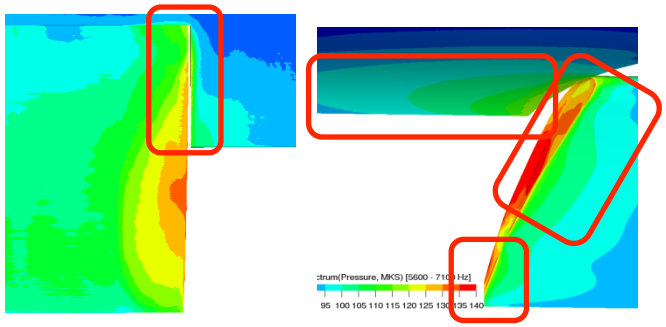
- Similar to baseline result on flap upper surface
- Higher pressure fluctuation level widely observed in cavity
- Increase of high pressure fluctuation around trailing-edge

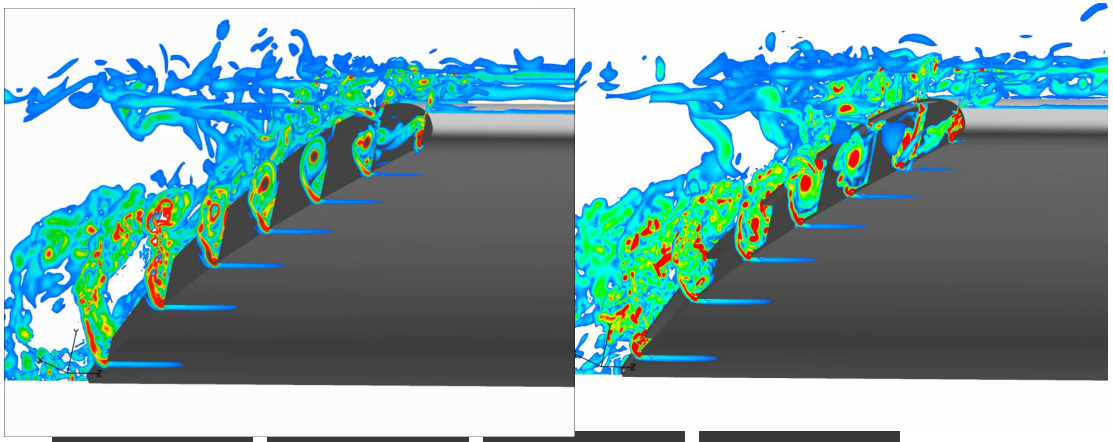
5.6kHz-7.1kHz

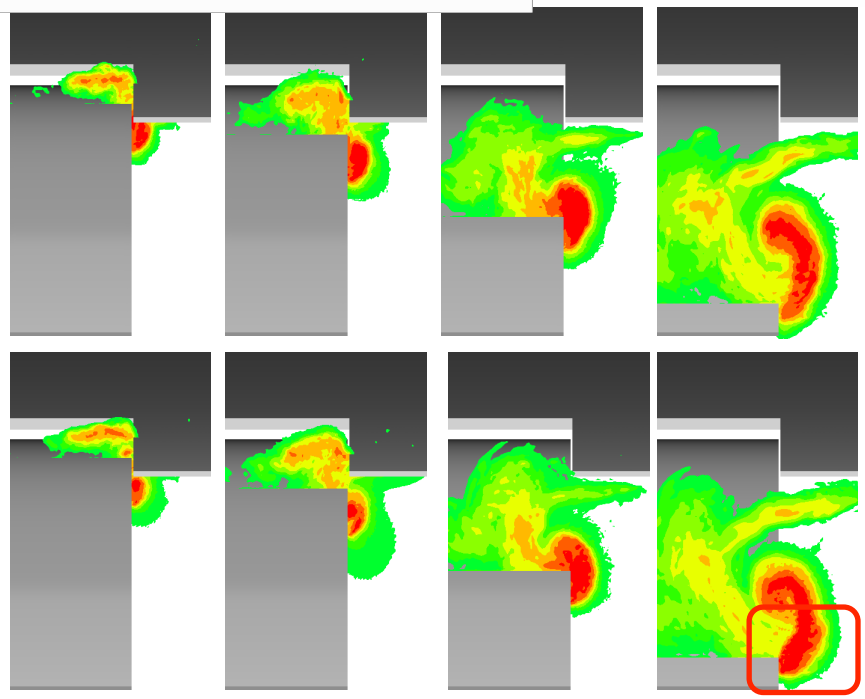
Baseline

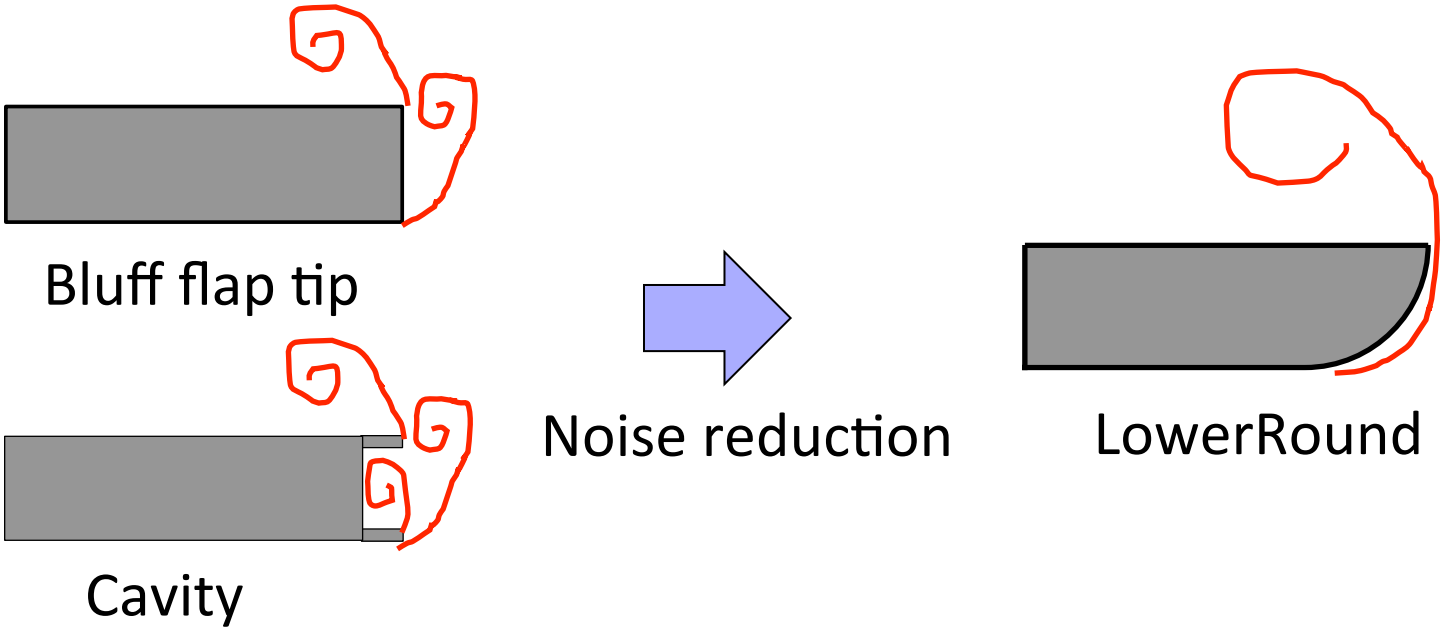


Cavity







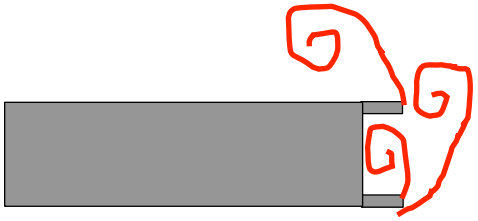


But, we need to round flap-tip itself and it is not so easy to apply for existing airplanes.

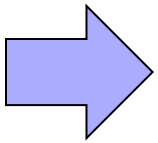
Any other solutions??



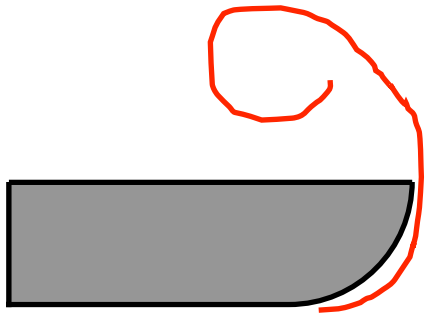
Bluff flap tip



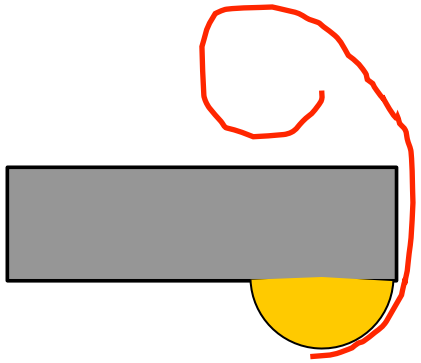
Cavity



Noise reduction



LowerRound

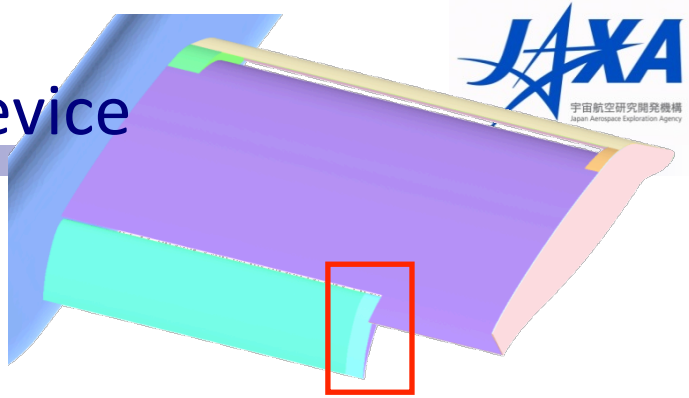


Protruding Device

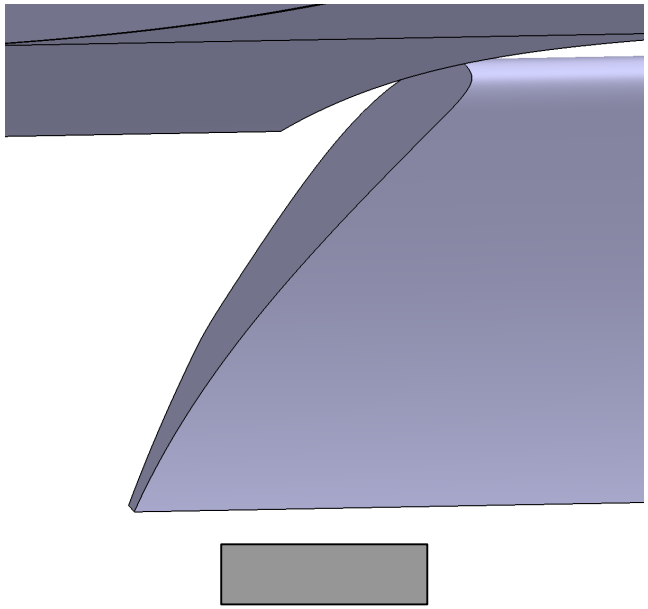
Additional type device to original flap

Imamura, T., Yokokawa Y., Yamamoto, K. (JAXA)
Hirai, M., and Takenaka K. (MHI)

