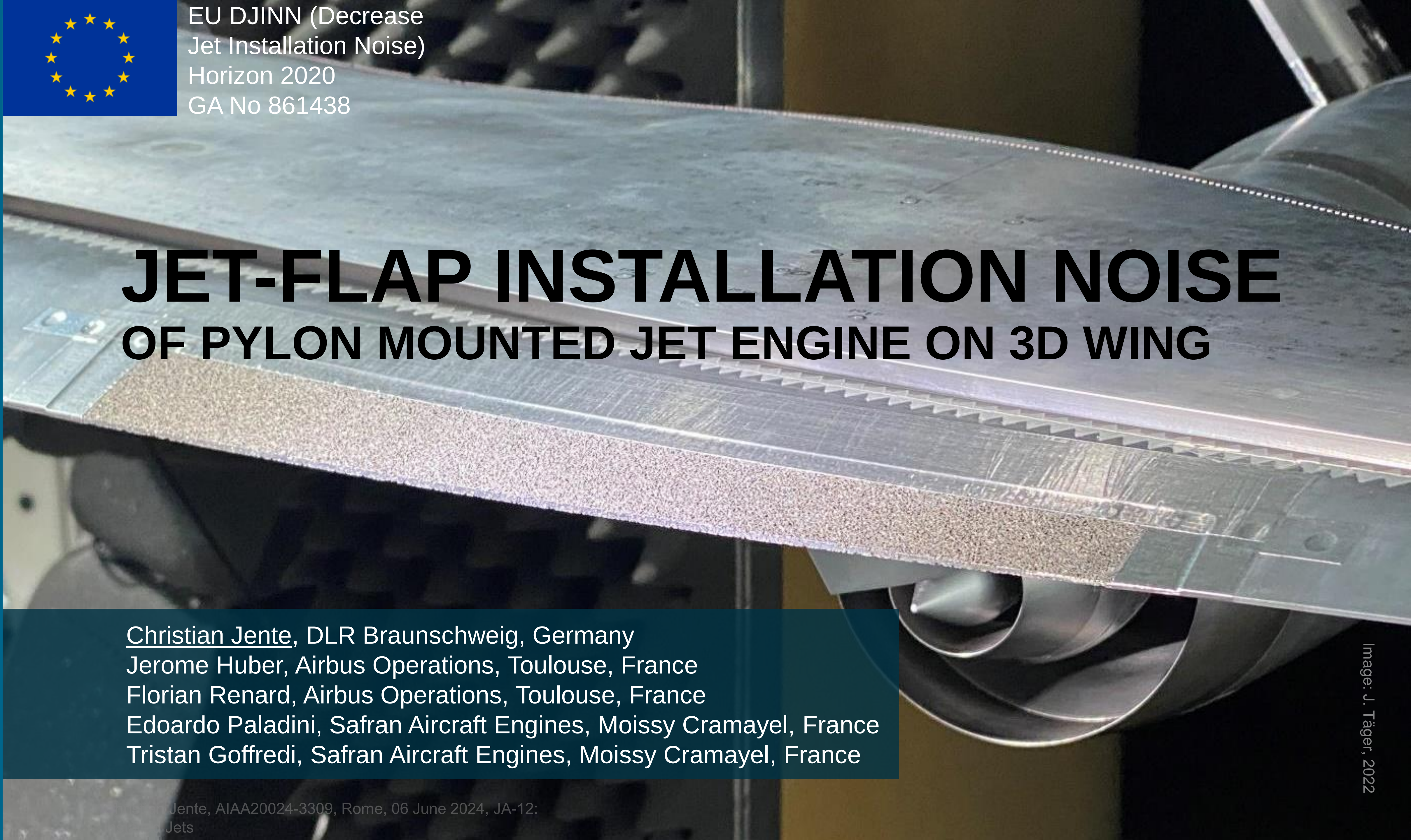
EU DJINN (Decrease
Jet Installation Noise)
Horizon 2020
GA No 861438



JET-FLAP INSTALLATION NOISE

OF PYLON MOUNTED JET ENGINE ON 3D WING

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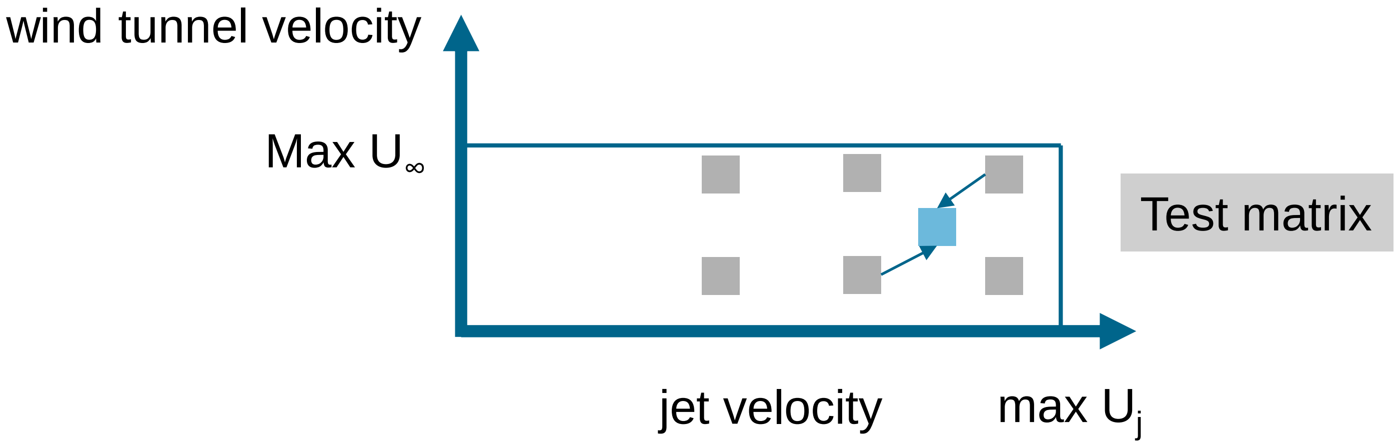
Image: J. Täger, 2022

Motivation

goal: understand velocity scaling of jet installation noise

- interpolate in between test conditions



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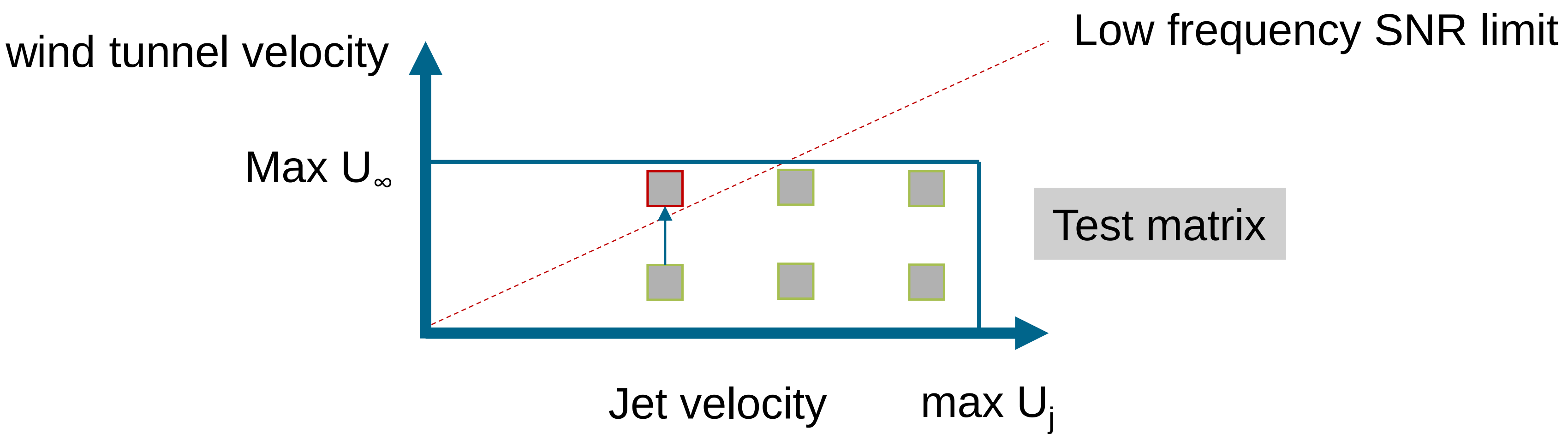
Motivation

goal: understand velocity scaling of jet installation noise

- interpolate in between test conditions
- repair corrupted spectra, e.g. with poor signal to noise ratio



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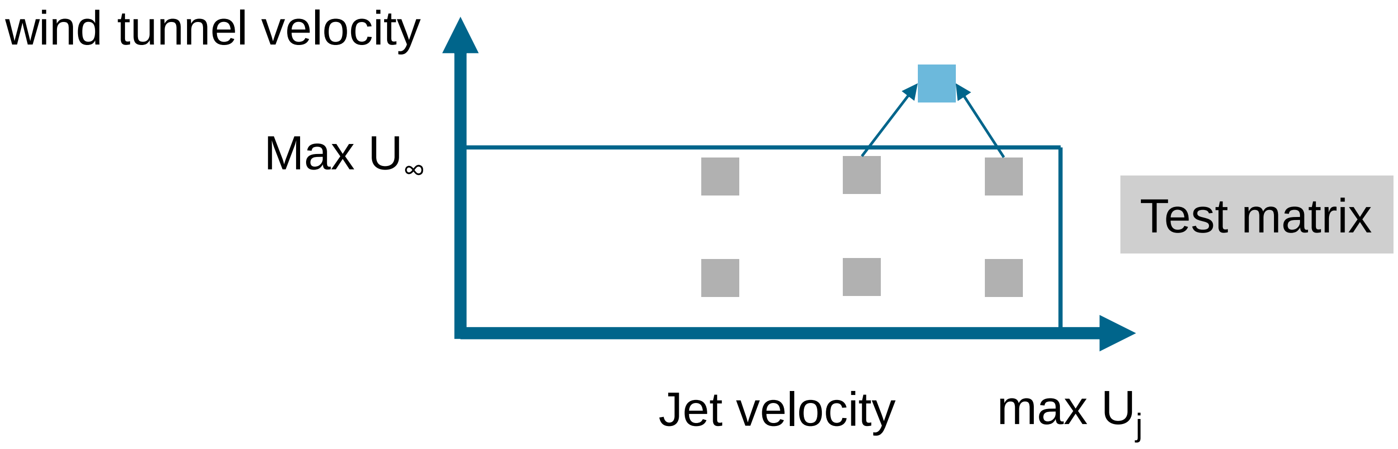
Motivation

goal: understand velocity scaling of jet installation noise

- interpolate in between test conditions
- repair corrupted spectra, e.g. with poor signal to noise ratio
- solve “max wind tunnel velocity problem”: extrapolate test data for an operation which is out of scope for the current test facility



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Outline

1. Analytics: derive far-field noise of installed flight jets w/pylon (FW-H)
2. Test velocity scaling relation against experimental data (DJINN – AWB test)
3. Different velocity scaling for forward-overhead arc vs. rear arc
   → show transition
4. Put findings into practice: showcase “max wind tunnel velocity problem”
5. Transferability Limits: Can I use the findings for related JFI problems?
   Pylon vs. non-pylon mounted installation

