Drivers of Jet-flap interaction noise: The thrust vs. shear layer difference velocity experiment

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Motivation

- not fully known: velocity scaling parameter for two-phase / flight ops JFI problems
- Can we predict JFI noise using a simple engine velocity parameter? (maybe with focus on high frequencies, radical engine integrations)
  - exponent known
  - more than one suitable flow parameter candidate available

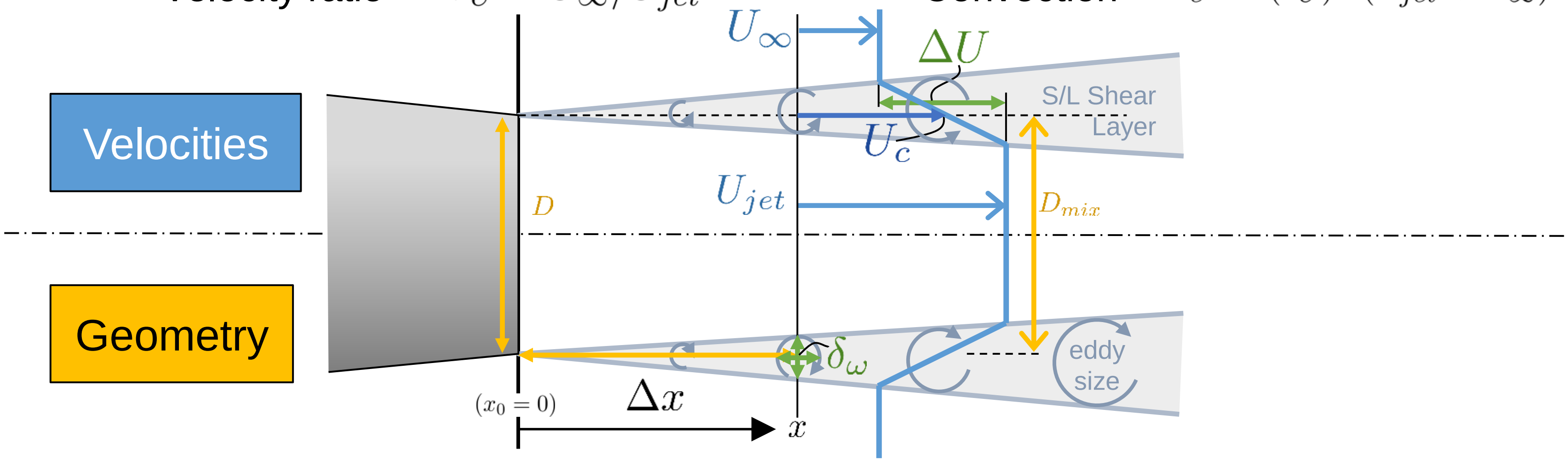
Definition of jet shear layer properties

Cold Jet / Co-flow

- Jet (Mean) Velocity U_{jet}
- Flight Velocity U_∞
- Velocity ratio $r_U = U_\infty / U_{jet}$

Shear Layer

- Difference $\Delta U = U_{jet} - U_\infty$
- Mean $\overline{U} = 1/2 \cdot (U_{jet} + U_\infty)$
- Convection $U_c = c(r_U) \cdot (U_{jet} + U_\infty)$



- Nozzle Diameter D
- Mixed Jet Diameter D_{mix}

Engine Nozzle

- Streamwise direction x
- S/L width δ_ω

Christian Jente and Jan Delfs. Velocity scaling of shear layer noise induced by cold jet flow with co-flowing flight stream. In 25th AIAA/CEAS Aeroacoustics Conference, Aeroacoustics Conferences. American Institute of Aeronautics and Astronautics, 2019. 2019-2496