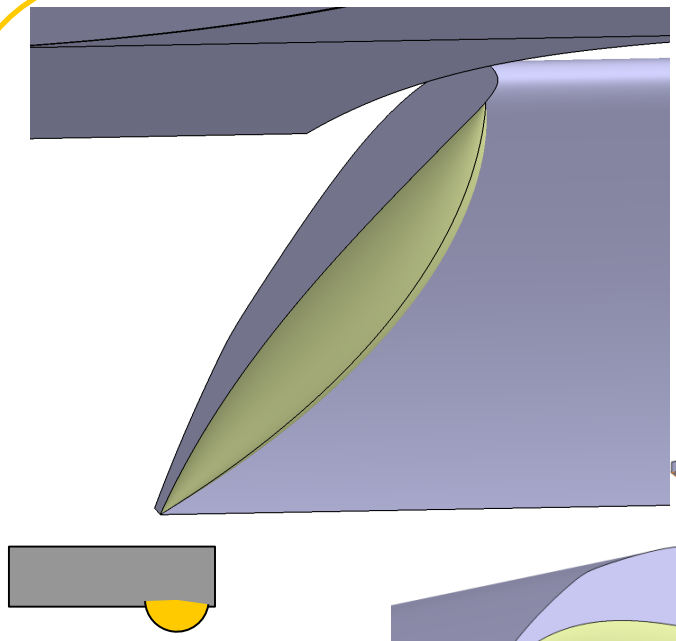
Flap Side-edge with a Protruding Device

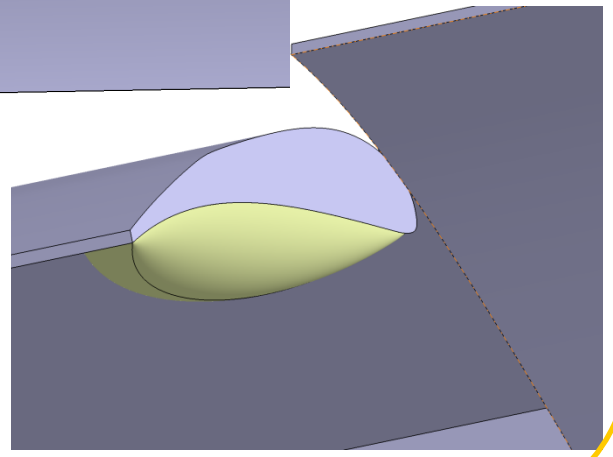


- Flap Side-edge with a protruding device on lower surface of flap



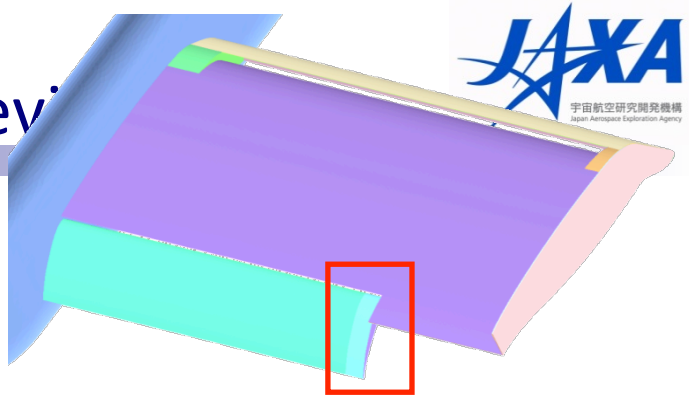
Baseline





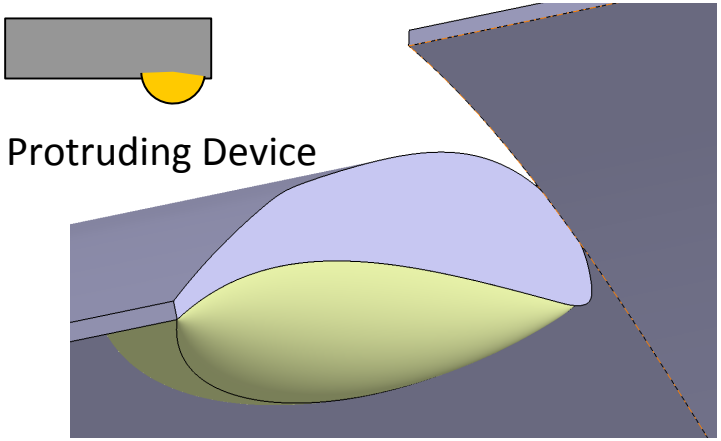
Protruding Device

Flap Side-edge with a Protruding Dev



- Flap Side-edge with a protruding device on lower surface of flap



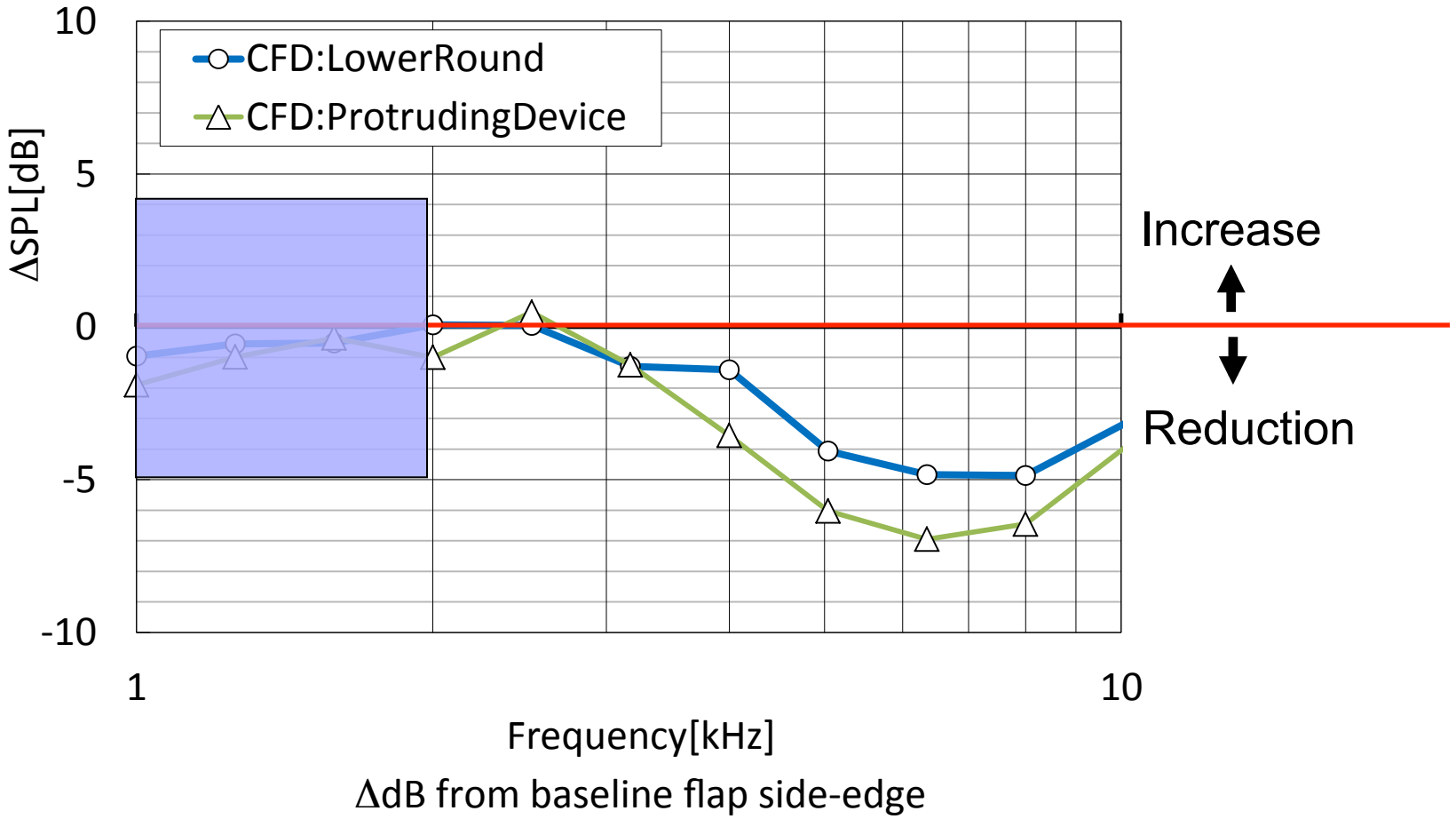


- Noise reduction by weakening side-vortex
- Need to round flap-tip itself

- Similar noise reduction concept to weaken side-vortex
- Additional type device to original flap

Noise reduction effect by protruding device

- Protruding device
  - Greater noise reduction effect than that of “LowerRound”

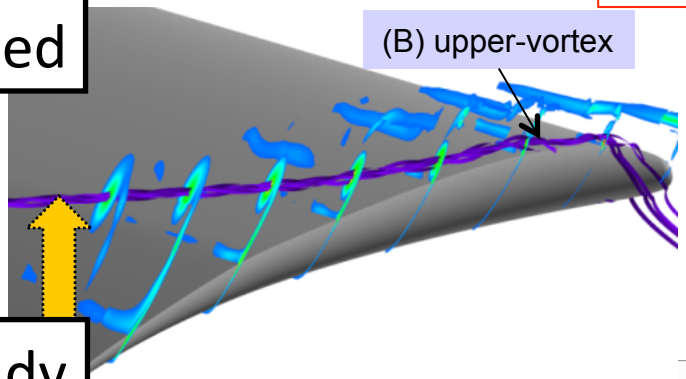


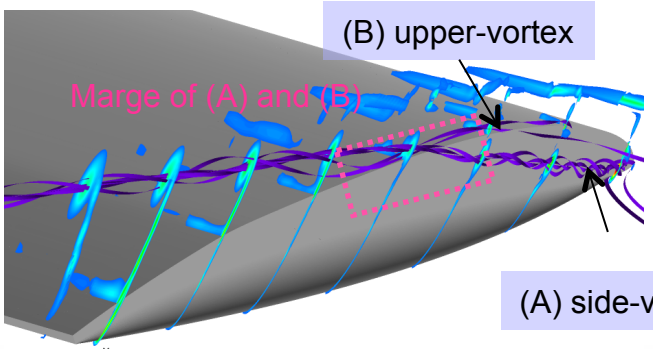
Vorticity magnitude

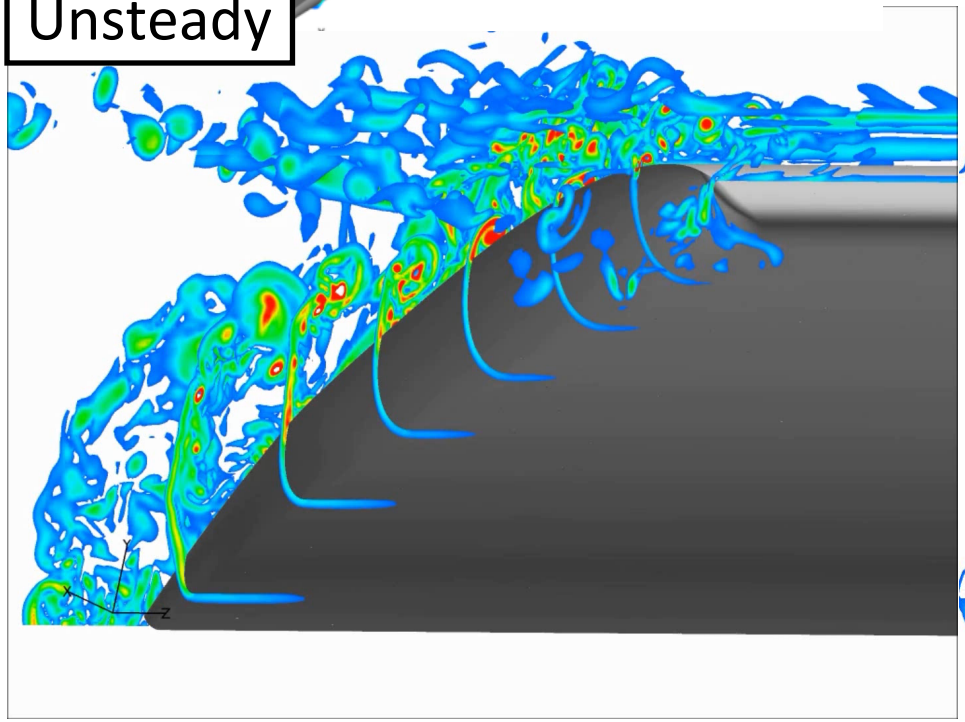
- Side-vortex is generated but weak than that of baseline
- Upper-vortex is weaker than that of LowerRound
- Two vortices merge earlier near 40%c (baseline 60%)