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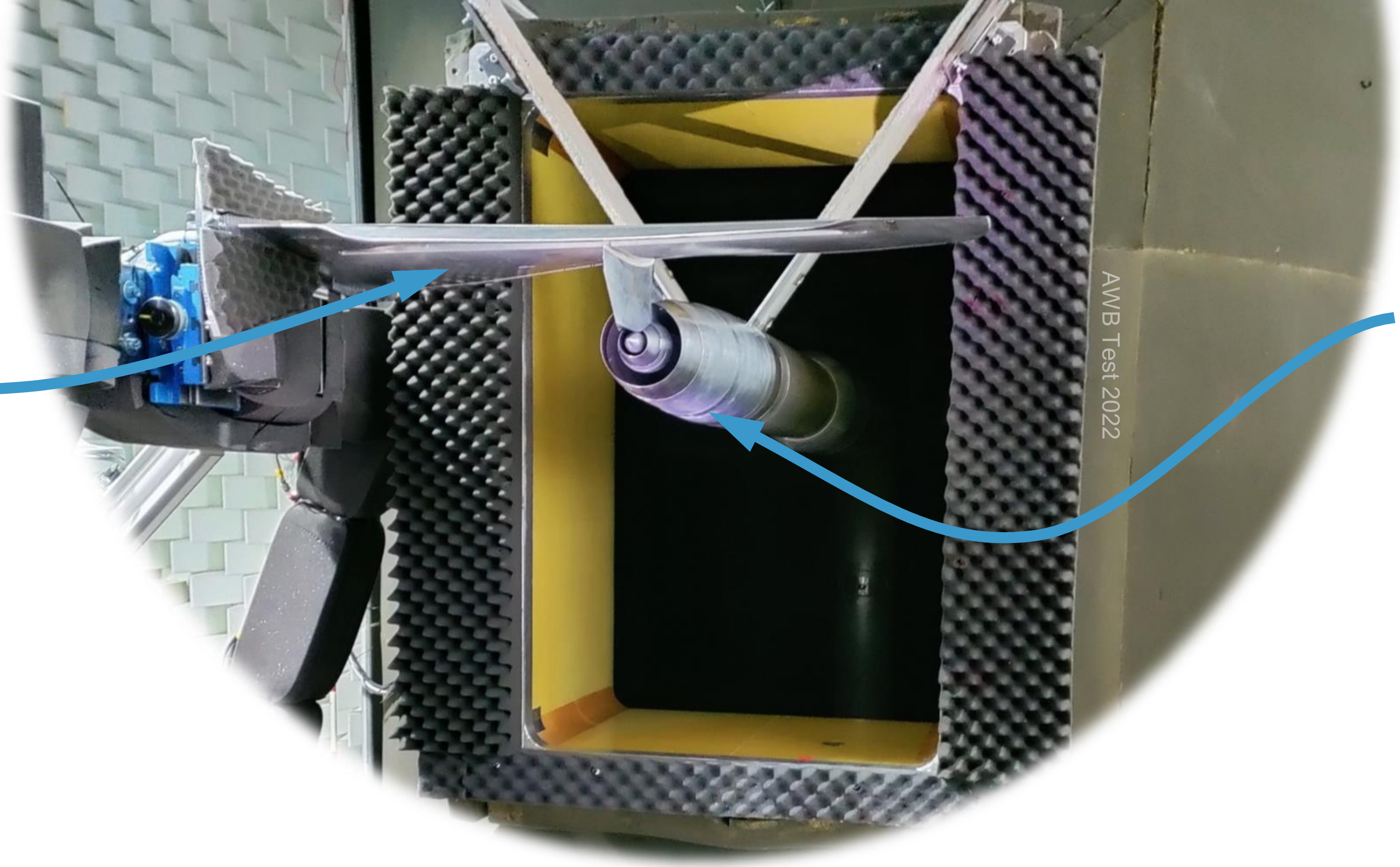
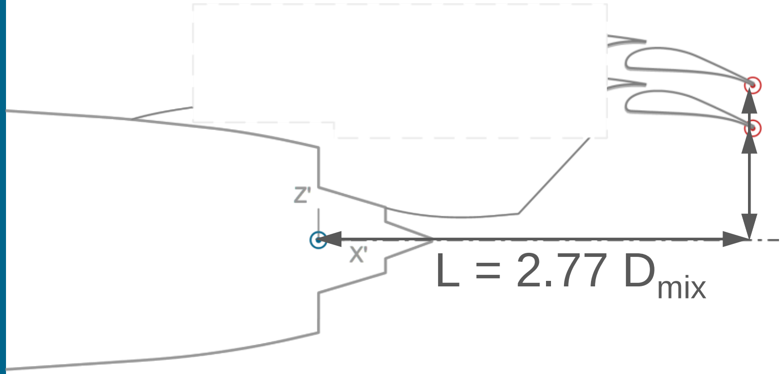
Models for experiment



WING
AIRBUS RDJ80
right-hand half model
$c_{mid} = 3\ D_{mix}$
two-element wing
flap $\delta_F=14°$

ENGINE MODEL
SAFRAN
dual stream
short cowl
UHBR engine
$A_{Byp}/A_{Core} \sim 7$
$D_{mix} \sim Ø100mm$



ENGINE INTEGRATION incl. Pylon
$H_1 = 0.98\ D_{mix}$
$H_2 = 0.71\ D_{mix}$

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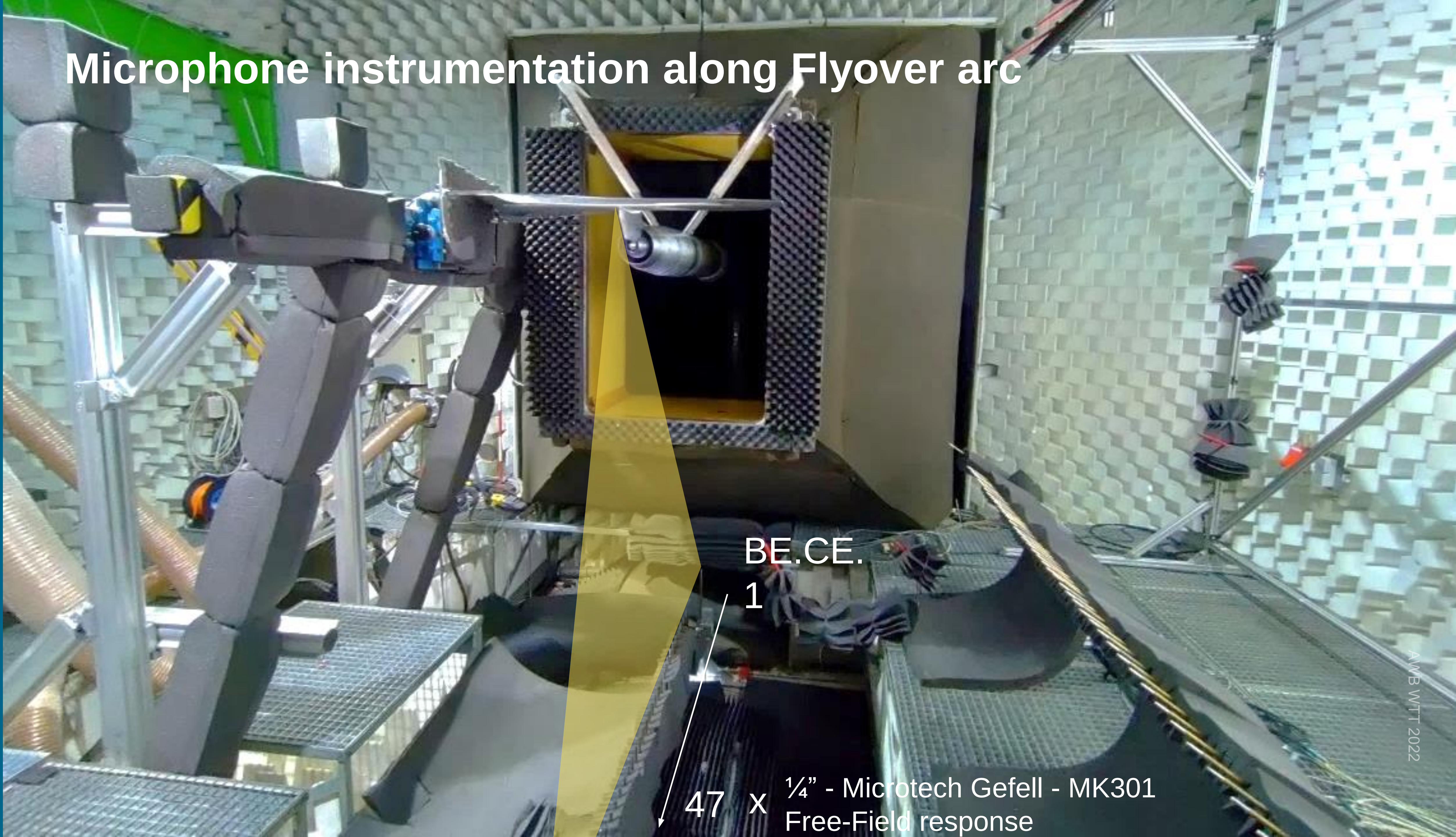
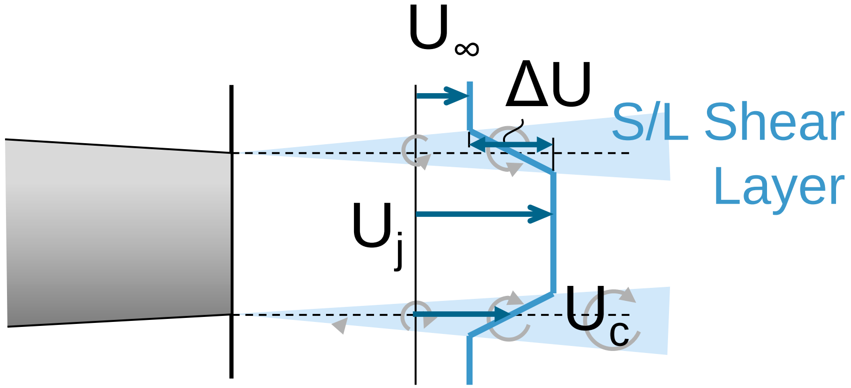
Microphone instrumentation along Flyover arc