DLR

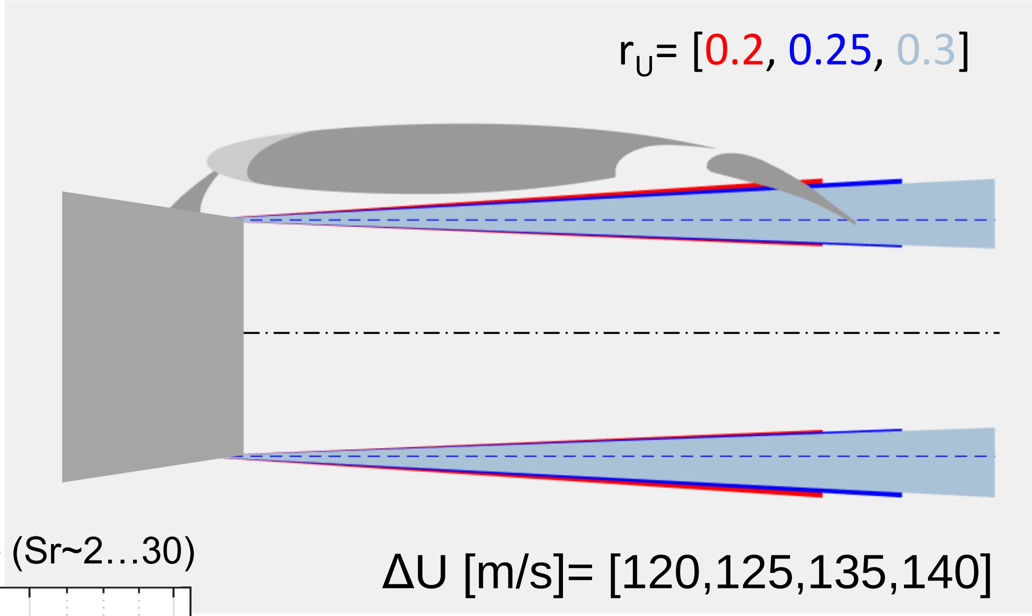
Definition of velocity parameters

- Velocity ratio $$r_U = \frac{U_\infty}{U_{jet}}$$
- Thrust $$F := \rho_j A_j \cdot U_j\left(U_j - U_\infty\right)$$
- Thrust „velocity“ $$U_{th} := \sqrt{\frac{F}{\rho_j A_j}} = \sqrt{U_j\left(U_j - U_\infty\right)} = U_j\sqrt{1 - r_U}$$
- S/L Difference velocity $$\Delta U := U_j - U_\infty = U_j(1 - r_U)$$
- Thrust-ΔU - relationship $$U_j = \frac{U_{th}}{\sqrt{1 - r_U}} = \frac{\Delta U}{(1 - r_U)}$$

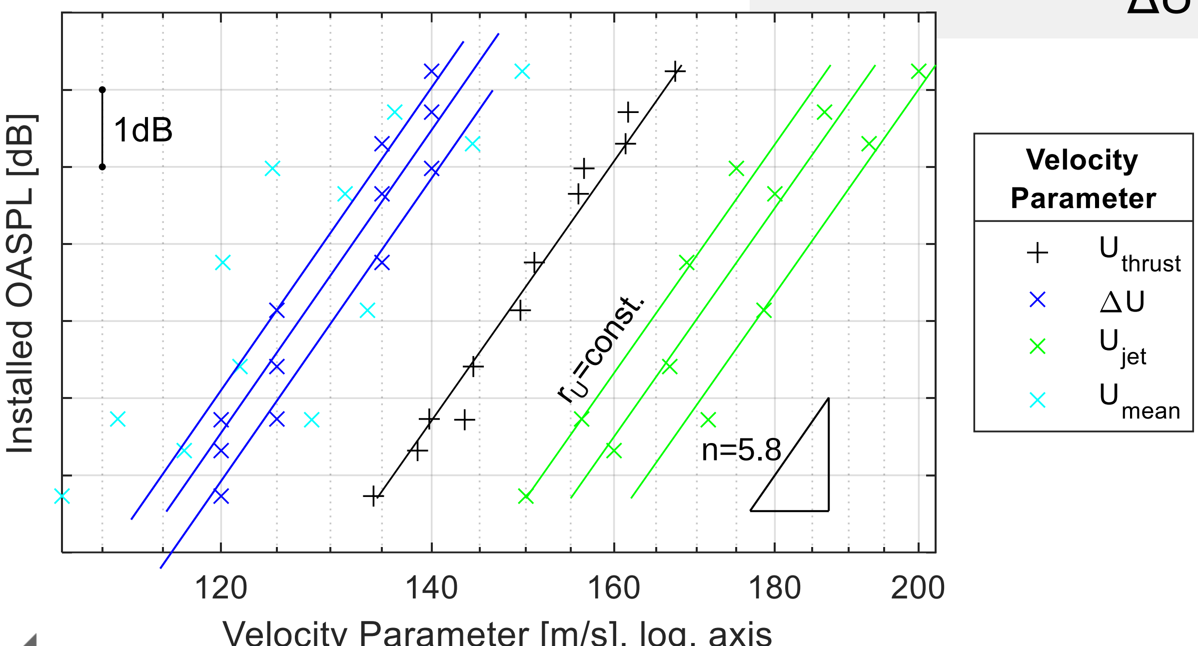
Assumptions inlet-to-outlet
no mass flow loss
no static pressure difference