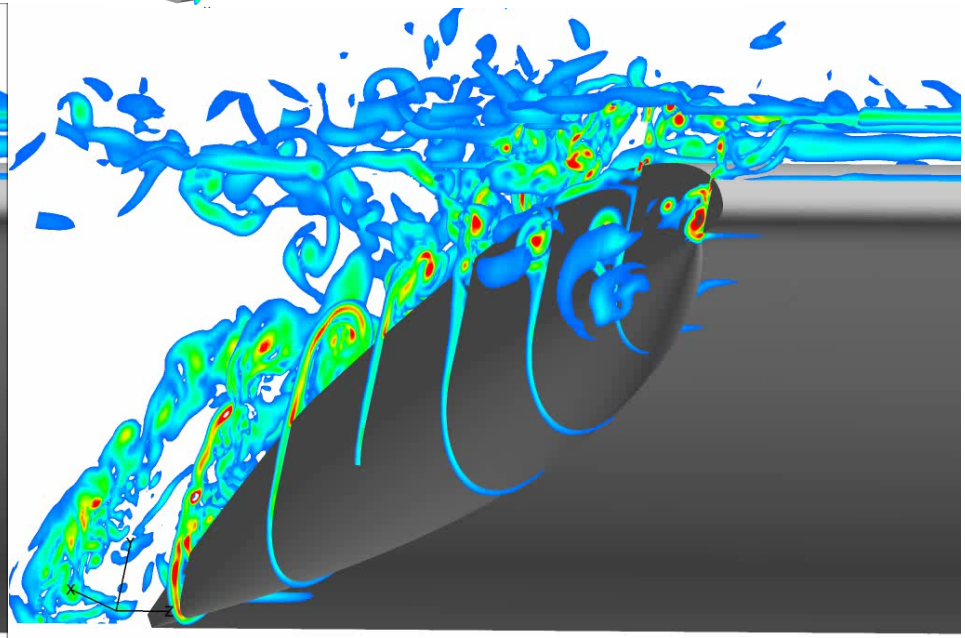
Averaged

Unsteady







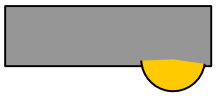


View from lower-side

LowerRound

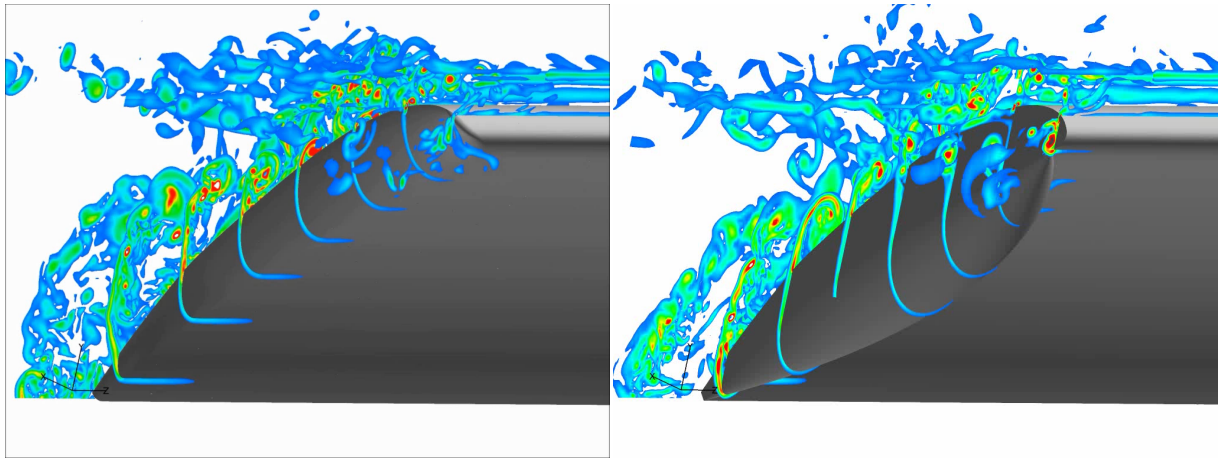


A Protruding device



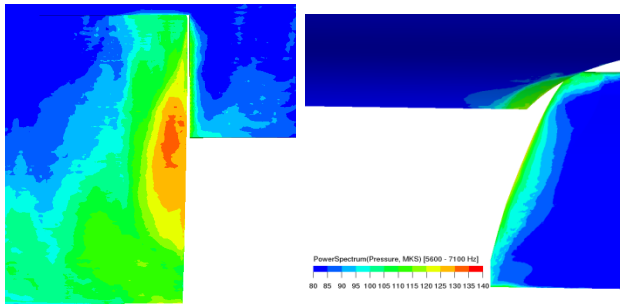
Comparison of high pressure fluctuation region

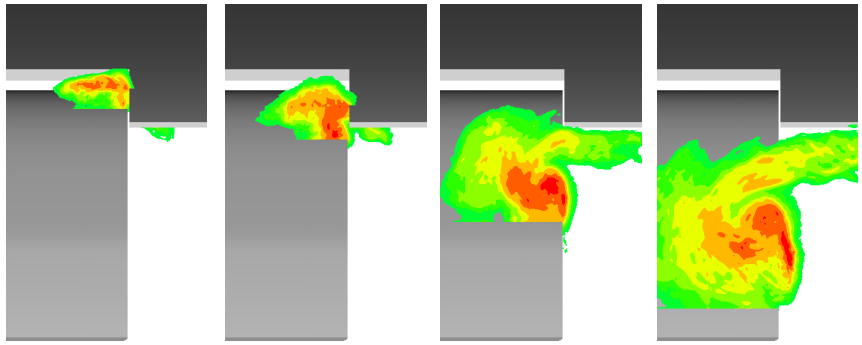
- High level found around side-vortex path, but much lower than that of baseline
- Decrease of high area around 5%-25% by weakened upper vortex



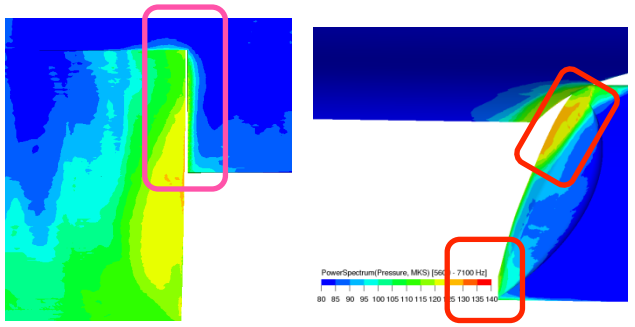
5.6kHz-7.1kHz

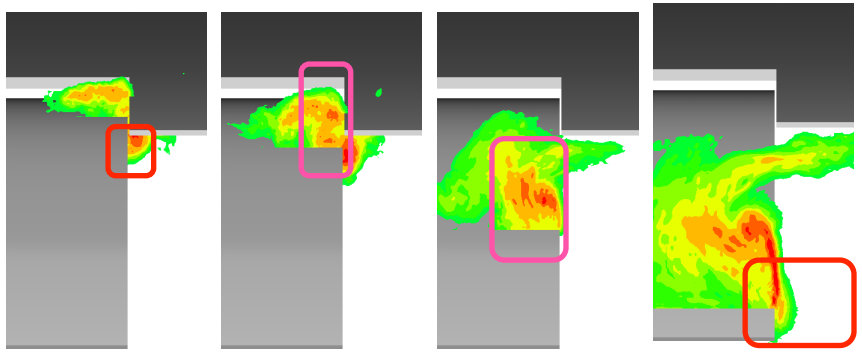
LowerRound



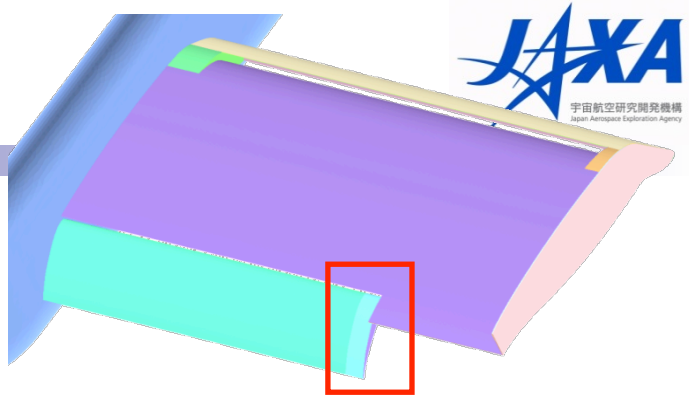


Protruding Device

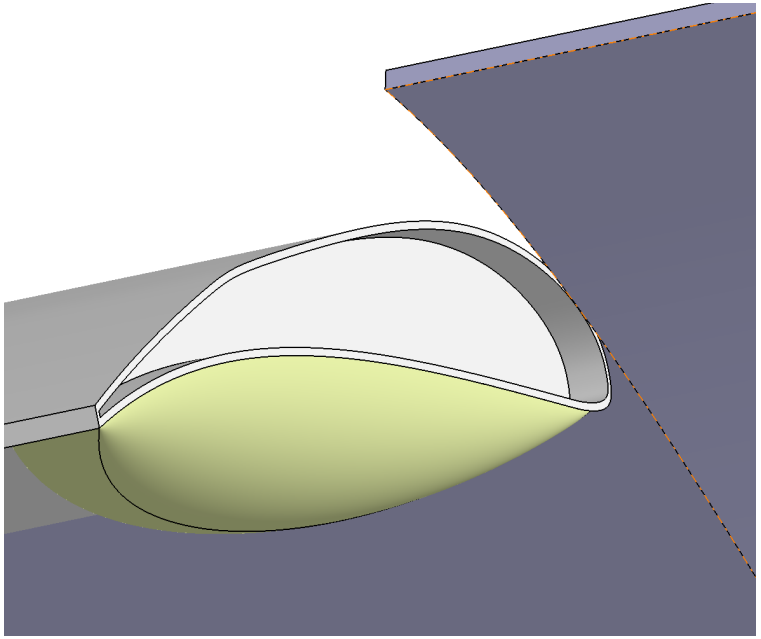




Results



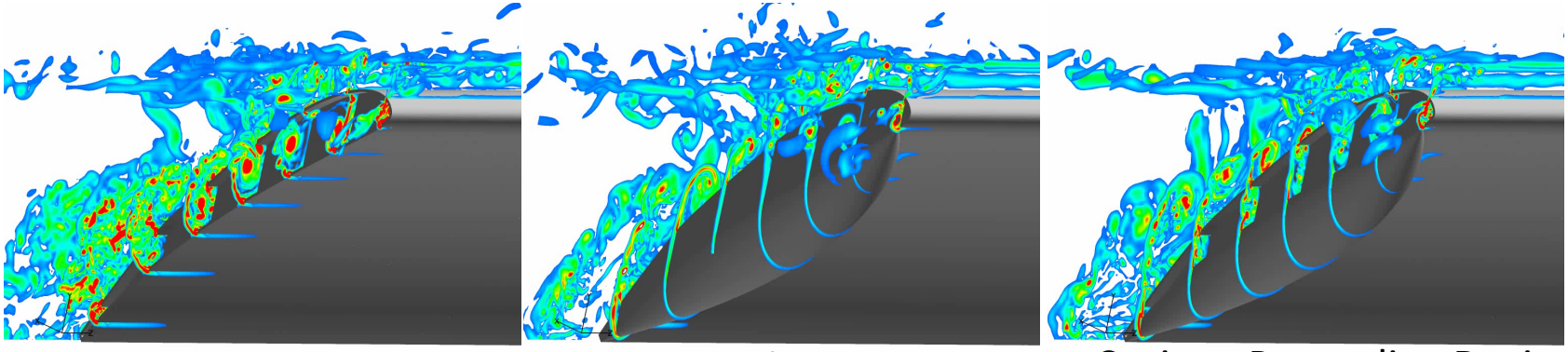
- Protruding Device flap side-edge “with a cavity”



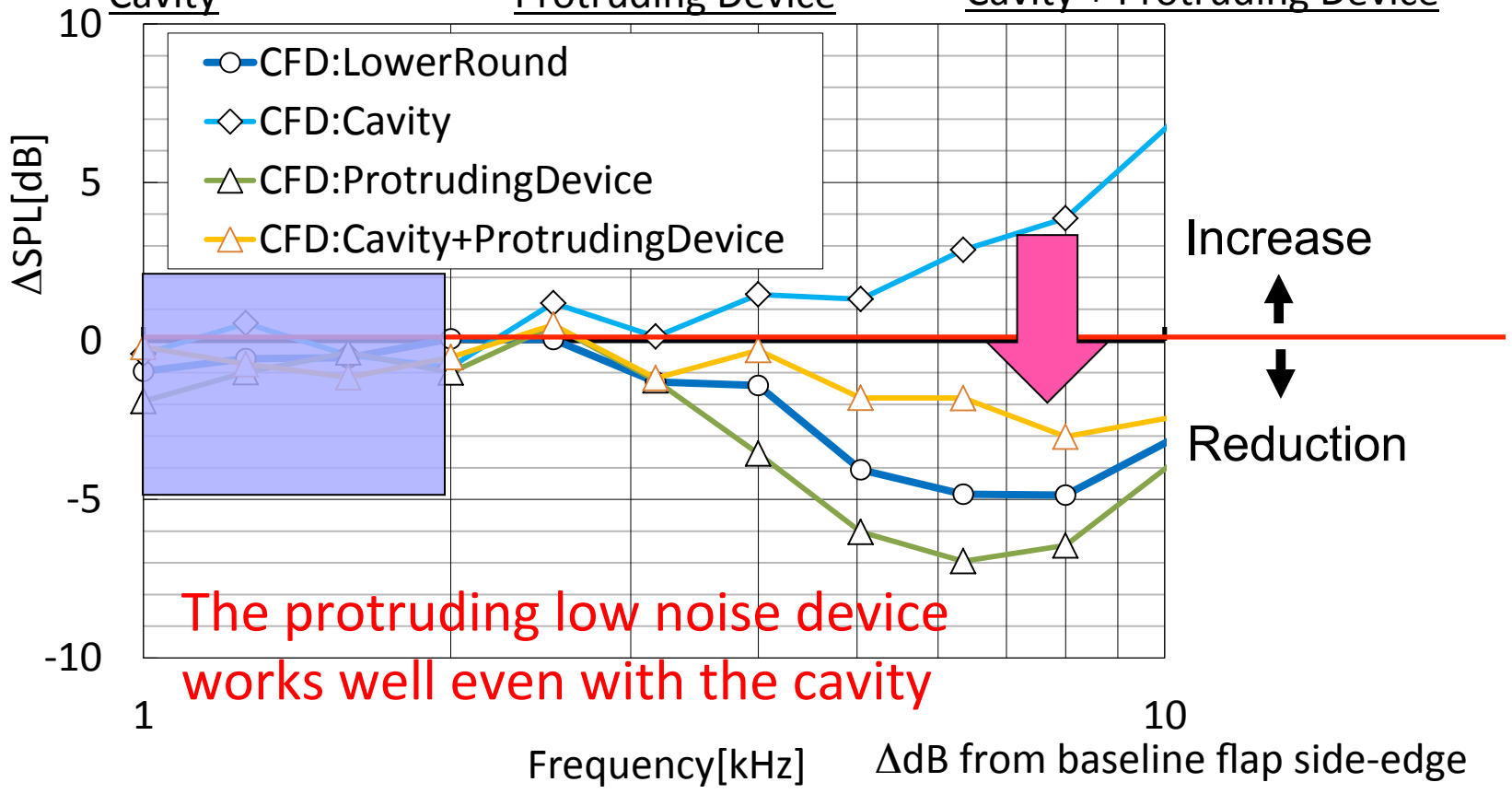
Cavity + Protruding device



Noise reduction effect by protruding device



Cavity | Protruding Device | Cavity + Protruding Device



The protruding low noise device works well even with the cavity

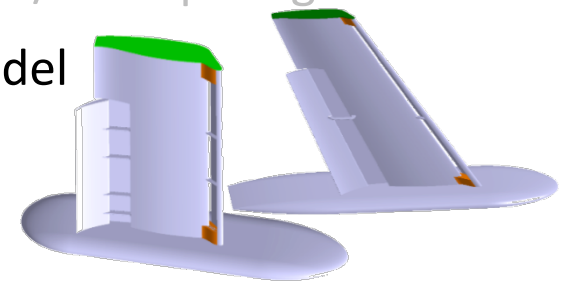
What is obtained from OTOMO model ?