47 x ¼” - Microtech Gefell - MK301
Free-Field response

Operations



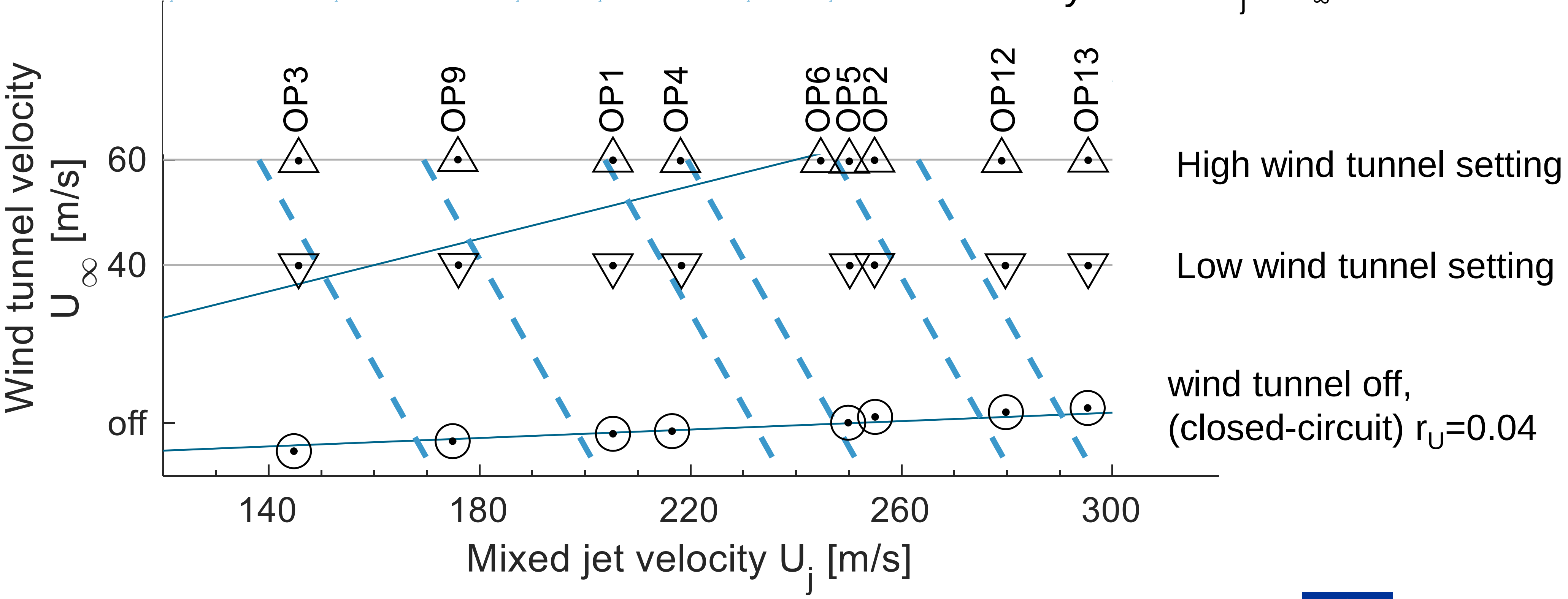
wind tunnel velocity U_∞

jet velocity U_j

velocity ratio $r_U = U_\infty / U_j$

S/L convection velocity $U_c = U_\infty + 0.64\,\Delta U$

S/L difference velocity $\Delta U = U_j - U_\infty$



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1 Analytic Derivation
Aerodynamic near-field of the jet shear layer

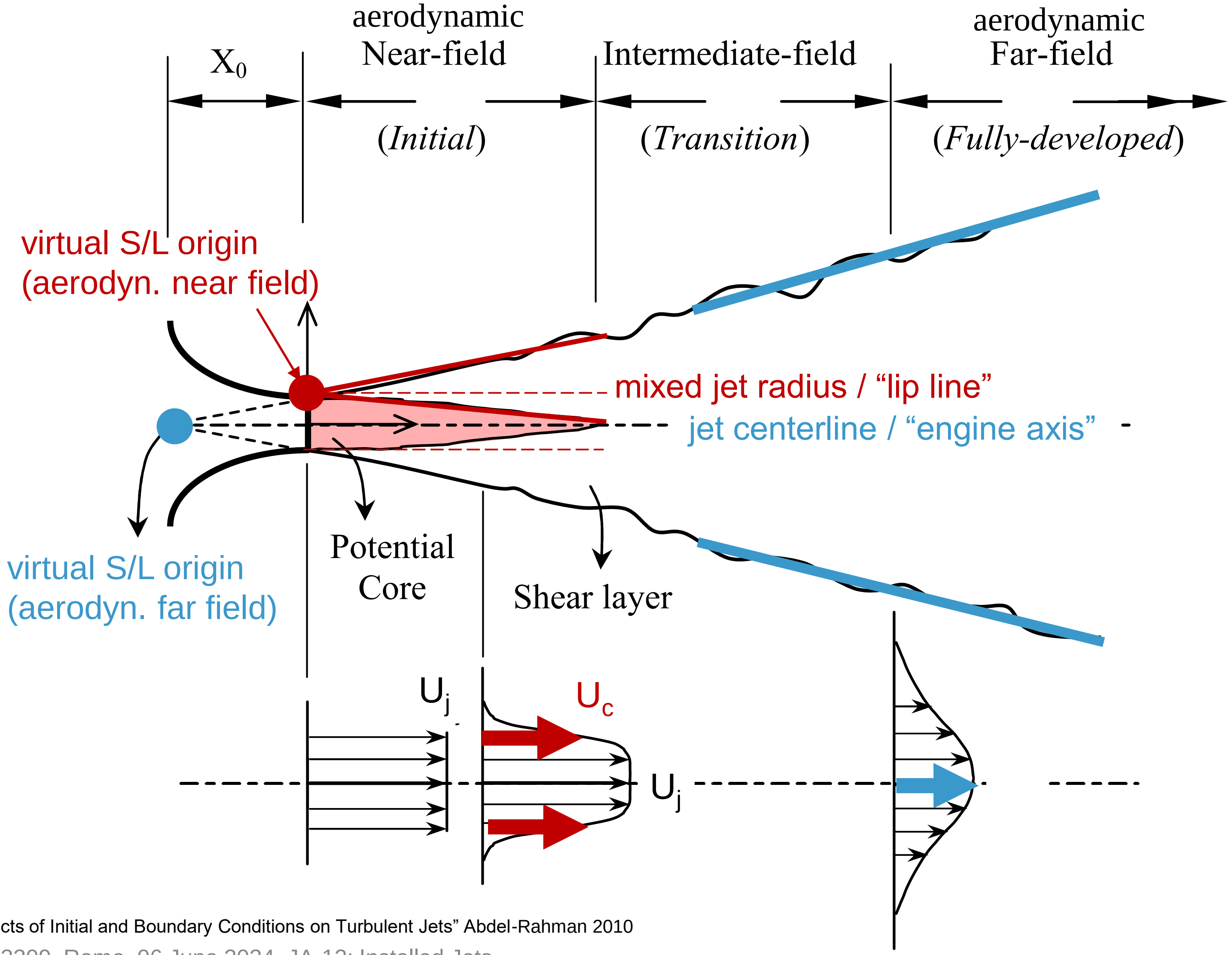

Image based on: "A Review of Effects of Initial and Boundary Conditions on Turbulent Jets" Abdel-Rahman 2010

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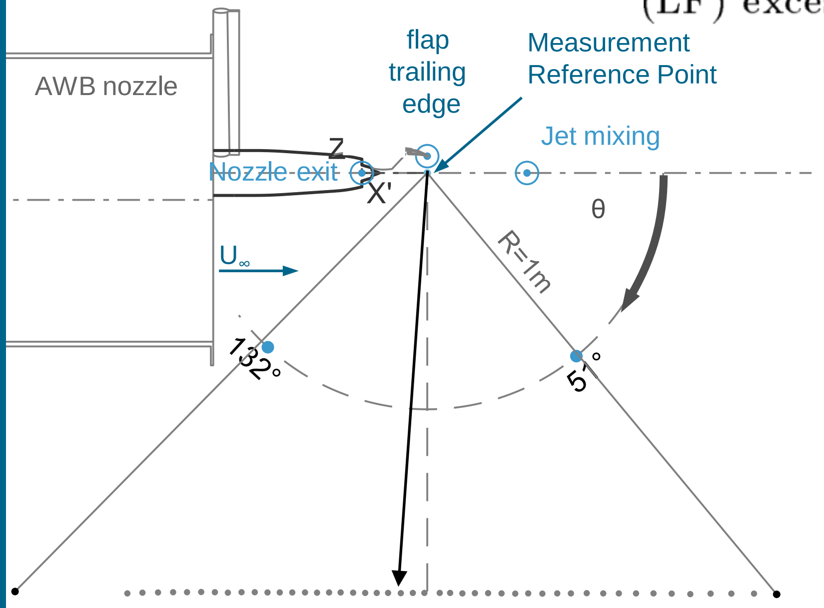
1 Analytical derivation – static jet, forward arc

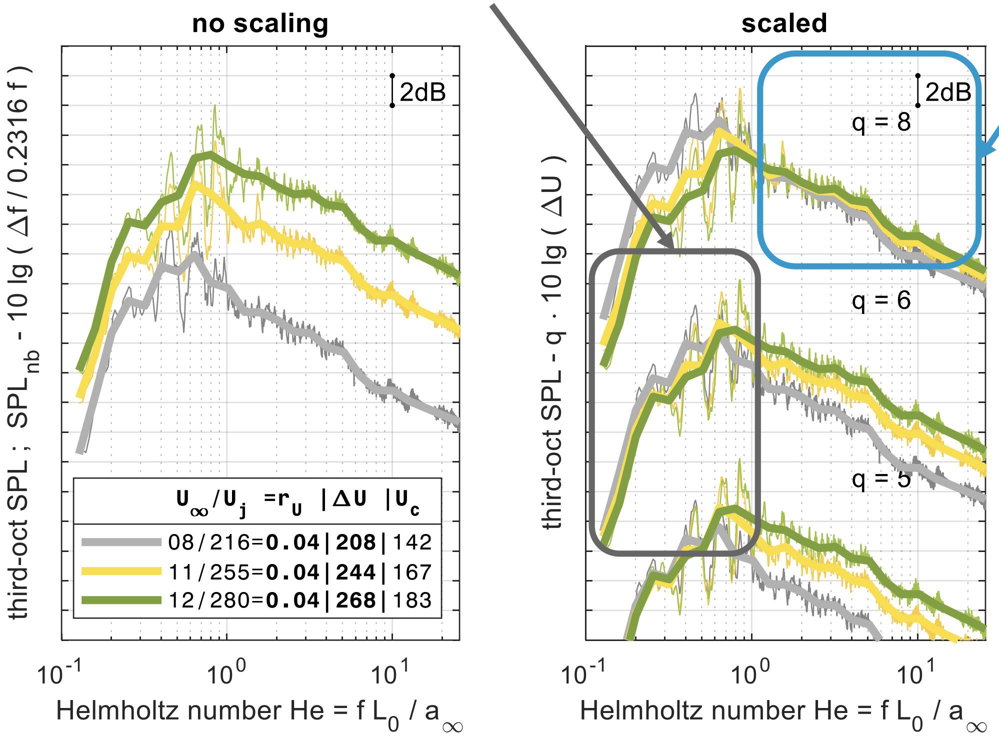
Farfield solution FWH:

$$p' \simeq \underbrace{\frac{1}{4\pi a_\infty r_0}\boldsymbol{e}_{r_0}\cdot\frac{\partial}{\partial t}\int_{\partial V_B}(p\boldsymbol{I}-\boldsymbol{\tau})\cdot\boldsymbol{n}\,dS}_{\text{(LF) excess noise due to presence of wing}}+\underbrace{\frac{1}{4\pi a_\infty^2 r_0}(\boldsymbol{e}_{r_0}\boldsymbol{e}_{r_0}):\frac{\partial^2}{\partial t^2}\int_{V'_\infty}\boldsymbol{T}\,dV}_{\text{(HF) free turbulence}}$$