Motivation

- Self-similar velocity profiles $r_U := U_f / U_j$



Velocity Scaling of high-frequent JFI-noise (Sr~2…30)



account this as preliminary

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Hypothesis 1: Assume thrust is scaling parameter

- thrust scales with n=5...6, same-thrust spectra collapse (no matter which ΔU)
  (or higher, n=6..7? Mahdi Azarpeyvand: “An overview of jet noise research at the University of Bristol”, DJINN Conference)

- What is the expected scaling difference for thrust (while keeping ΔU const!)?

$$U_{th}(\Delta U) = \sqrt{1 - r_U}\,\Delta U$$

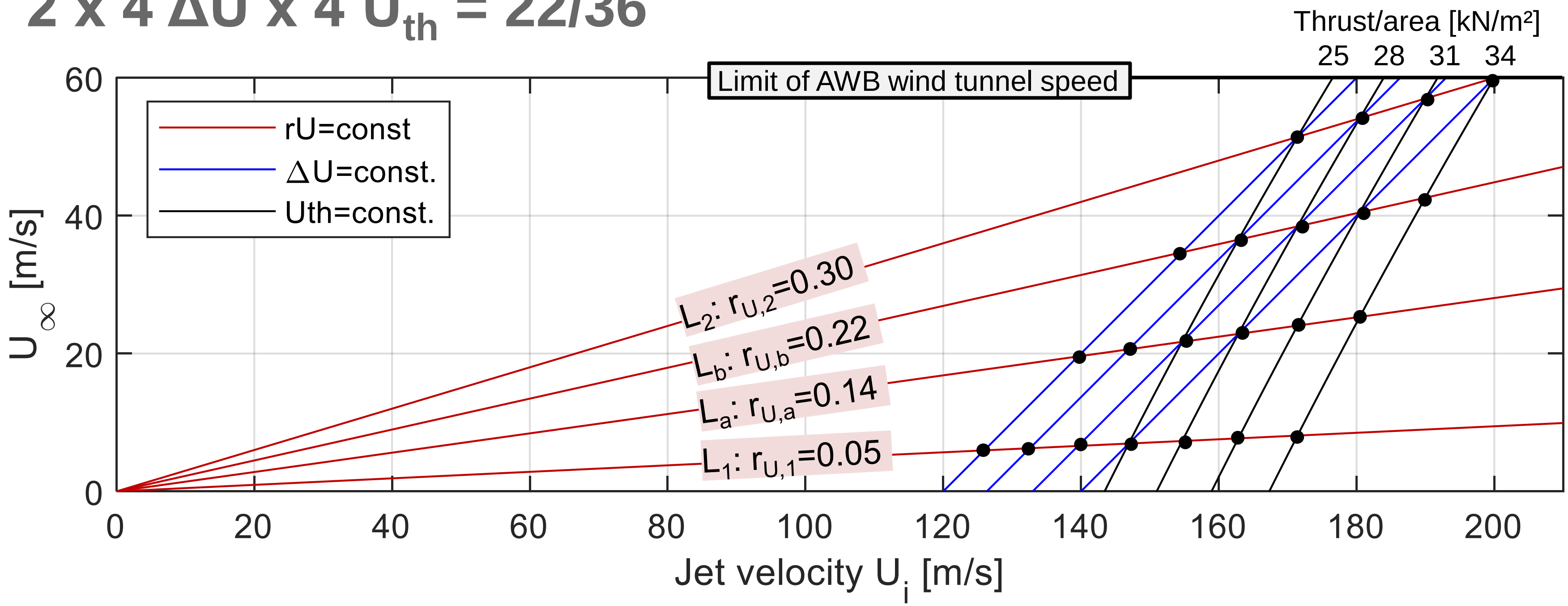
$$\Delta SPL_{Uth} = n \cdot 10 \cdot \lg\left(\frac{\sqrt{1 - r_{U1}}}{\sqrt{1 - r_{U2}}}\right) = 55\ \lg\left(\frac{\sqrt{1 - r_{U1}}}{\sqrt{1 - r_{U2}}}\right)$$