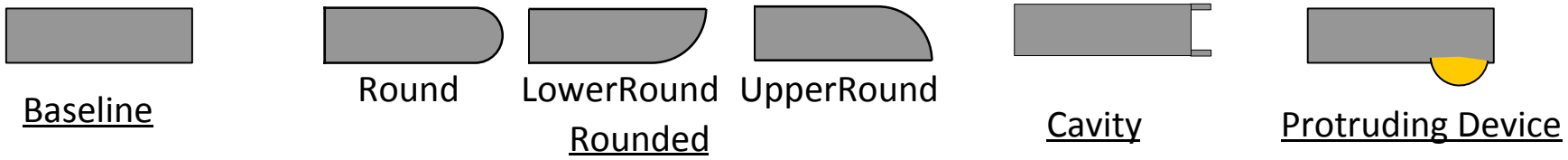
- Change of far-field noise level was shown
  - UpperRound > Cavity > Baseline > Round > LowerRound
- Noise generation and reduction mechanisms of several selected flap side-edge shapes were clarified by the numerical simulation with wind tunnel test
- A protruding device flap side-edge was proposed
  - Similar noise reduction mechanism with “LowerRound”
    - To weaken side-vortex rolled-up from lower flap side-edge
    - Compatible even with the cavity flap side-edge

Baseline > Round > LowerRound **>= Protruding Device**

Outline

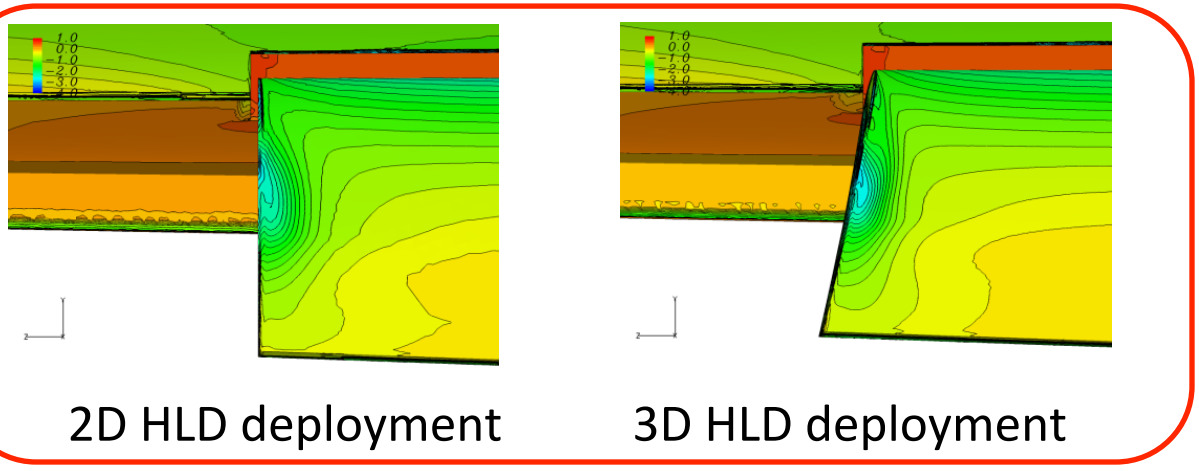
- Introduction
  - Importance of airframe noise reduction
  - JAXA FQUROH project
- Investigation on airframe noise due to flap side edge and its reduction
  - Background and objectives
    - Investigation of flow fields and far-field noise by flap side-edge shape
  - Investigation using simplified high-lift wing model w/o swept angle
  - Investigation using more realistic high-lift wing model
- Concluding Remarks





What is next step?

- Improvements to predict and reduce airframe noise from actual aircrafts
  - Influences of the omitted parameters and load distribution on noise generation mechanisms and effectiveness of low noise concepts
    - Will spanwise flow due to swept angle change characteristics of slat noise?
    - How will detail parts such as slat tracks and cavities of actual aircrafts affect?
    - Will flap deployment in 3D change the noise characteristics?
    - Will the low-noise concepts be effective for realistic model?

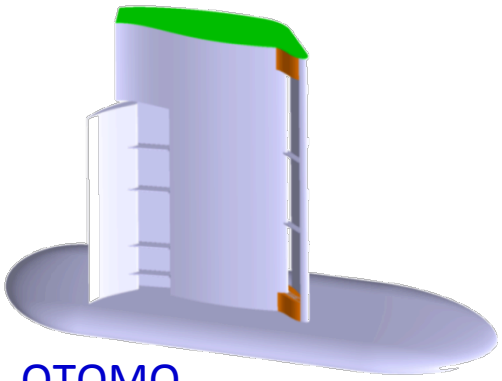


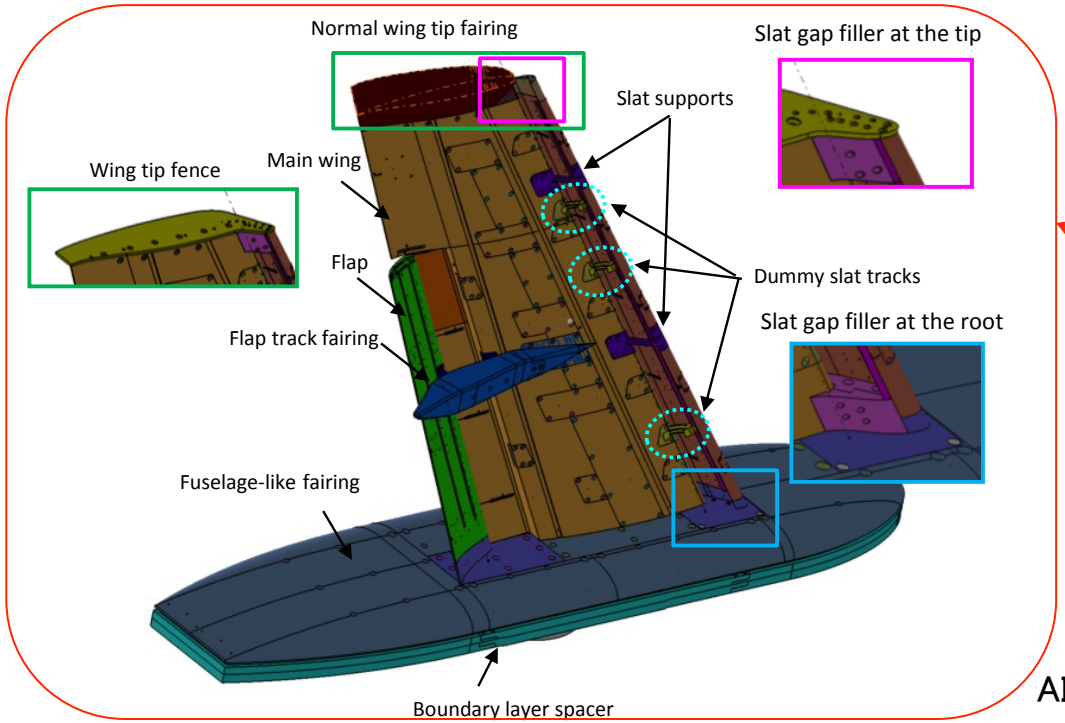
2D HLD deployment　　3D HLD deployment

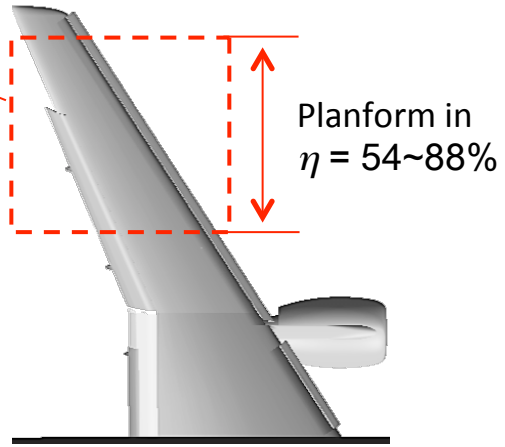
Comparison by difference of HLD deployment methods

High-lift swept and tapered wing model “OTOMO2”

- Outer wing of a reference 100-passenger class civil aircraft
- Full-span slat (δ_{slat}=25°) and a part-span single-slotted flap (δ_{flap}=30°)
- Geometry: 24% scale of the assumed aircraft
  - Chord length: 0.57m, wing half-span: 1.2m
  - Taper ratio: 0.65, L.E. swept angle 33°



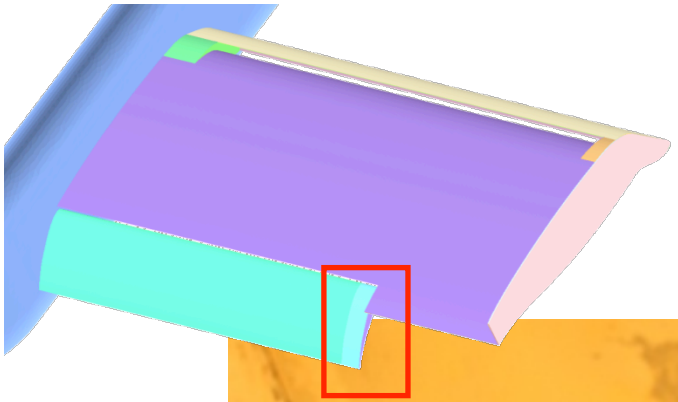


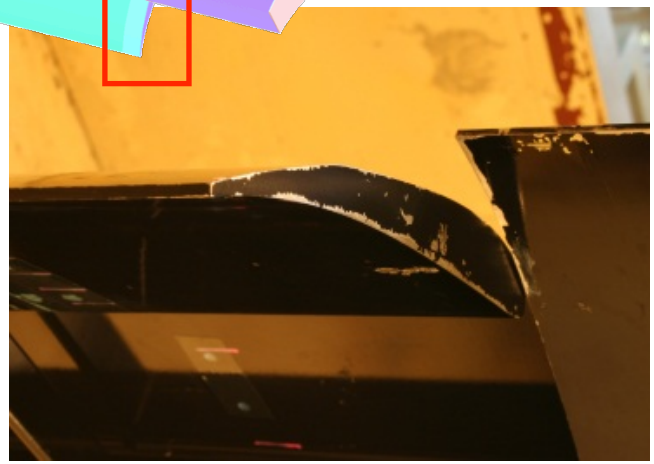


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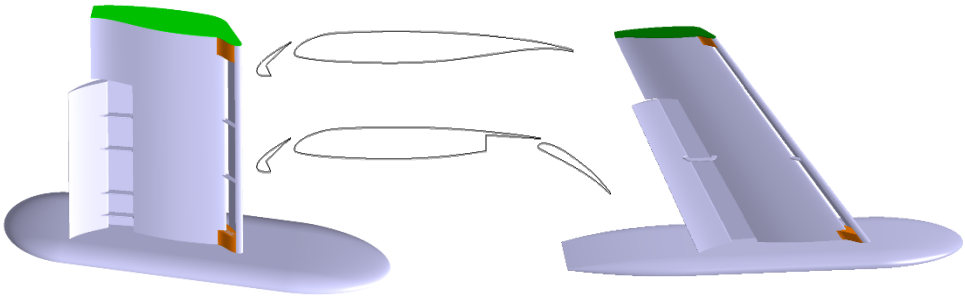
Objective of flap noise investigation by OTOMO2

- Qualitative comparison for discussion of differences of flowfields between the models w/ and w/o taper-ratio and swept angle by CFD