Forward-overhead

loading noise
I~(ΔU)^6 for He<1



deformed jet /
reflected jet noise
I~ $U_j^8 \cdot f(U_\infty/U_j)$

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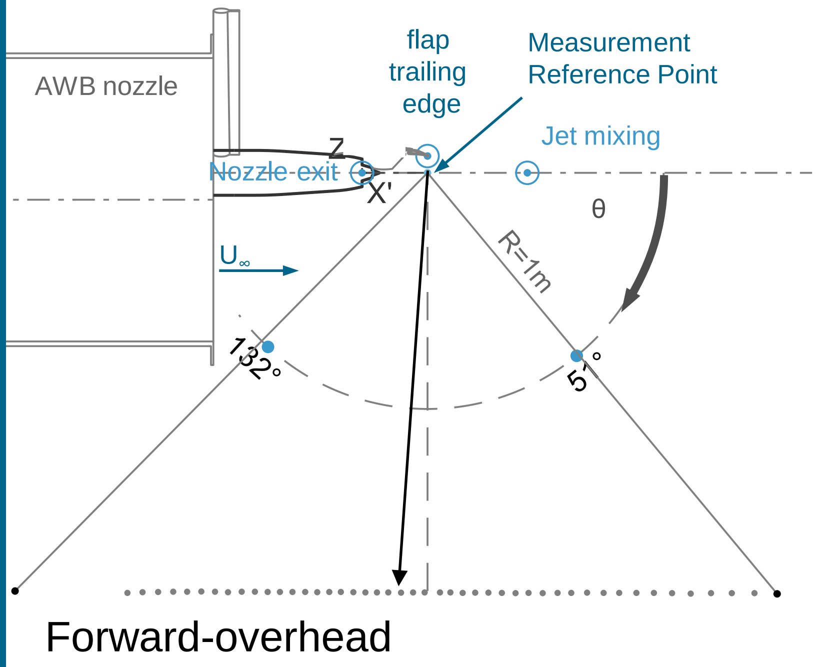
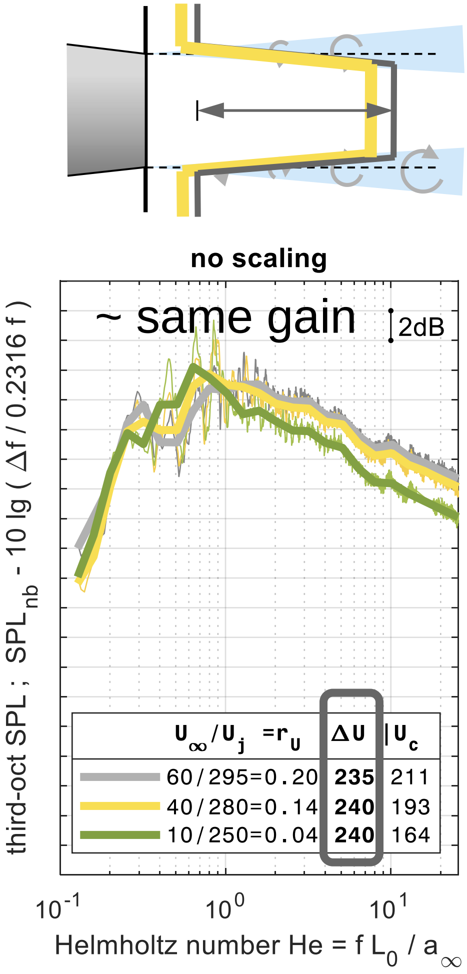
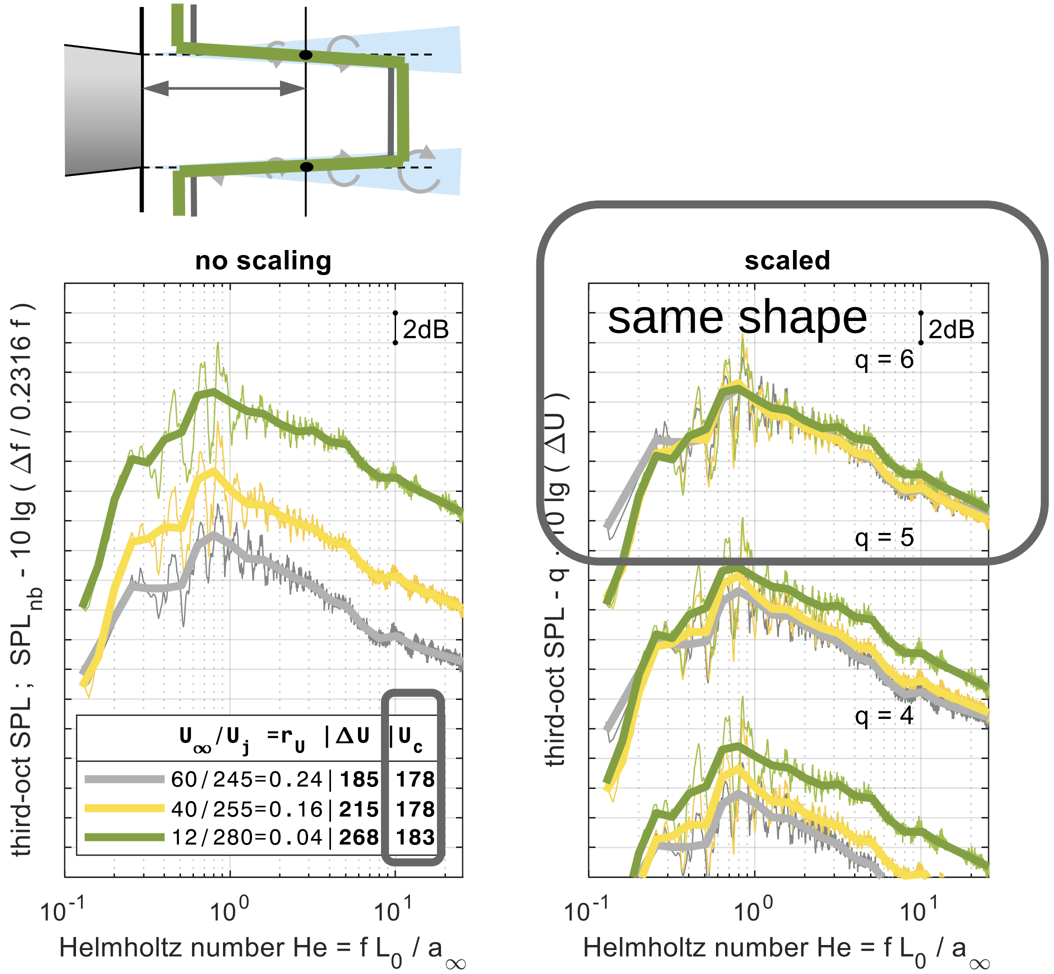
2 Experimental determination of the velocity scaling
in the forward-overhead arc



1 same ΔU



2 same U$_c$



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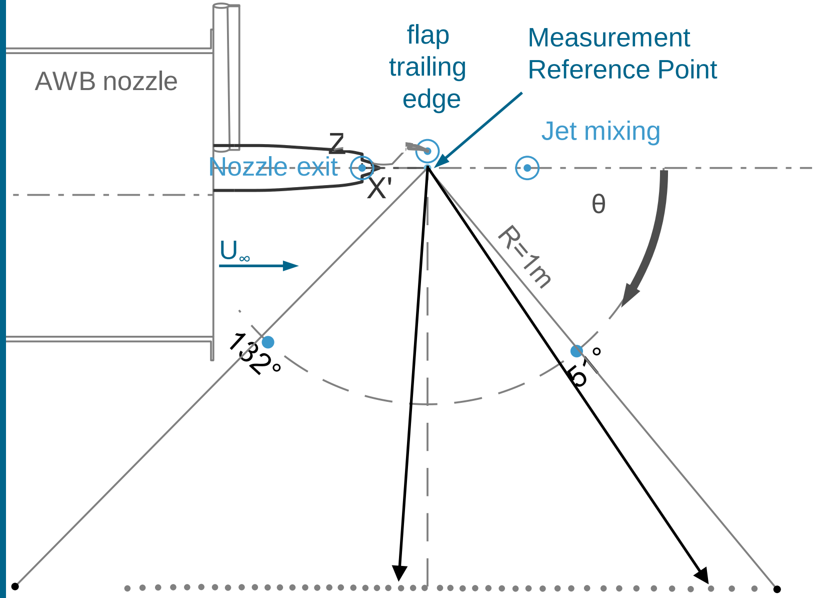
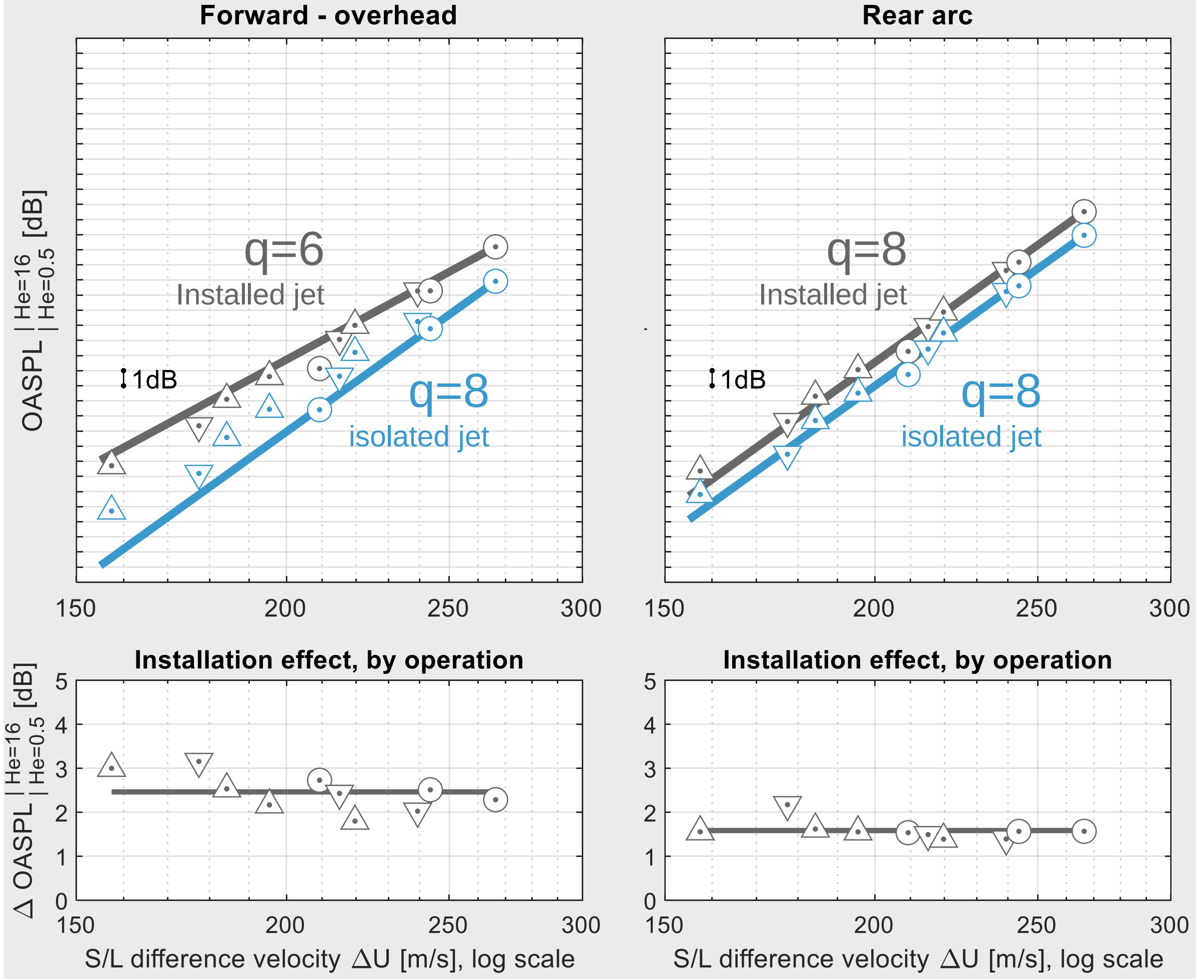
3 Velocity scaling of pylon-integrated jet engine