- AWB minimum r_{U1}=0.04…0.05 (quasi-static jet, closed-circuit wind tunnel)
- for max use r_{U2}=0.2 (good limit, high jet speed possible) — ΔSPL=2dB
- or maybe r_{U2}=0.3 (wind tunnel limit 60 m/s) — ΔSPL=3.6dB

Hypothesis 2: Assume ΔU is scaling parameter

- ΔU scales with n=5...6, same difference velocities collapse (no matter which thrust is used)
- Same scaling difference

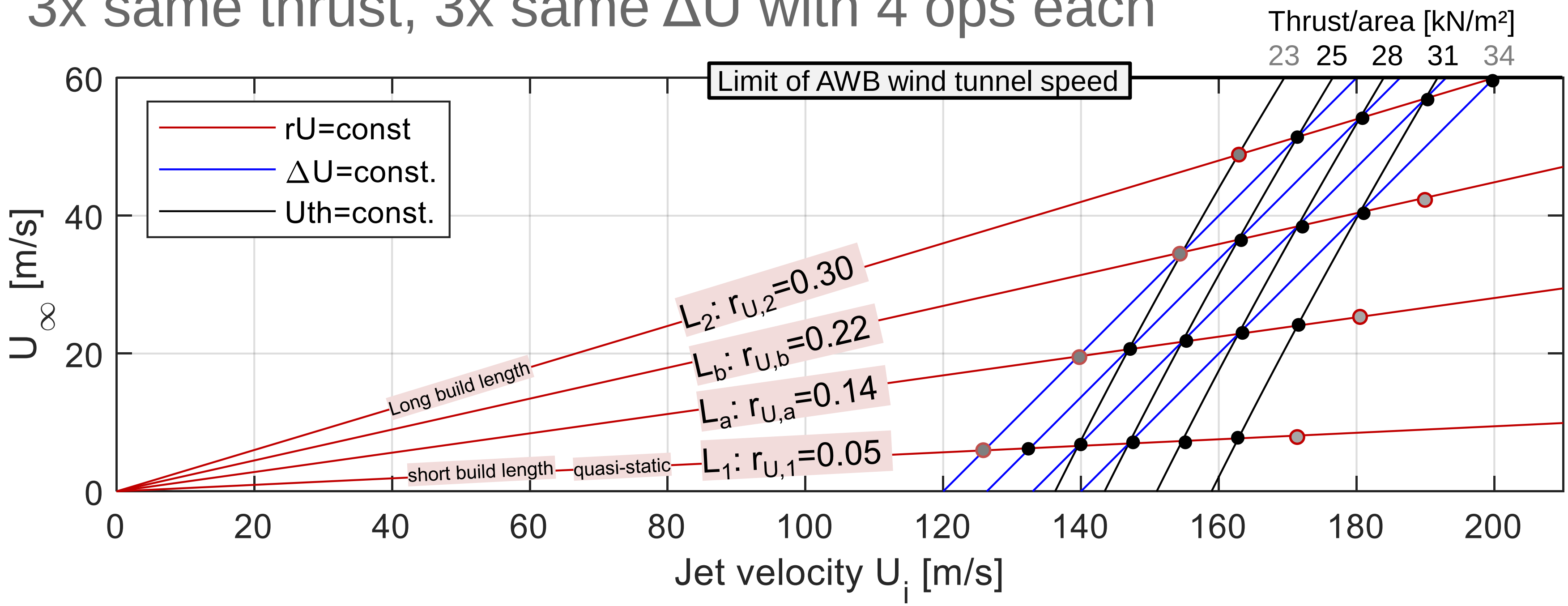
Definition of test operations
2 x 4 ΔU x 4 U_{th} = 22/36