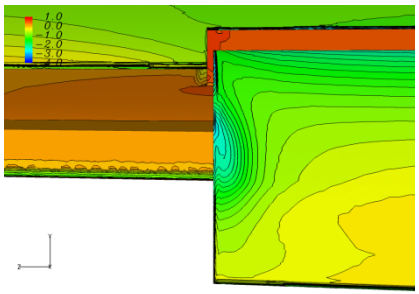


Baseline bluff flap side-edge

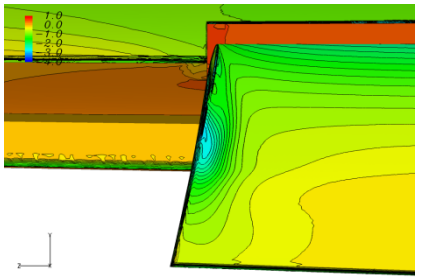


OTOMO

OTOMO2



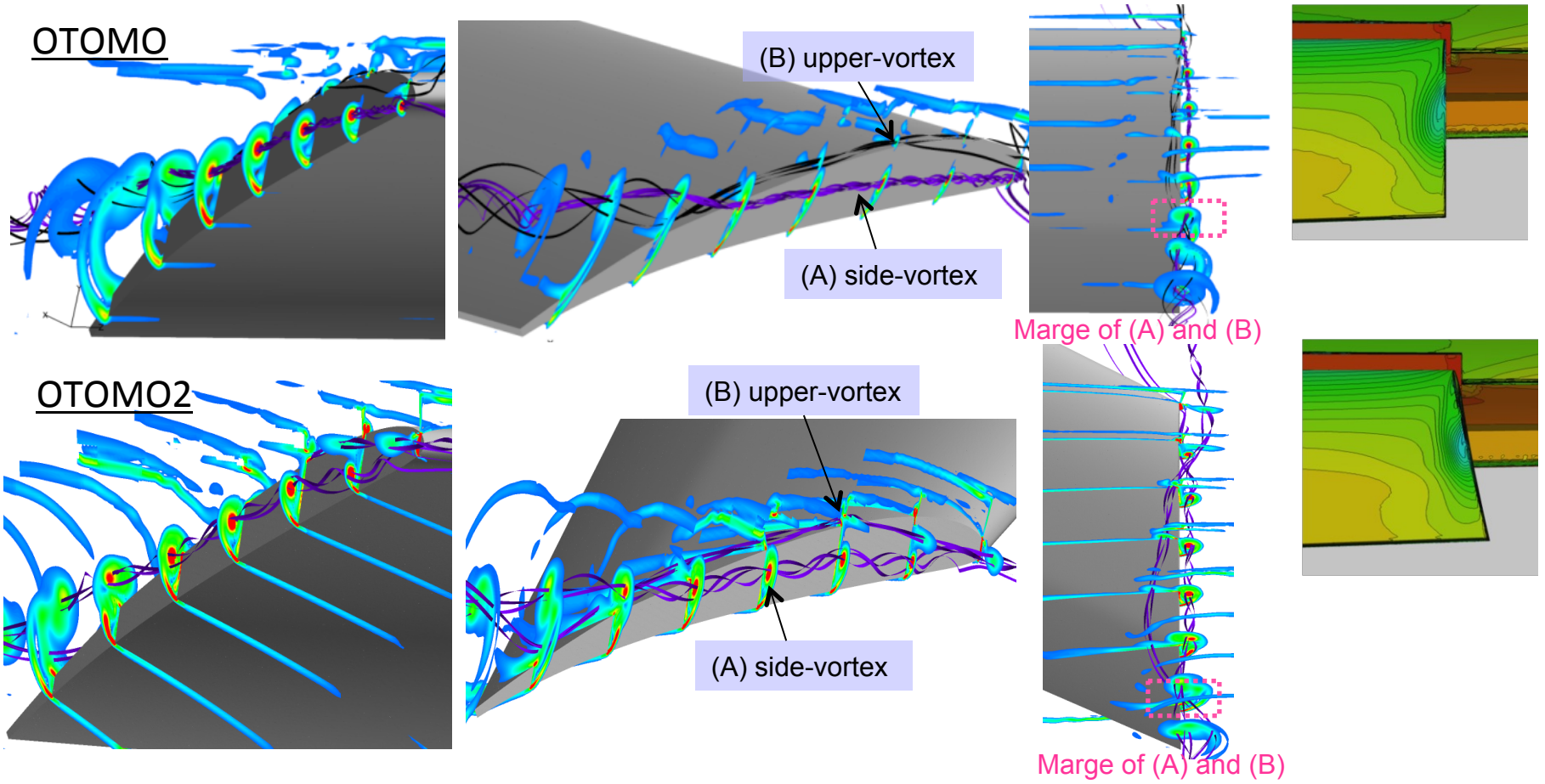
2D HLD deployment



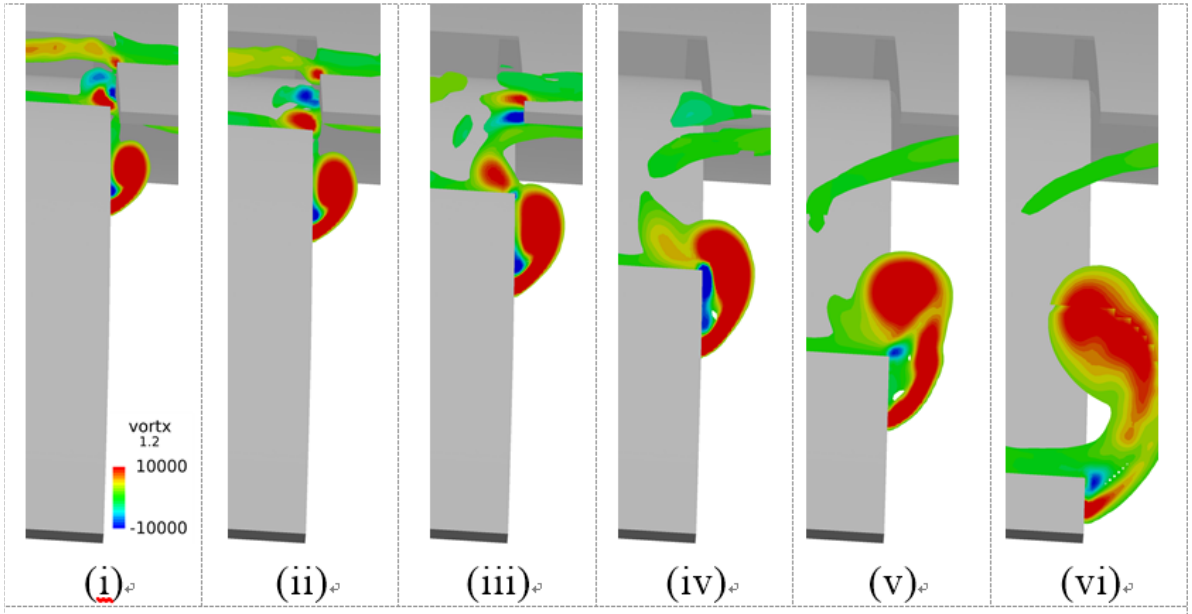
3D HLD deployment

Comparison between OTOMO/OTOMO2: Vorticity

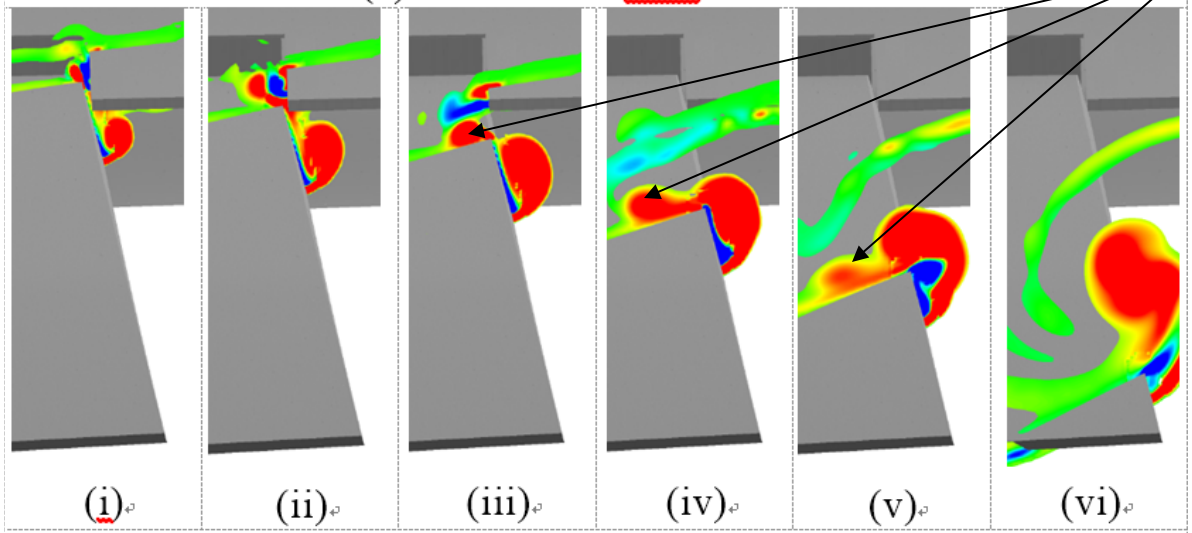
- Major differences between OTOMO/OTOMO2
  - Path of (B): Further inboard on the upper surface of flap due to flap deployment in an oblique direction (OTOMO2)
  - Merging location: 60% flap-chord for OTOMO, 75% flap-chord for OTOMO2



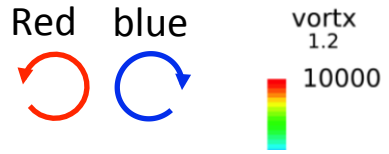
Comparison between OTOMO/OTOMO2: X-dir Vorticity



(a) OTOMO at $AoA = 10.0°$



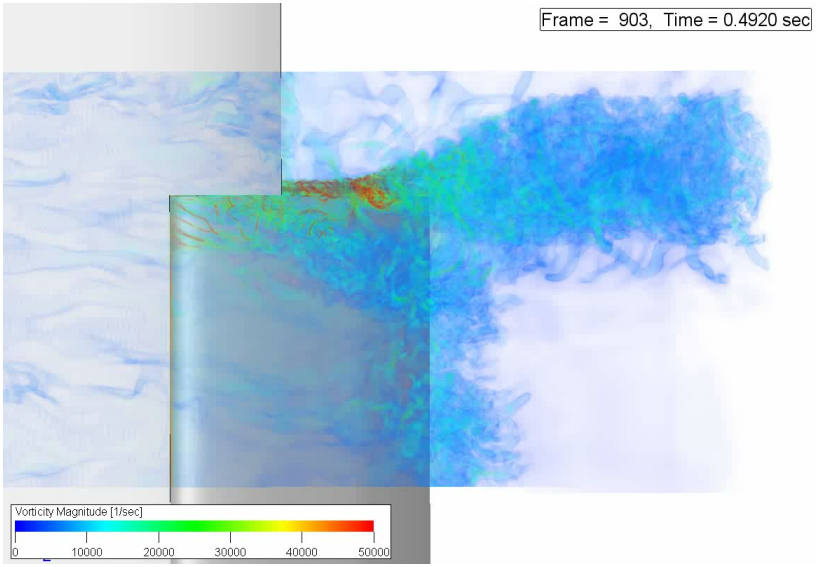
(b) OTOMO2 at $AoA = 8.0°$.