forward-overhead arc vs. rear arc





Just a slight offset to Jet noise

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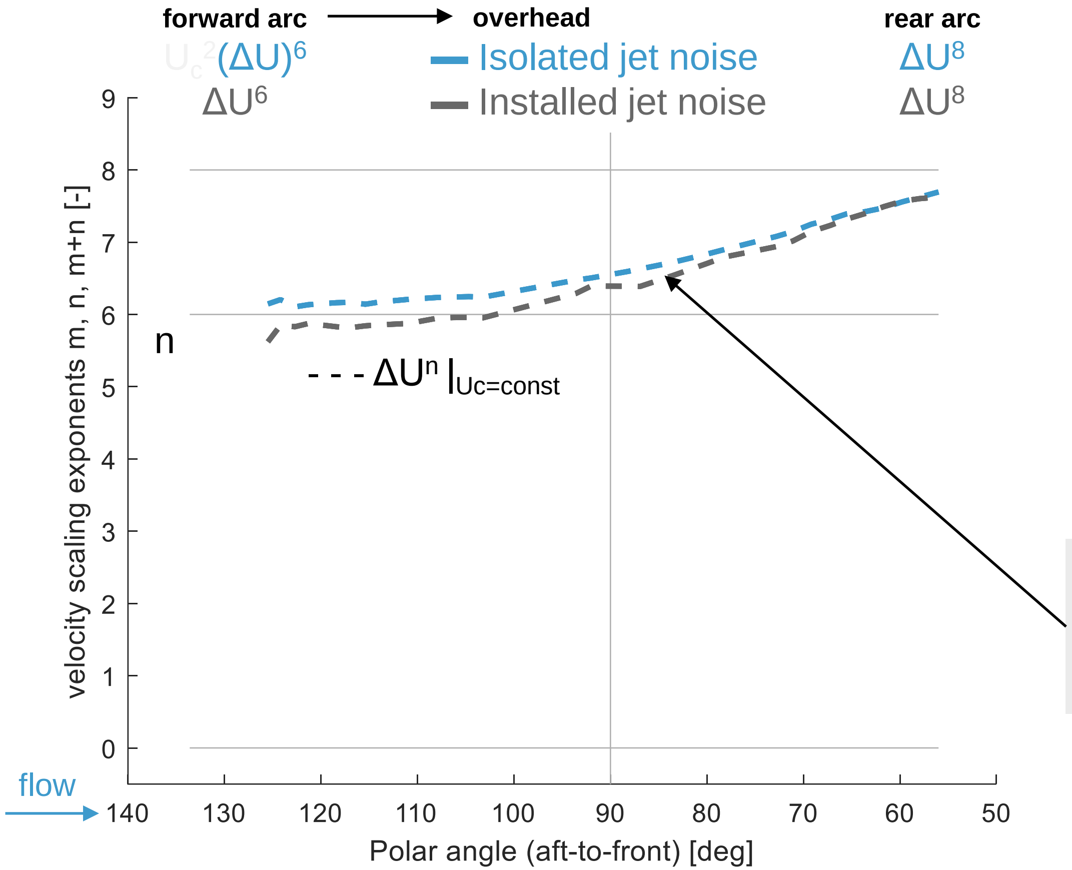
3 The transition between forward-overhead and rear arc

This is the major contribution of this paper!



Use linear regression to determine velocity scaling exponent for each microphone position individually:

- find n in ΔU^n: 3 test op's U_c=const

The n exponents are very similar for both isolated as well as installed jet noise.

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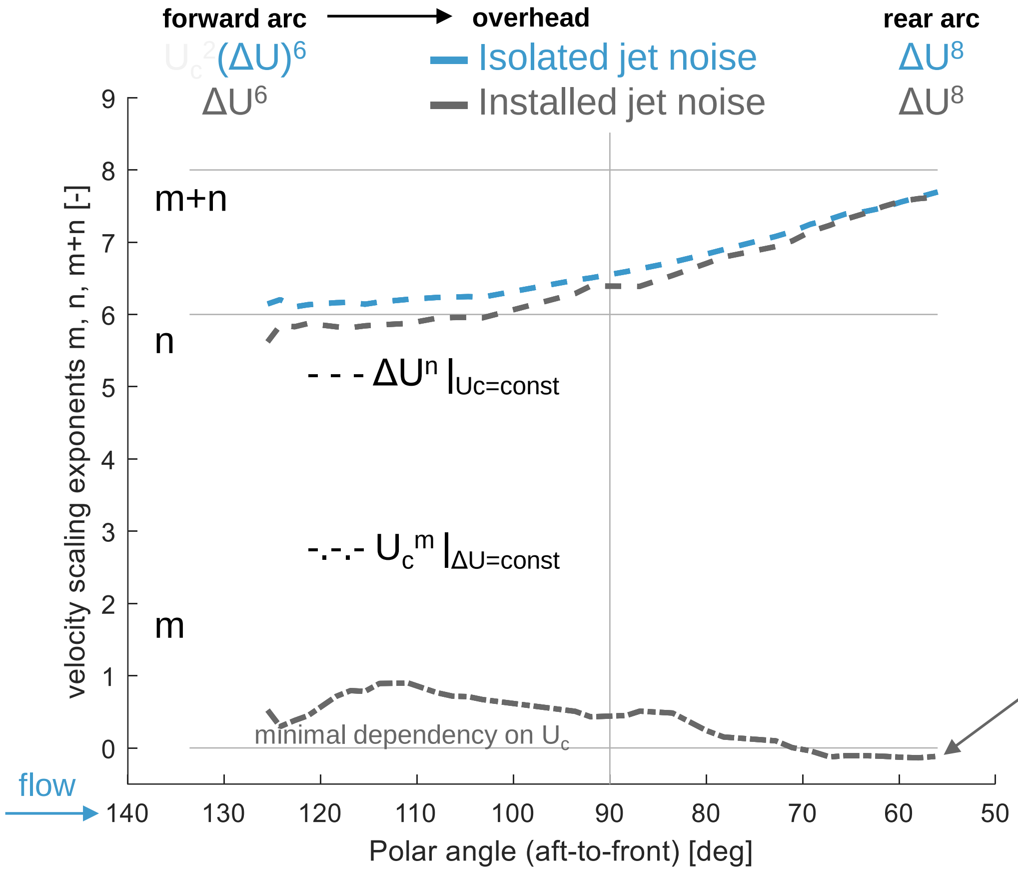

Use linear regression to determine velocity scaling exponent for each microphone position individually:

- find n in ΔU^n: 3 test op's U_c=const
- find m in U_c^m: 3 test op's ΔU=const

The m exponents on installed jet noise are almost negligible. Hence, installed jet noise can be modelled using $I \sim \Delta U^n$.

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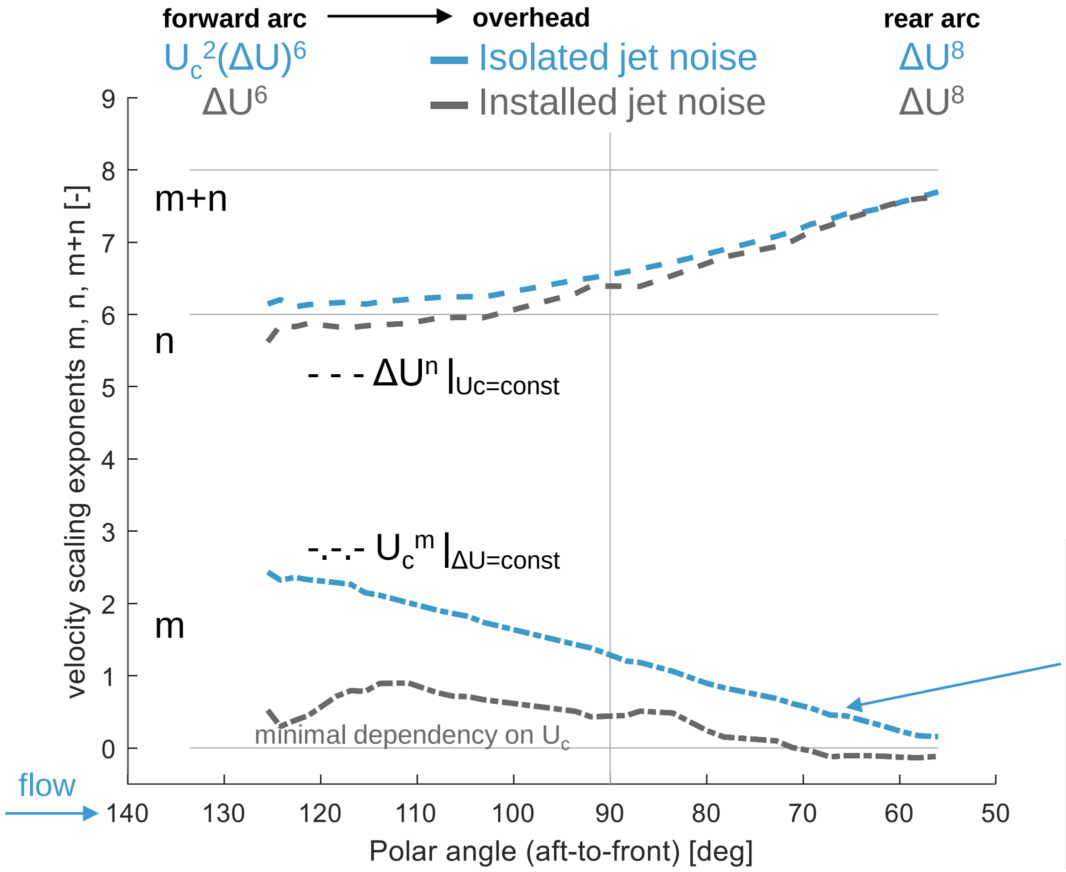

Use linear regression to determine velocity scaling exponent for each microphone position individually:

- find n in ΔU^n: 3 test op's U_c=const
- find m in U_c^m: 3 test op's ΔU=const

The m exponents on isolated jet noise transition from m=2 to m=0.
"Same ΔU produces same jet noise" is not generally valid, i.e. only valid in the rear arc.