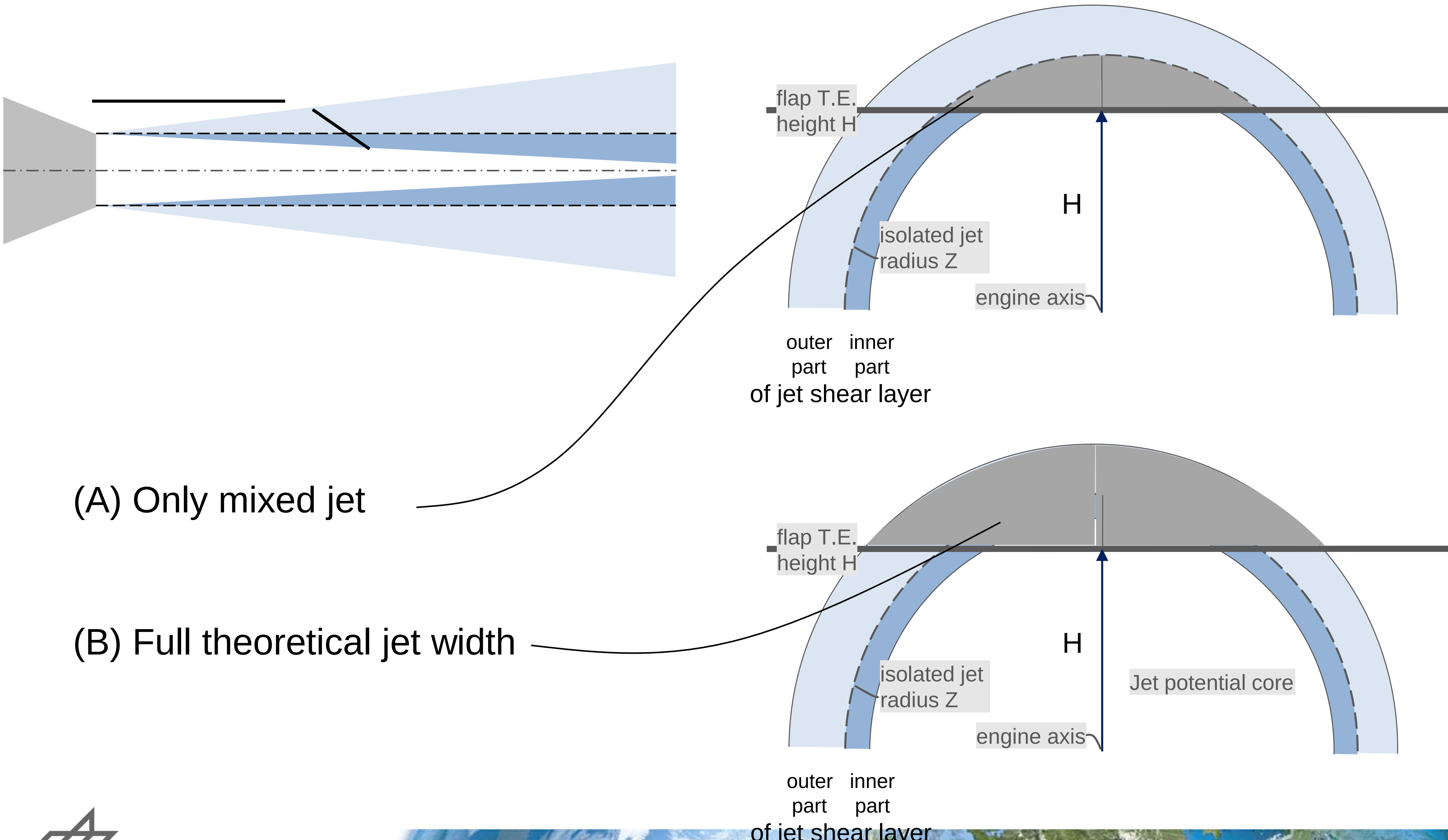
- For generation of general grid, can be optimized