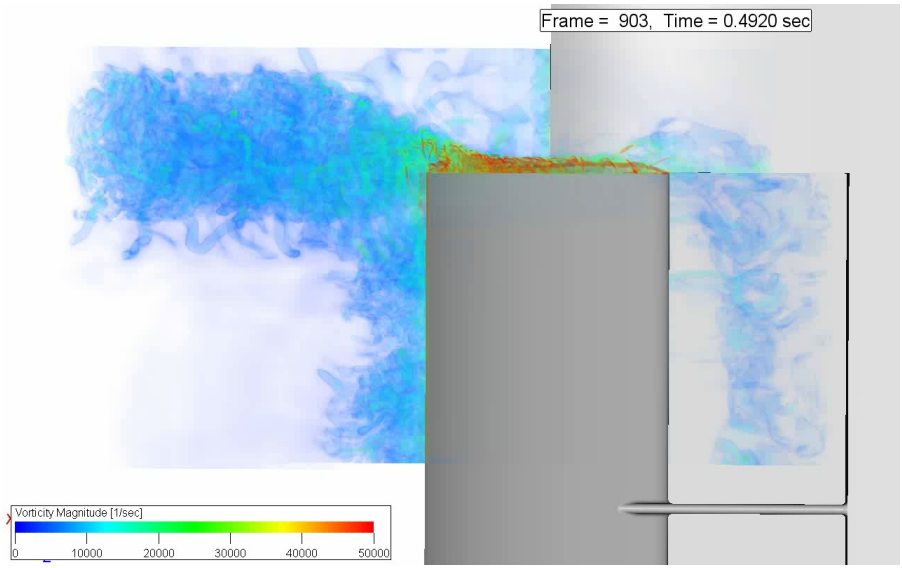


- Stronger upper vortex
- Located further inboard
- Delay of the merging point of two vortices

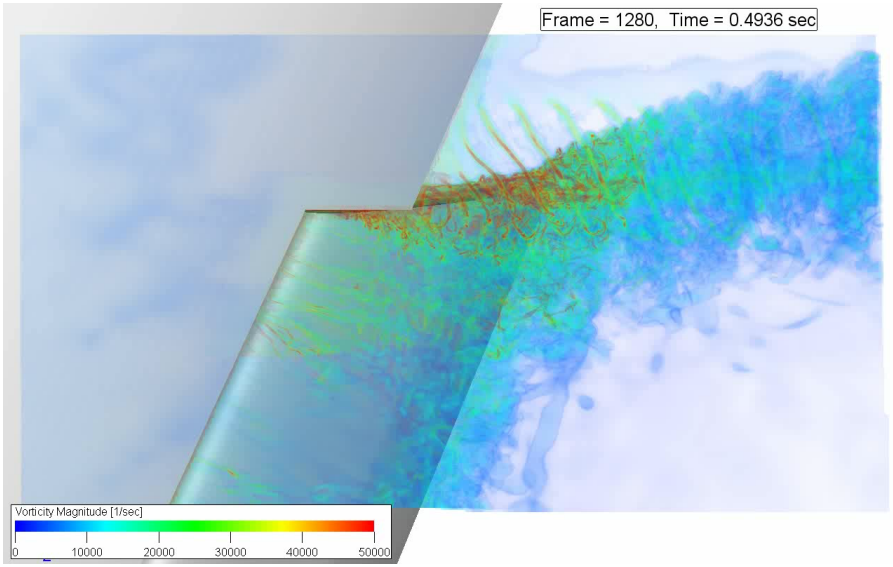
Comparison between OTOMO/OTOMO2: Vorticity

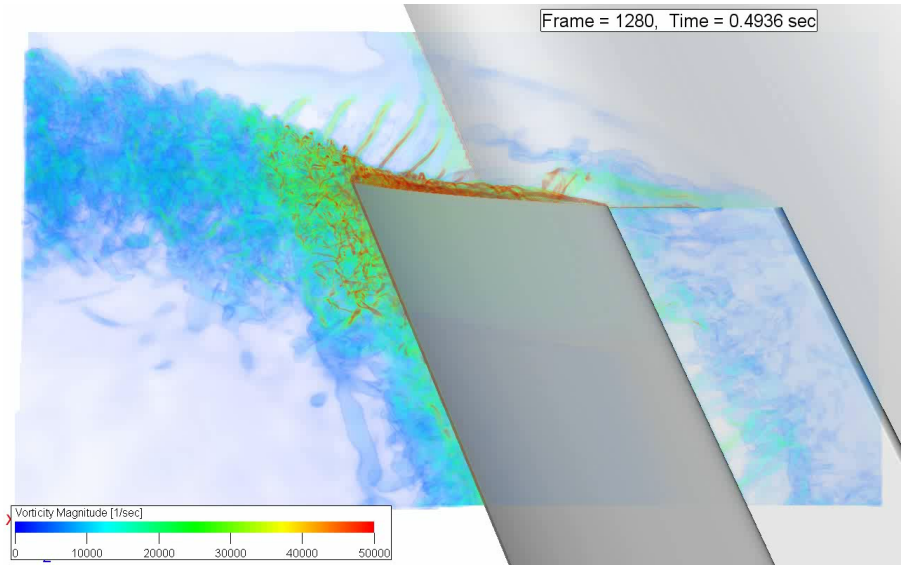
OTOMO



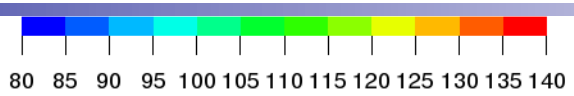


OTOMO2

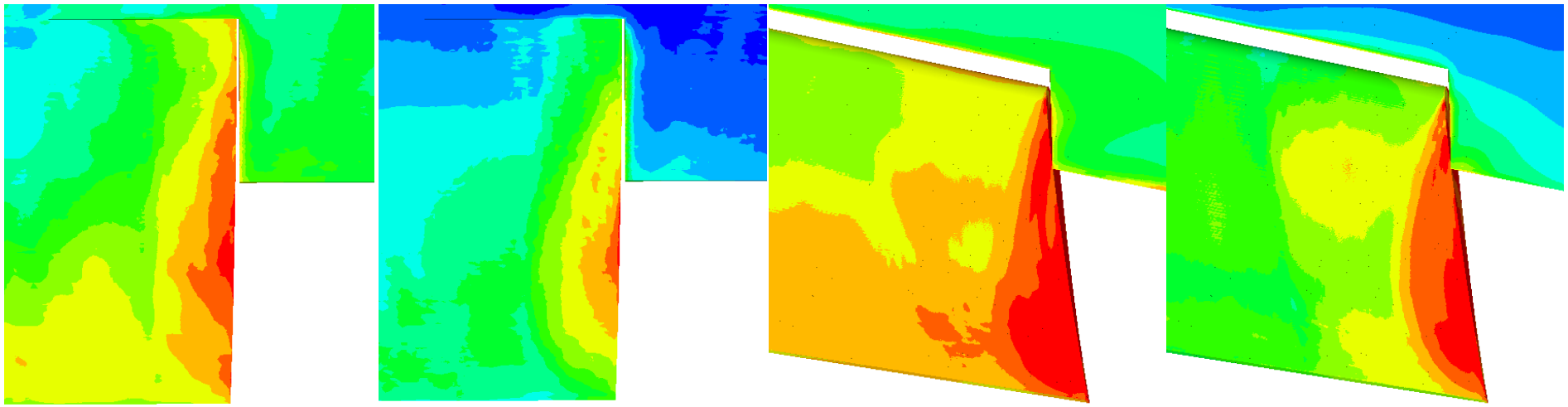




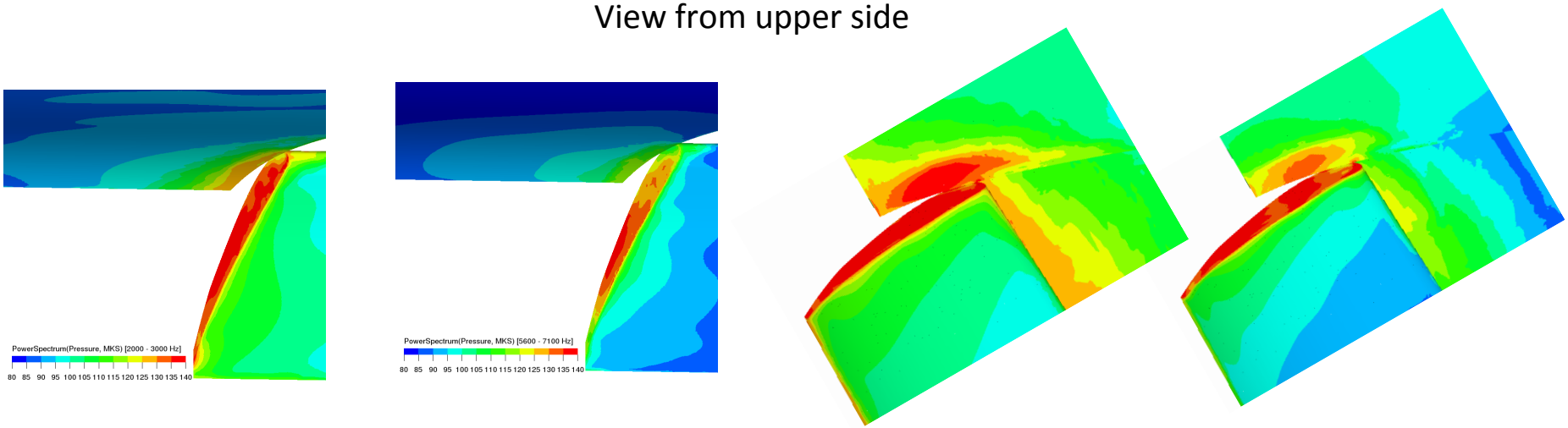
Comparison between OTOMO/OTOMO2: Surface dB