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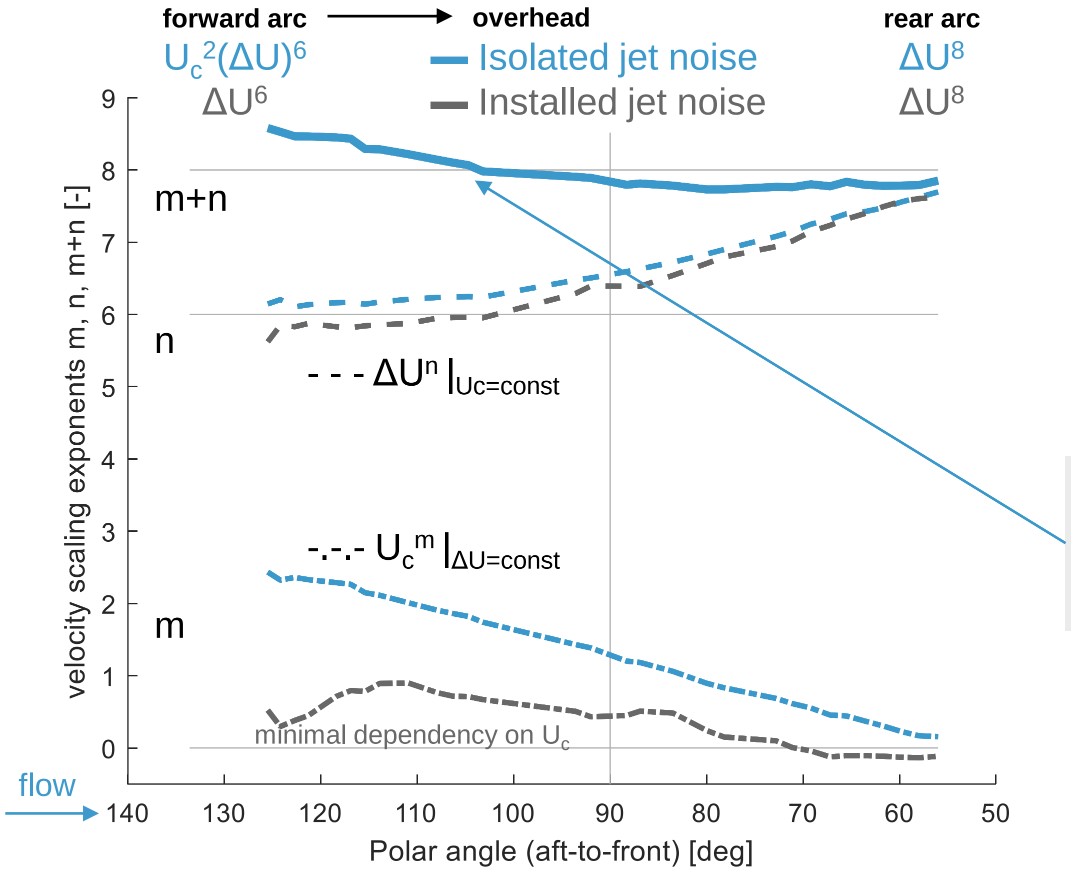

Use linear regression to determine velocity scaling exponent for each microphone position individually:

- find n in ΔU^n: 3 test op's U_c=const
- find m in U_c^m: 3 test op's ΔU=const

The combination m+n = 8 for *isolated jet noise* agrees with Lighthill's analogy.

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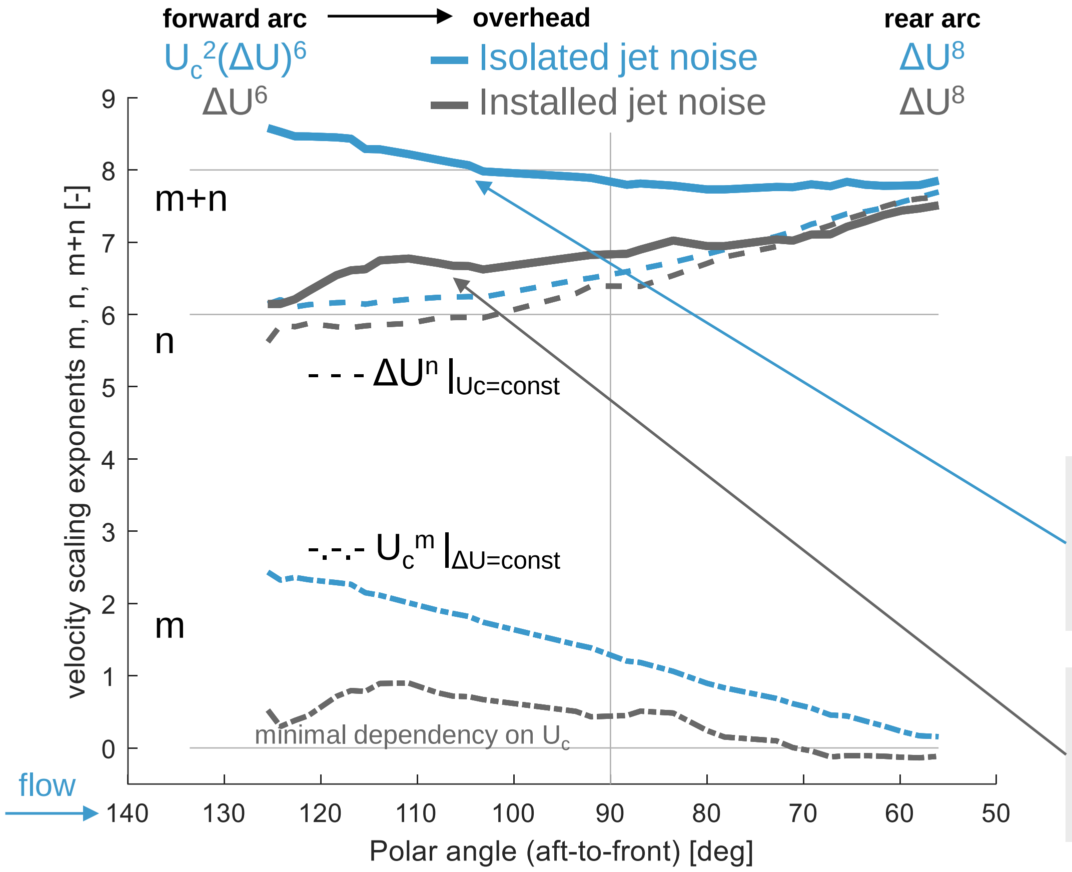

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Installed jet noise transitions from exponent 6 to 8. [same trend as Brown&Ahuja 1984-2362]

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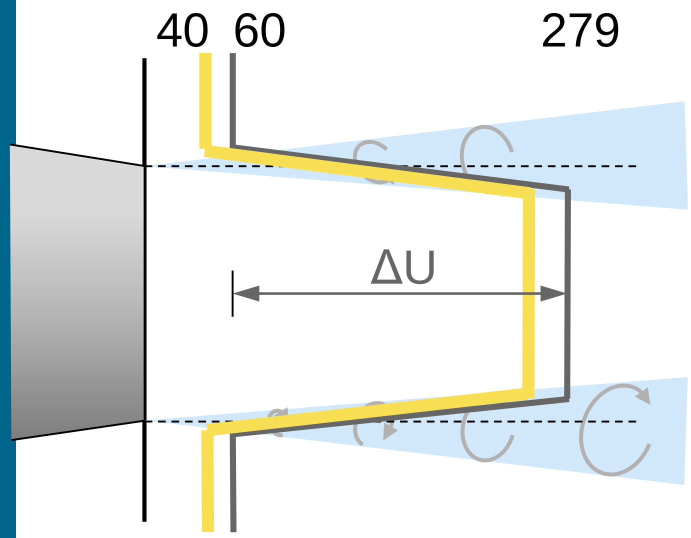
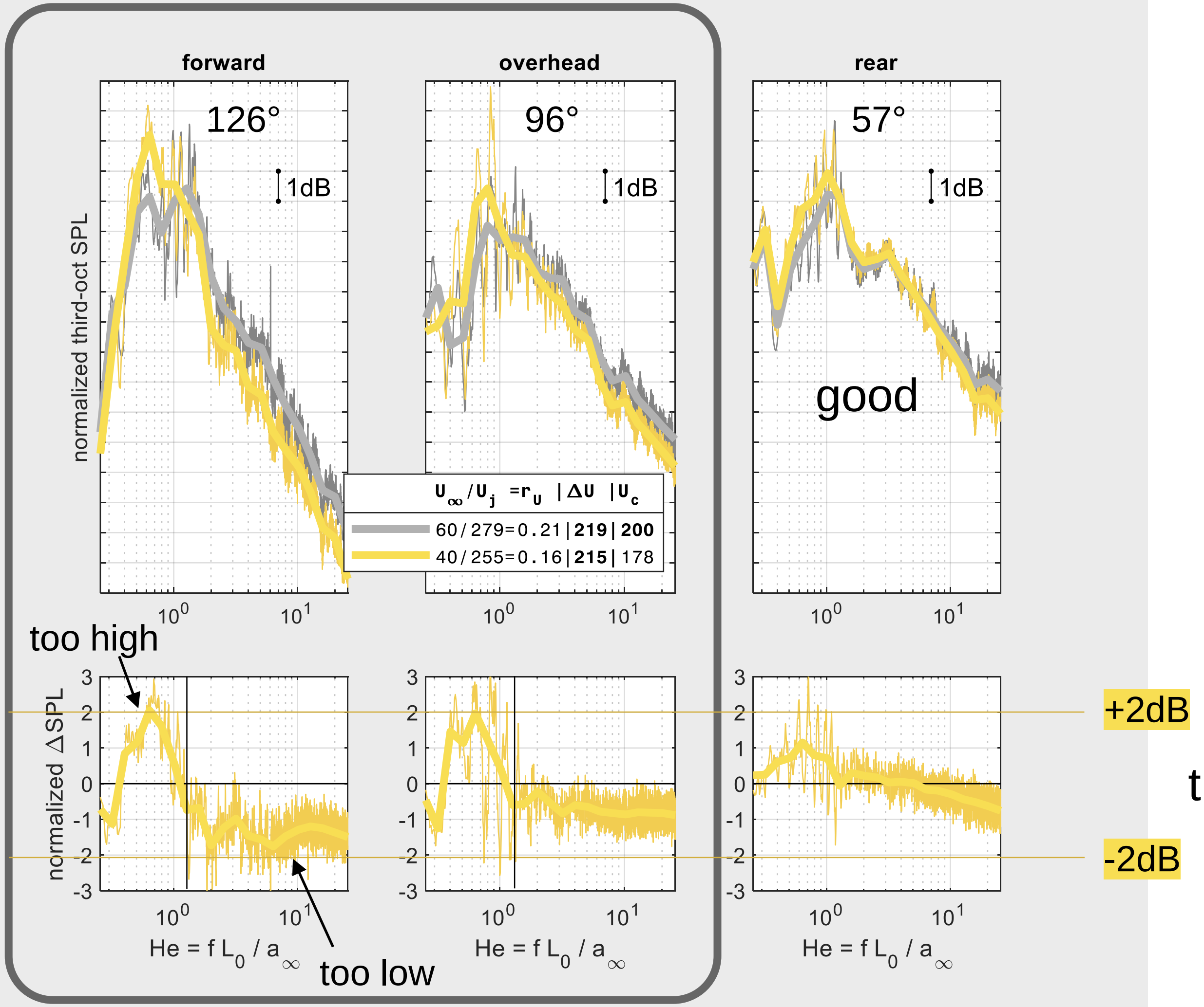
4 Max wind tunnel velocity problem (installed jet)

- Reference with high wind tunnel velocity, tested e.g. conducted in other facility





third-octave band

Produce comparable spectrum despite limited wind tunnel velocity:

Same 🟨 $\Delta U = U_j - U_\infty$

+ same OASPL (*here:* within 0.3dB)