Definition of test operations, optimized

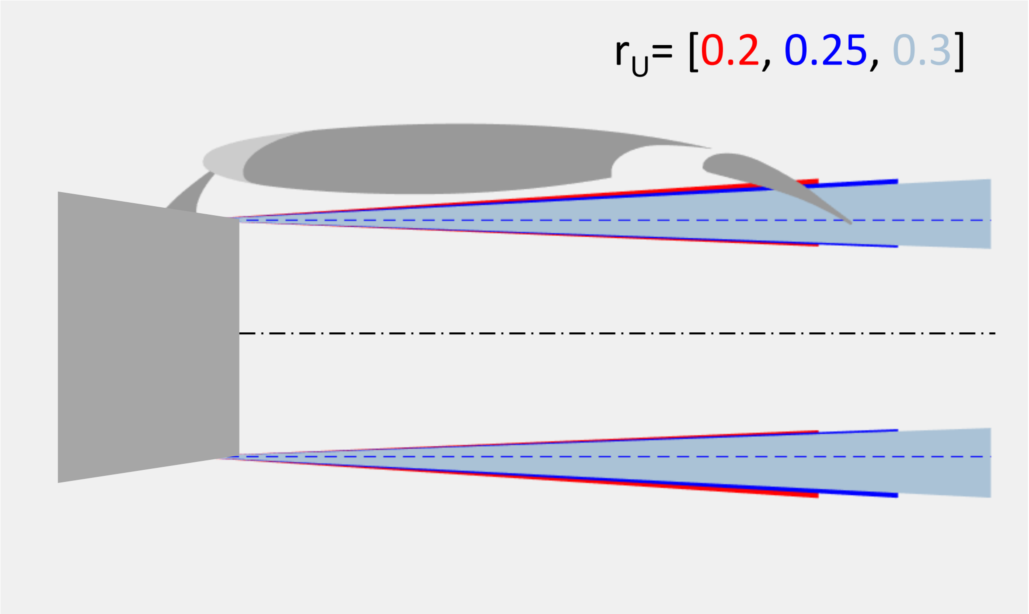
3x same thrust, 3x same ΔU with 4 ops each



Dependence on (theoretical) jet impingement areas



Calculation of length adjustment



$$\delta_\omega \propto (L - x_0) \cdot \frac{1 - r_U}{1 + r_U}$$

$$\frac{(L_2 - x_0)}{(L_1 - x_0)} = \frac{1 - r_{U1}}{1 + r_{U1}} \cdot \frac{1 + r_{U2}}{1 - r_{U2}} = 1.68$$

Results

Typical campaign

1 build/
16 Ops isolated

+

12 builds / 29x3 = 87 press. Ops installed + 87 BGN

	L1	La	Lb	L2
H1	5	4	16	4
H2	5	4	16	4
H3	5	4	16	4

- The derived experiment is tailored to force a definite result wrt. thrust or S/L velocity.
- Maybe there is no simple explanation, idea: downwash-velocities

Questions?

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