1.4kHz-2.8kHz | 5.7kHz-11.3kHz | 1.4kHz-2.8kHz | 5.7kHz-11.3kHz



View from upper side

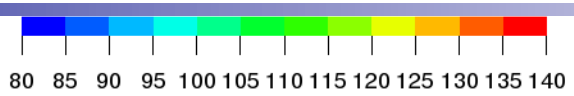


View from lower side

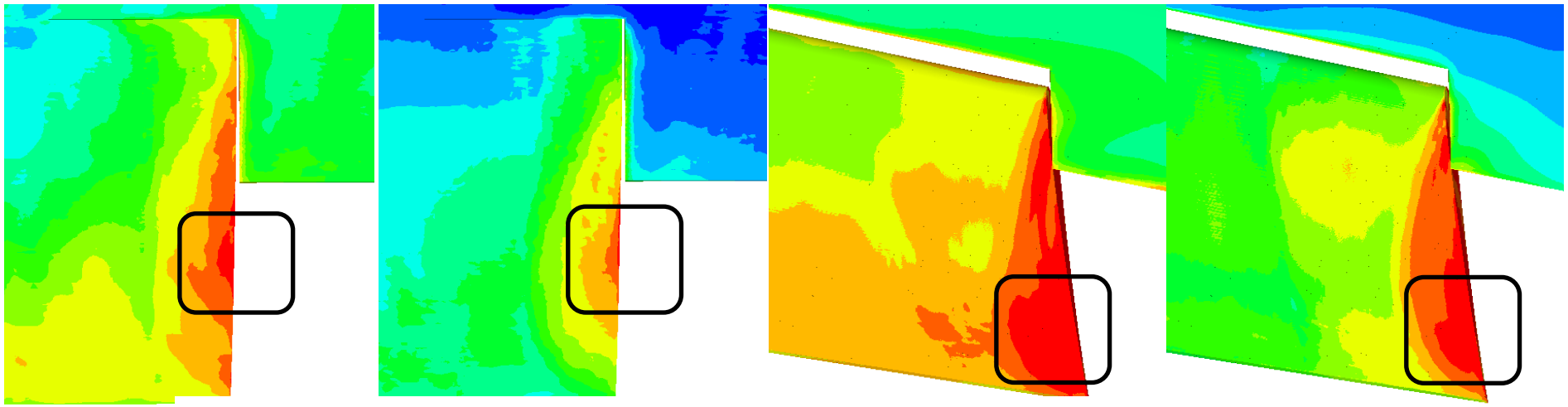
OTOMO

OTOMO2

Comparison between OTOMO/OTOMO2: Surface dB

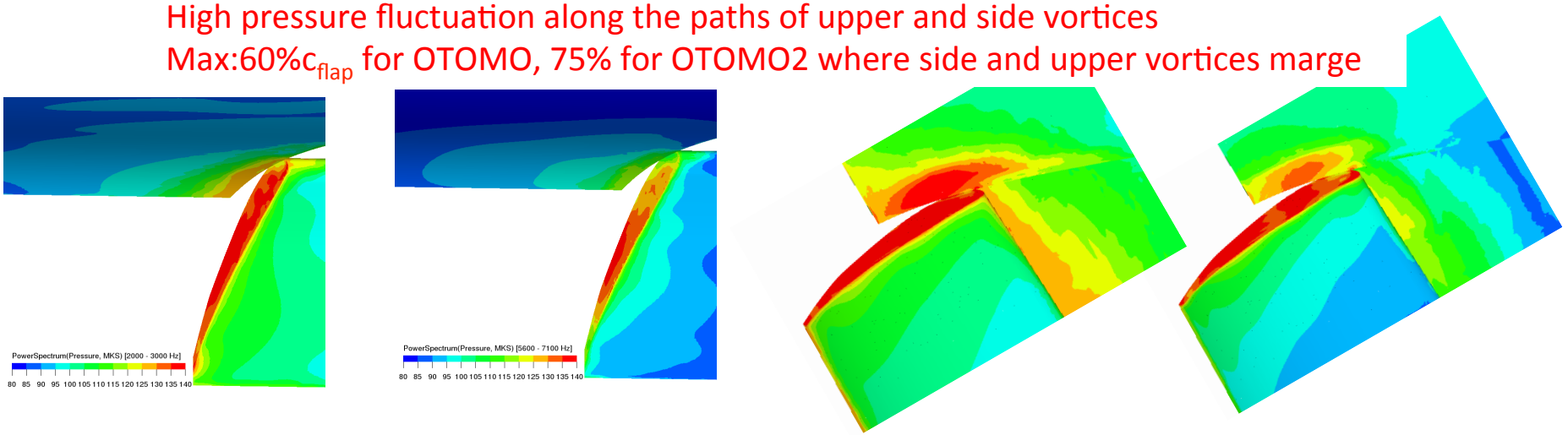


1.4kHz-2.8kHz | 5.7kHz-11.3kHz | 1.4kHz-2.8kHz | 5.7kHz-11.3kHz



High pressure fluctuation along the paths of upper and side vortices

Max:60%c_{flap} for OTOMO, 75% for OTOMO2 where side and upper vortices marge

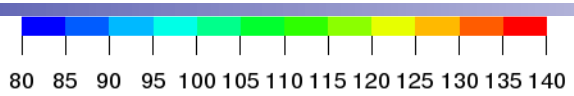


View from lower side

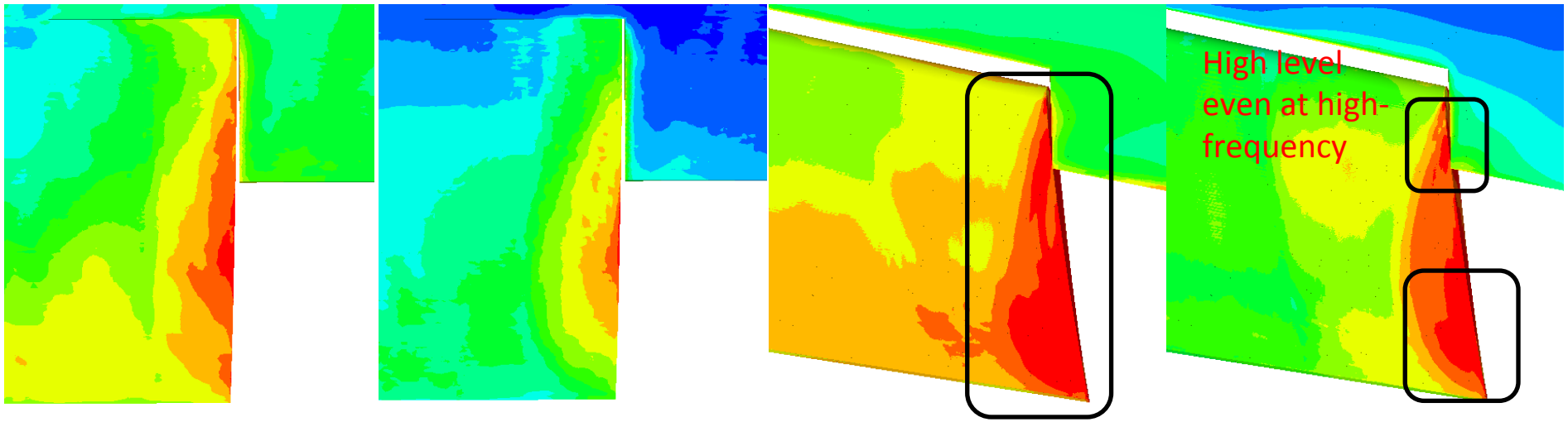
OTOMO

OTOMO2

Comparison between OTOMO/OTOMO2: Surface dB

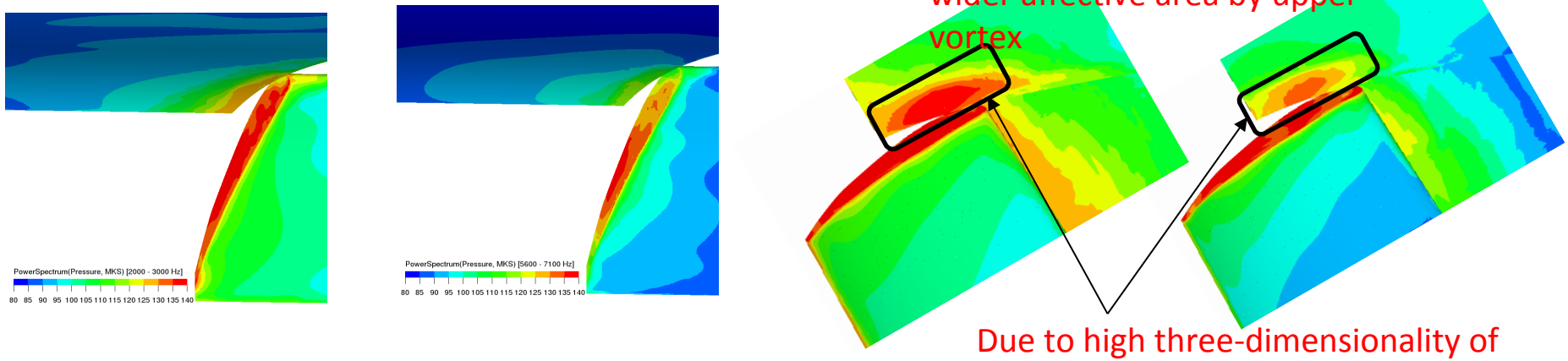


1.4kHz-2.8kHz | 5.7kHz-11.3kHz | 1.4kHz-2.8kHz | 5.7kHz-11.3kHz



View from upper side

Larger pressure fluctuation and wider affective area by upper vortex



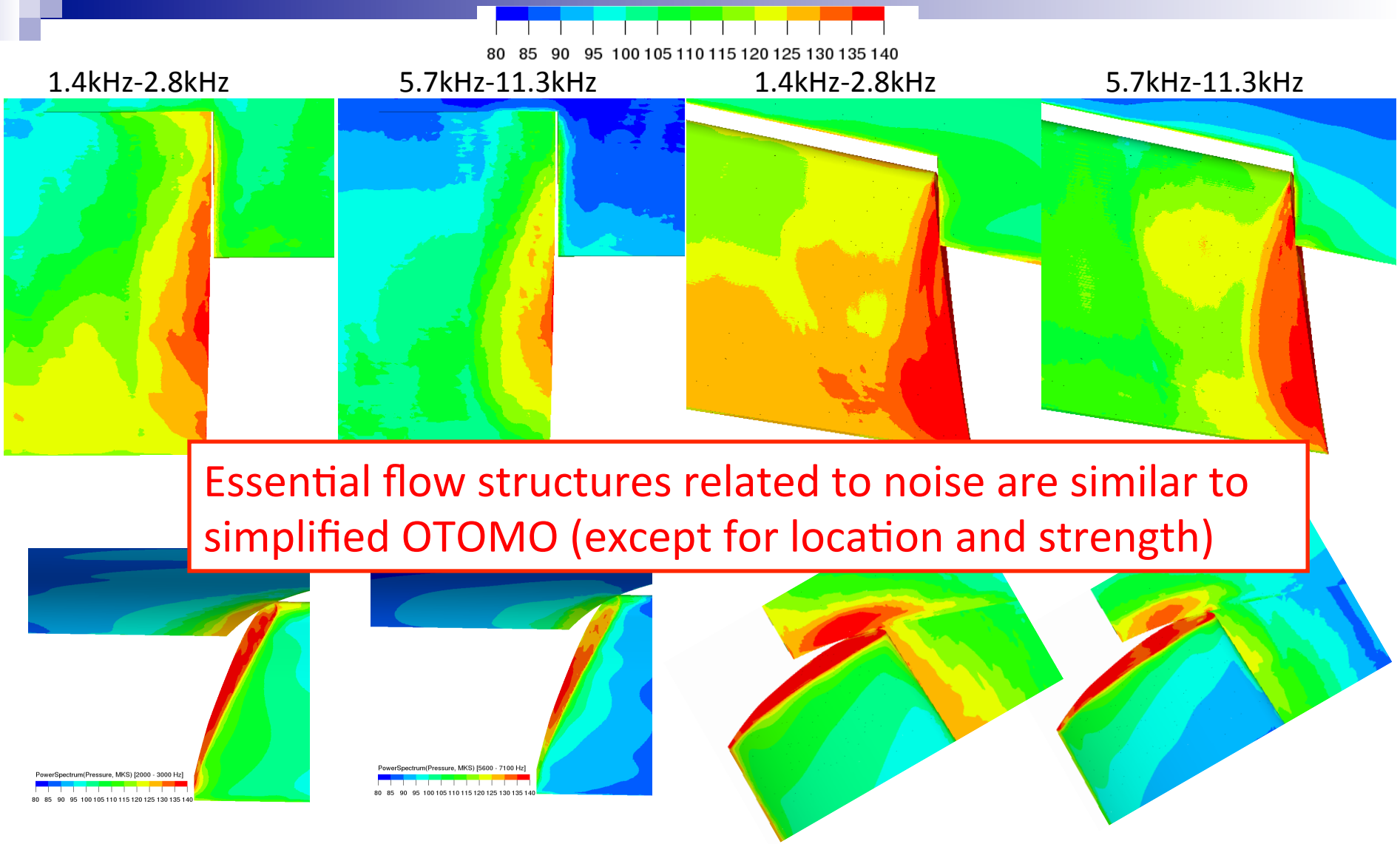
View from lower side

Due to high three-dimensionality of the flow in the cove of main wing

OTOMO

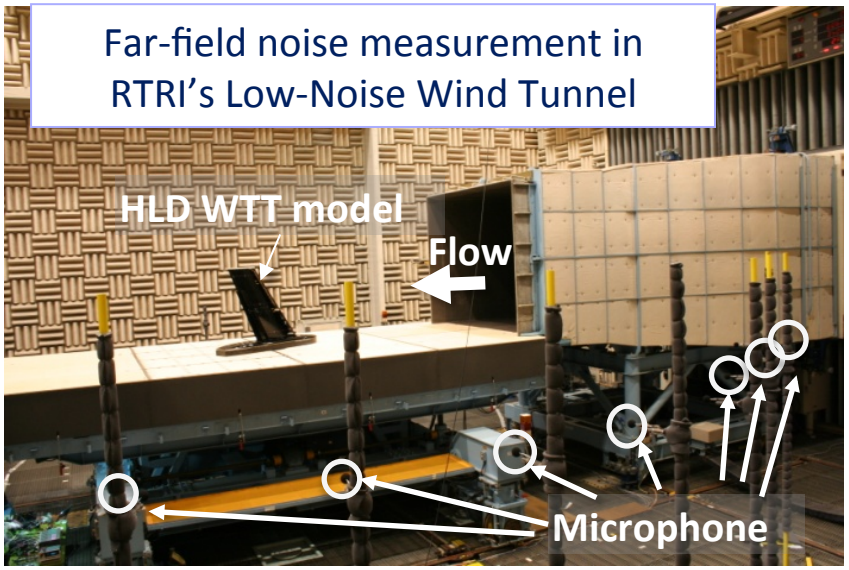
OTOMO2

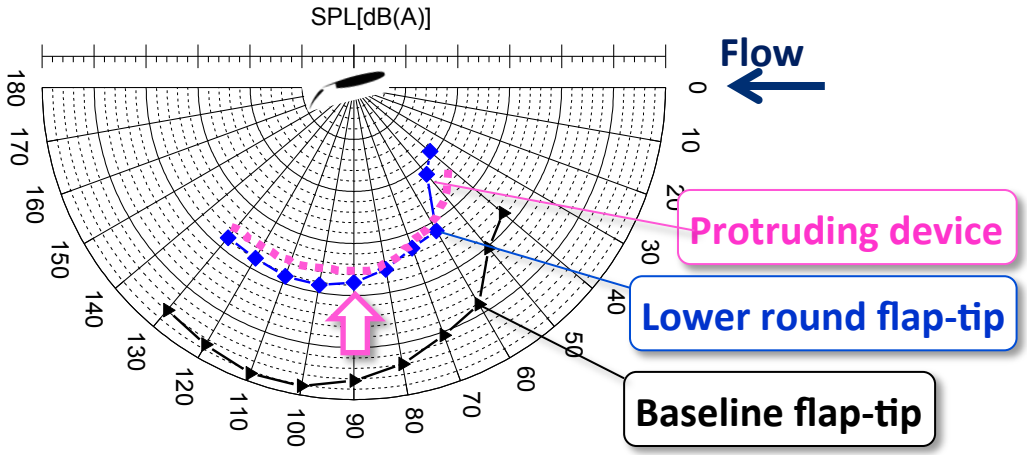
Comparison between OTOMO/OTOMO2: Surface dB