– but: shape function (gain by frequency) off

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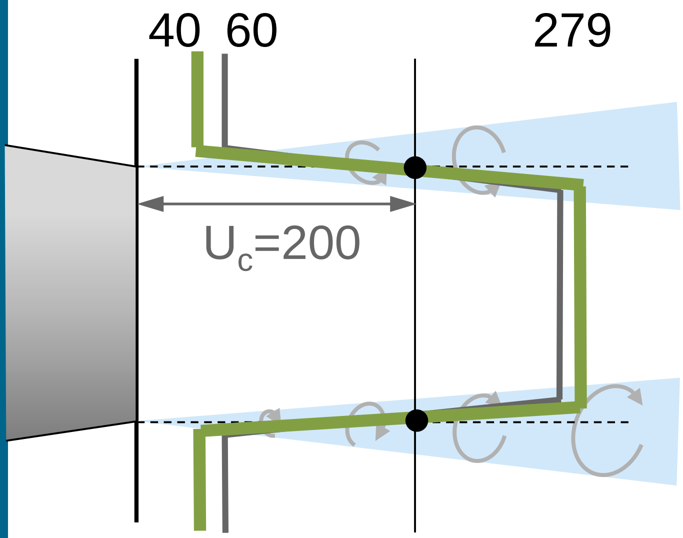
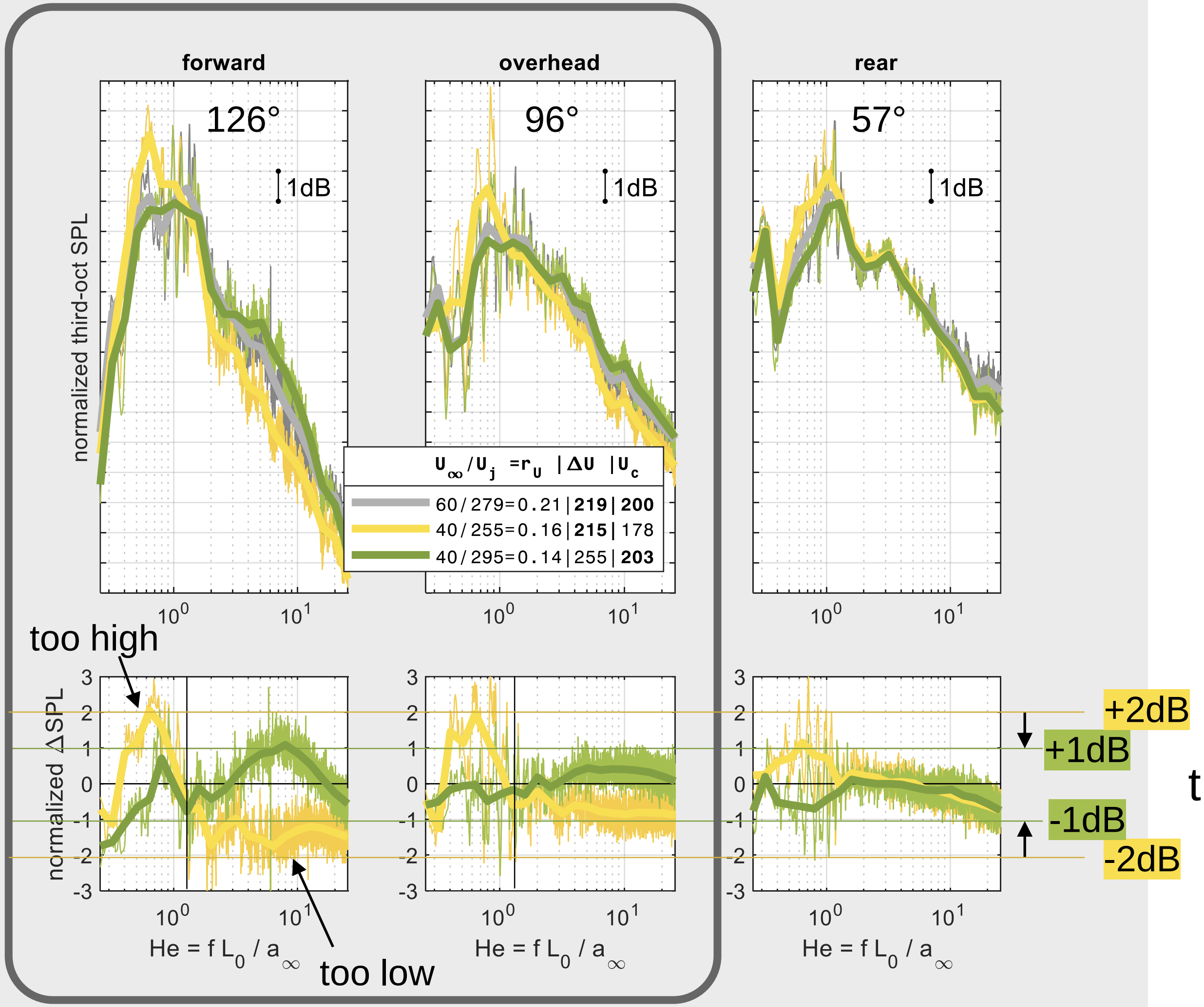


Produce comparable spectrum despite limited wind tunnel velocity:

Same ■ S/L convection velocity U_c

+ shape function (gain by frequency) better

– Higher ΔU: OASPL too high (*here:* +5dB), normalize gain with velocity scaling



third-octave band *improved!*

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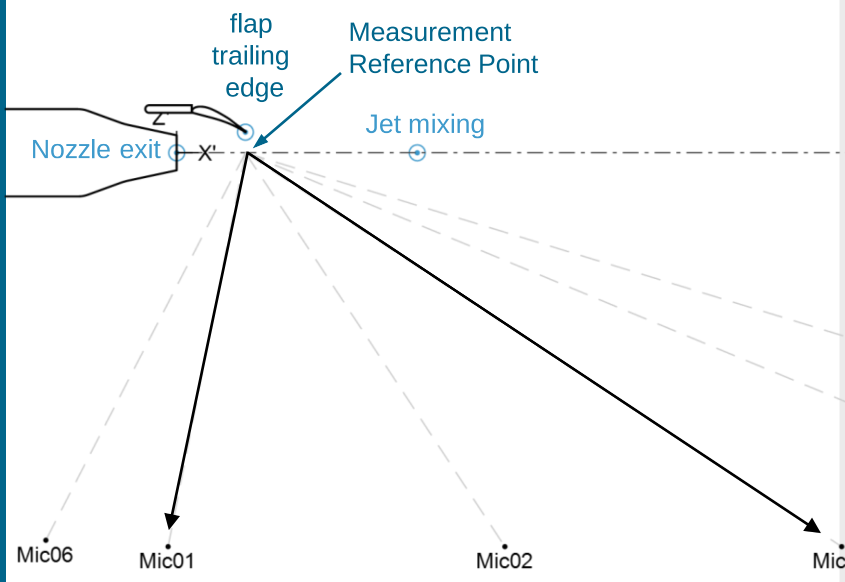
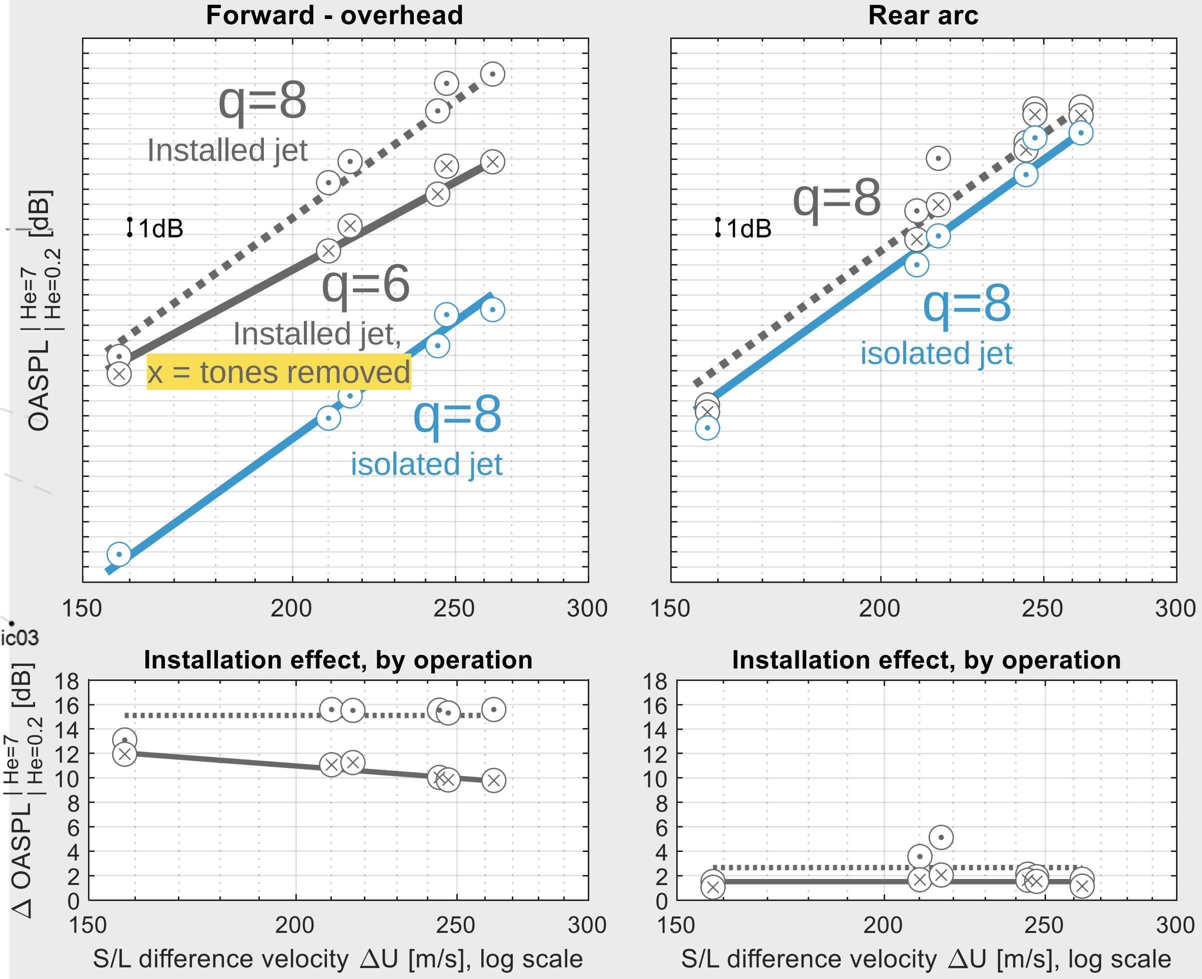
5 Velocity scaling: engine integrated w/o pylon

forward-overhead arc vs. rear arc

JExTRA experiment





spectra w/tones removed
produce same scaling coefficients

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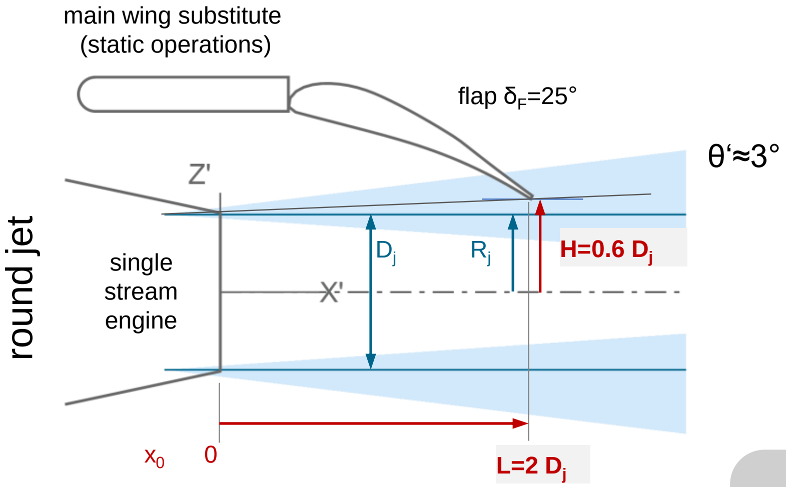
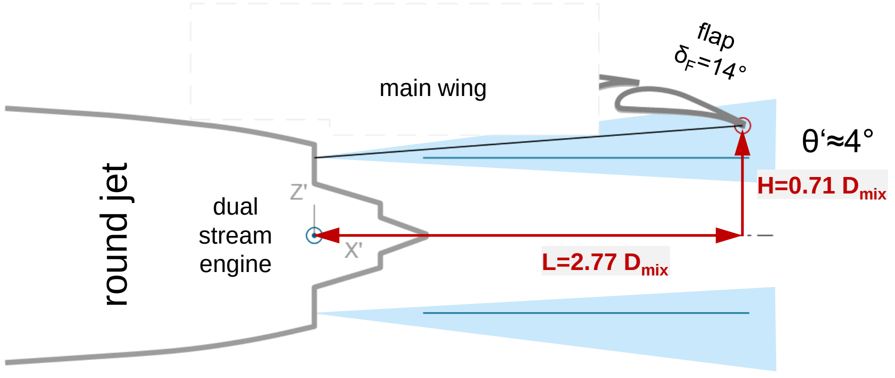
5 Aero-geometric characterization needs adaption for the pylon effect

JExTRA 2021
no Pylon



AWB 2022
assume Pylon negligible



$$\tan(\theta') = \frac{H - R_j}{L - x_{0,NF}}$$

θ' ≈ 3°
ΔOASPL = 10dB

θ'≈4°
ΔOASPL = 3dB

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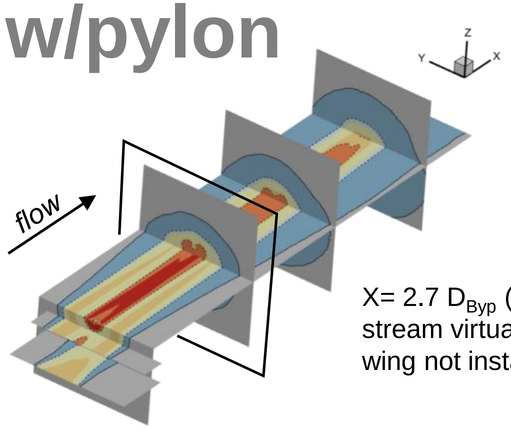
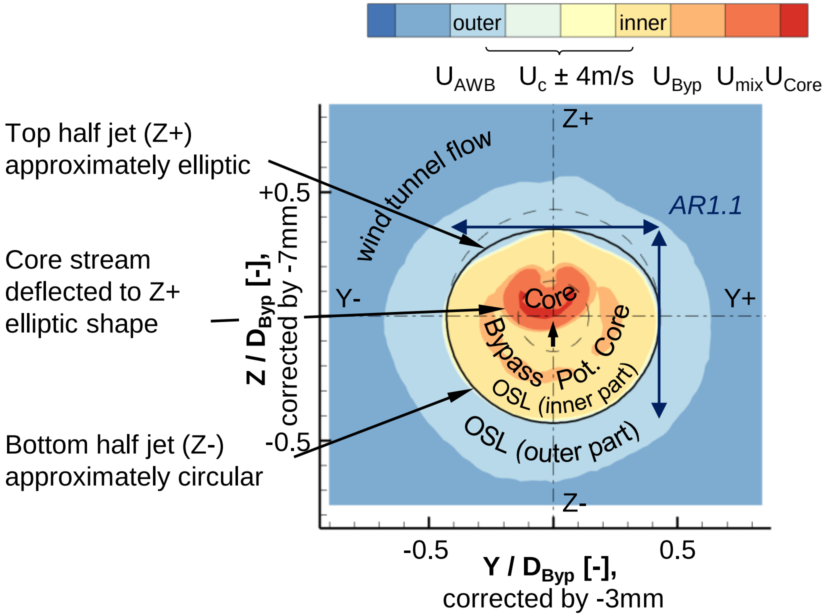
5 Steady aerodynamics flow analysis of isolated jet w/pylon



X= 2.7 D_{Byp} (just down-stream virtual flap TE/ wing not installed)

$$\tan(\theta') = \frac{H - R_j \nearrow}{L - x_{0,NF} \nearrow}$$

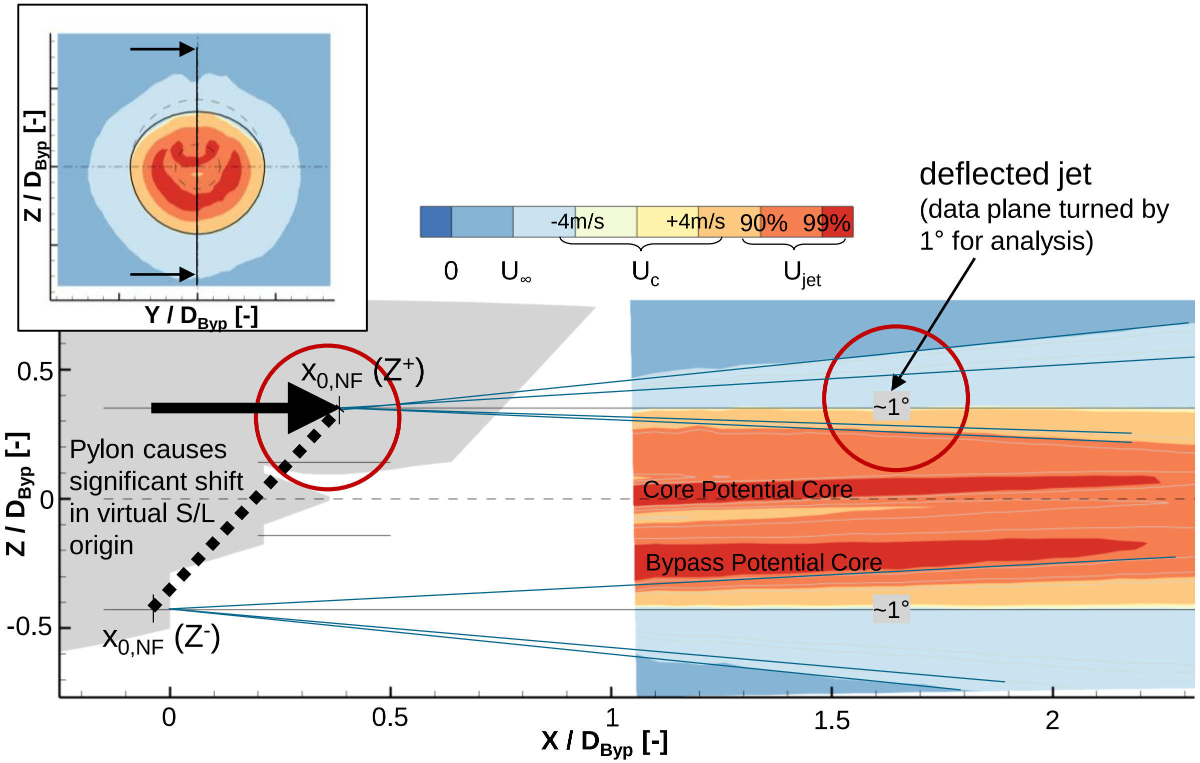


Top half jet (Z+) approximately elliptic

Core stream deflected to Z+ elliptic shape

Bottom half jet (Z-) approximately circular

XY-Plane for ENG = **OP8** ($U_{core} > U_{Byp}$) and UAWB = 60m/s



deflected jet
(data plane turned by 1° for analysis)

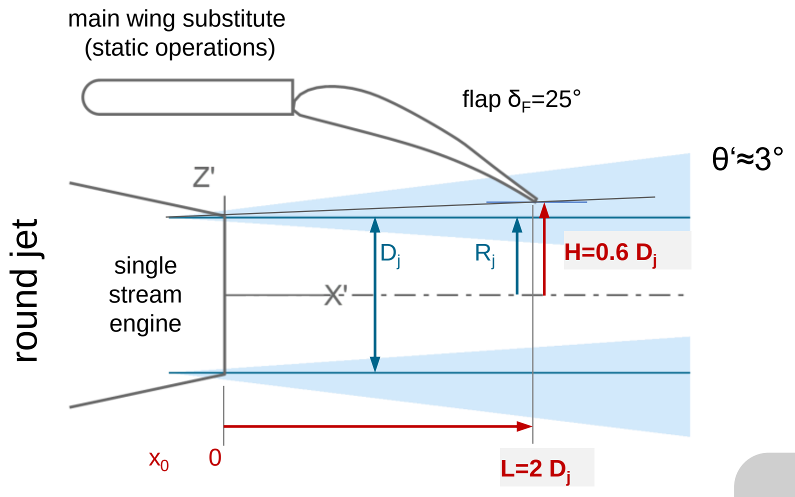
Pylon causes significant shift in virtual S/L origin

XZ-Plane for ENG = OP6 ($U_{Core} = U_{Byp}$ = 244 m/s) and UAWB = 60m/s

5 Aero-geometric characterization needs adaption for the pylon effect

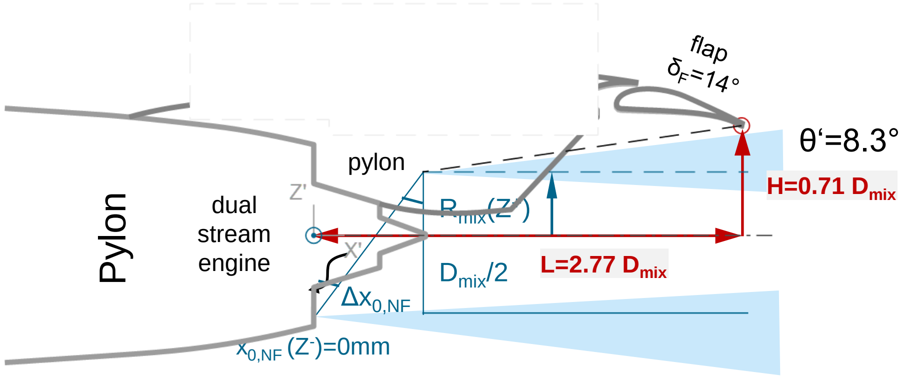
JExTRA 2021

no Pylon



AWB 2022

assume Pylon negligible



$$\tan(\theta') = \frac{H - R_j(Z+)}{L - x_{0,NF}(Z+)}$$

θ' ≈ 3°

ΔOASPL = 10dB

θ' ≈ 8.3°

ΔOASPL = 3dB

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Summary

- Aero-geometric characterization of the pylon-integrated problem is difficult
- presence of pylon → no tones → simplifies acoustic characterization
  - Velocity scaling with ΔU, exponents 6 (forward-overhead) to 8(rear)
  - frequency He<1 (loading noise) vs. He>1 (~ jet noise)
- Model building: Same shape functions with U_c
- Not discussed: Influence of core stream

Questions?

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