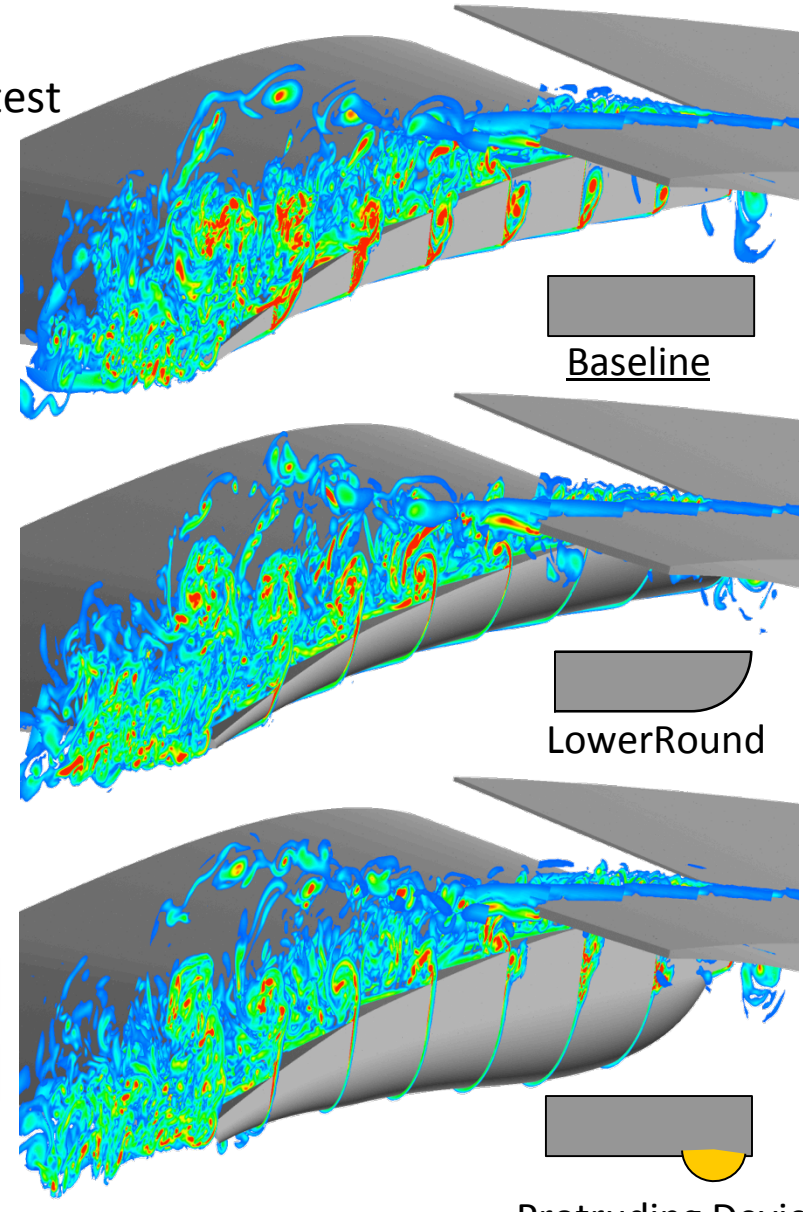


Device design for swept model OTOMO2

The device concepts were applied to OTOMO2 and confirmed to be effective by CFD and wind tunnel test

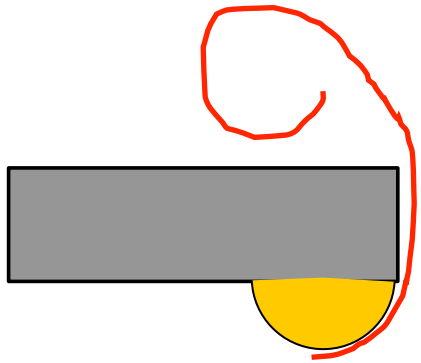






Question: Drag penalty at cruise condition?

How about drag penalty with additional device at cruise conditions?

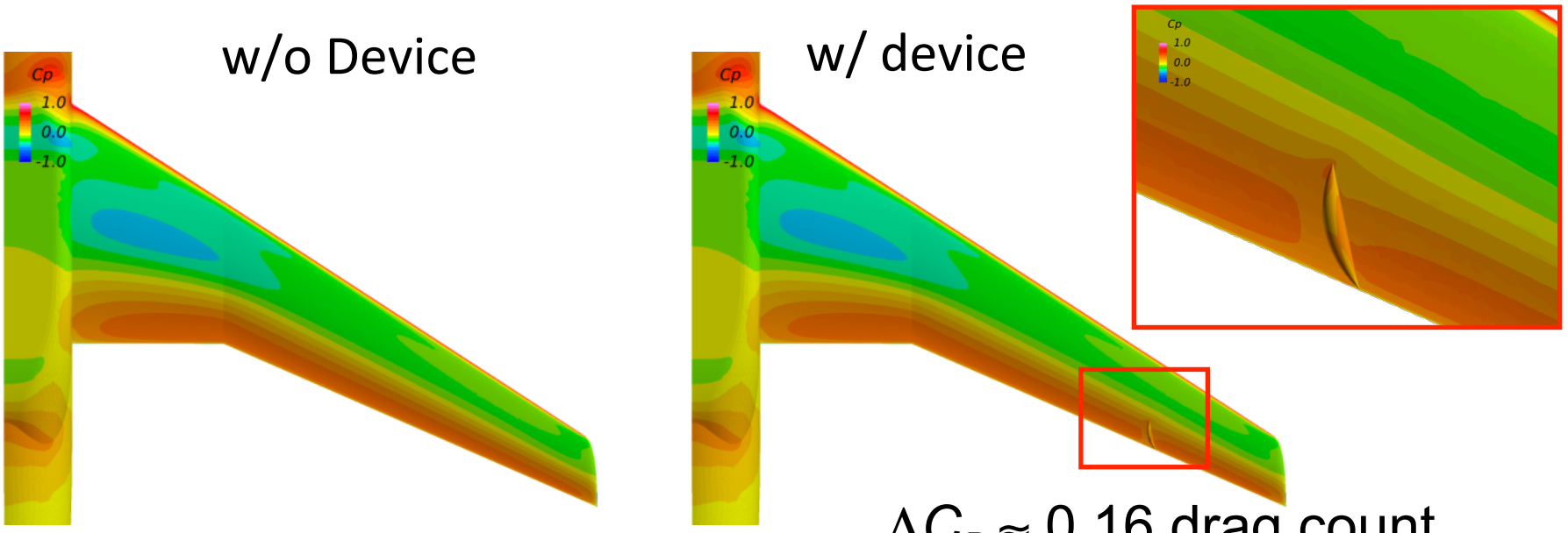


Protruding Device

Additional type device to original flap

Evaluation drag penalty at cruise condition

- Drag penalties at cruise conditions were evaluated by CFD when they were applied to a realistic JAXA aircraft research model, JSM



$\Delta C_D \approx 0.16$ drag count
(1 drag count = 0.0001)

Cp on lower surface@Mach = 0.8, CL = 0.48

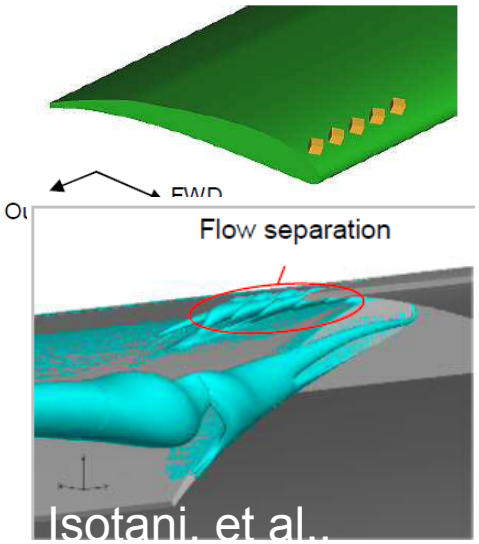
Concluding Remarks

- Noise generation and reduction mechanisms of selected flap side-edge shapes have been clarified by the numerical simulation with wind tunnel test
- Computational investigations on the unsteady flow field greatly aided the understanding of the noise generation mechanisms and help low noise design

- Currently, CFD/CAA for airframe noise prediction is still qualitatively used and still needs synergistic combination of CFD and WTT. Efforts to improve CFD/CAA with solving the following difficulties will be needed to help further advance the design methodology.
  - Easy grid generation suitable for CAA for complicated configurations
  - Improvement of prediction accuracy and its validation and benchmarking

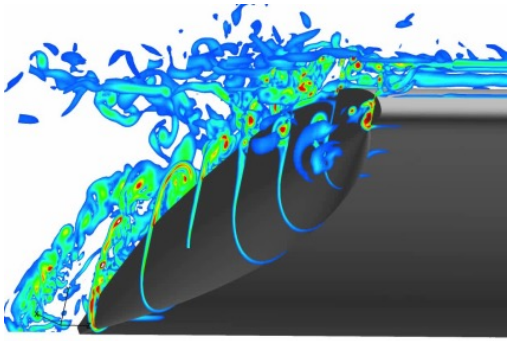
Current status of FQUROH Project

Several noise reduction concepts were designed suitable for JAXA's experimental aircraft (Cessna Citation Sovereign)

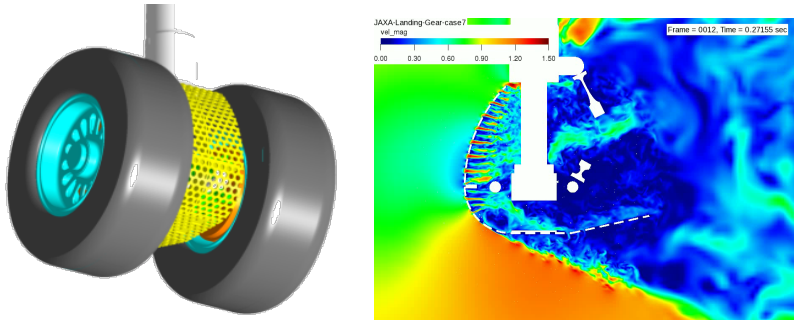


Isotani, et al.,
AIAA Paper 2013-2046





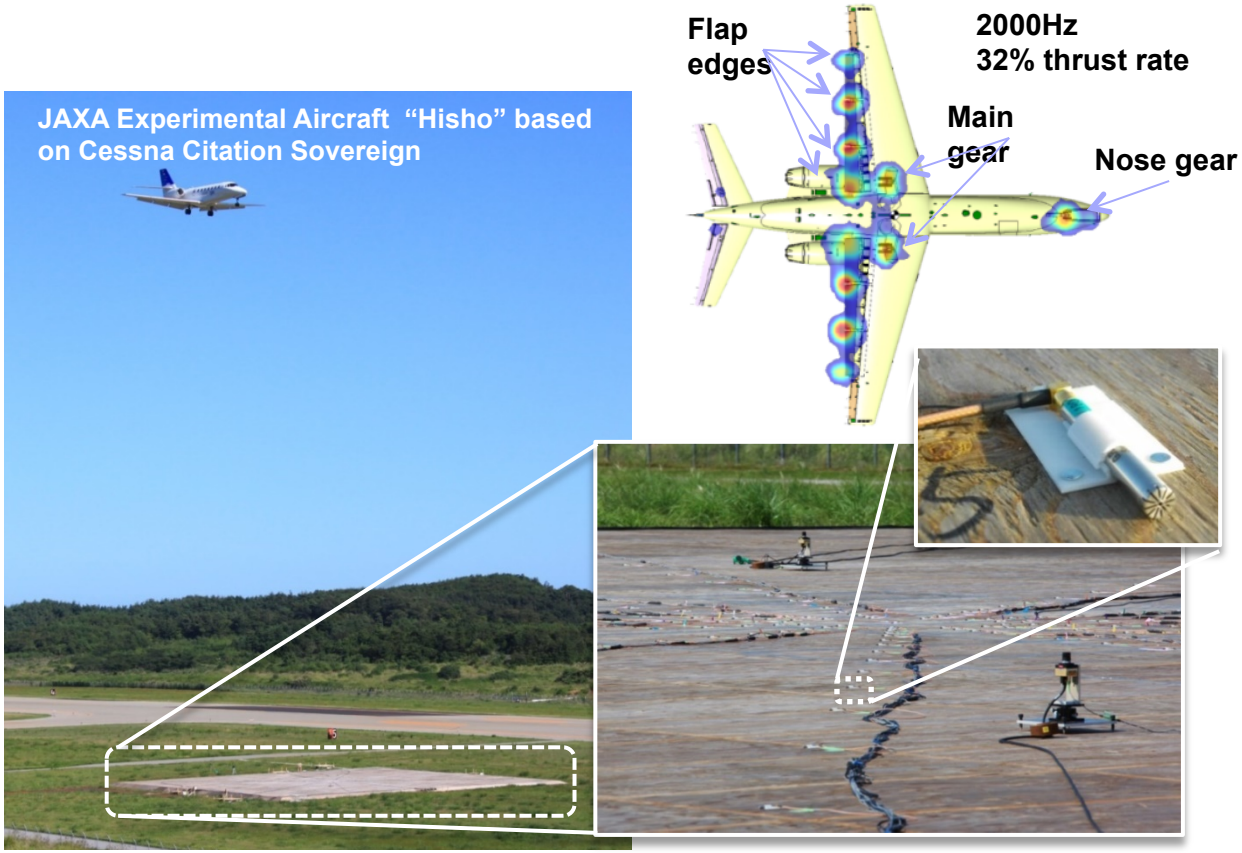
Murayama, et al.,
AIAA Paper 2013-2067



Murayama, et al., AIAA Paper 2012-2279

Current status of FQUROH Project

- Noise source measurements in fly-over test for the baseline configurations without devices were conducted in 2013 and 2015
  - To develop a phased array microphone system for capturing and localizing the noise sources of flying aircraft
- Flight tests for the modified low-noise “Hisho” are planned in 2016 and 2017



Vorticity distributions around flap

Noise level: UpperRound > Baseline > Round > LowerRound

