

# Reapplying of the Corrugated Skin Used at Junkers Aircraft's Wings and Fuselage in Manufacturing of the Future BLI/Electric European Aircraft for Noise Reduction and Performance Improvement

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## Abstract

This paper shows that corrugated skin used by Junkers for increasing of fuselage's and wing's rigidity increasing leads to reduction of annoyance produced by aircraft through emitted noise scattering.

It is shown that if the pressure side of wing which is placed above the engine is corrugated, the jet noise which is reflected by wing is scattered. The diffuse acoustic field created in this way has a lower intensity at ground level and implicitly a lower impact on community.

Similar, it is shown that nose landing-gear noise and main landing-gear noise which is reflected by the underside of fuselage is scattered, too, and the diffuse acoustic field created in this way is better supported by community.

Some recent measurements done in auto-tunnels covered at the interior with corrugated sheet metal indicated a reduction of maximum noise level with 30%.

On the other hand, some experiments done at low scale on an Airbus A380 wing model (scale 1:375) shown that the jet-noise reflected by the corrugated skin of wing is smaller with 4 dB in the near field.

In conclusion, this paper shows that reintroducing of corrugated skin in manufacturing of modern aircraft is beneficial because, on a hand, it reduces the annoyance created by aircraft jet-noise and landing gear noise and, on the other hand, it permits reduction of the aerodynamic drag of aircraft and, finally, it permits manufacturing of crash resistant passenger aircraft.

# Outline

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- 5. Experimental facts**
- 6. The case of BLI (Boundary Layer Injection)**
- 7. Discussion on re-using of Junkers solution at future European aircraft**
- 8. Conclusions**

# 1. Introduction

- **At the middle of the 20-th century, Junkers created an aircraft with corrugated skin over wing and fuselage**
- **This solution could be partially used in the next future in special areas of wing skin and fuselage for noise reduction through scattering both in the case of classic aircraft and BLI or Electric/BLI aircraft**
- **Several possibilities of using the Junkers solution in manufacturing of future European aircraft are discussed in this paper**

## 2. Junkers 52 design solution

Corrugated sheet metal used at Junkers 52 Aircraft  
for increasing of skin stiffness

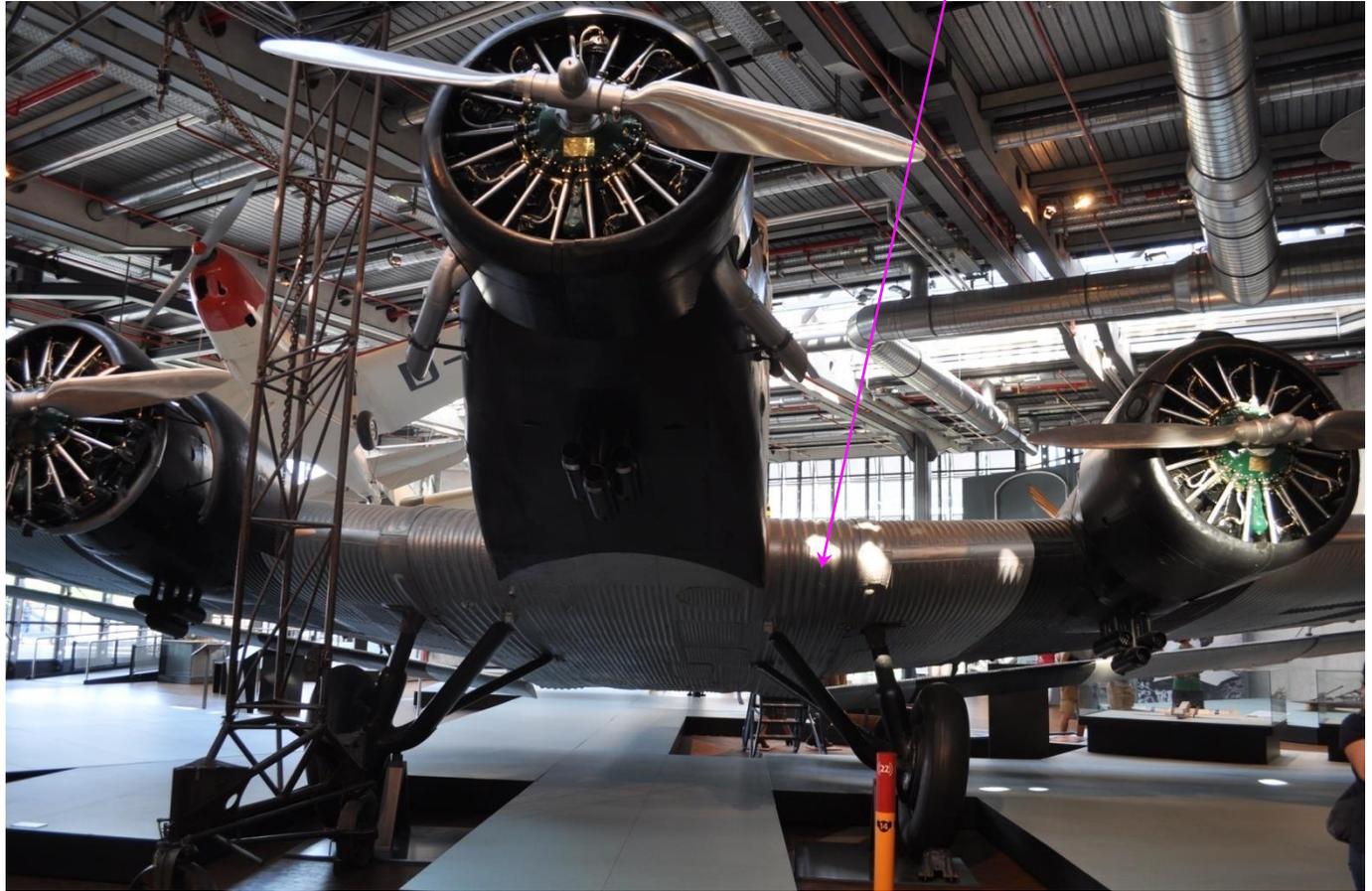
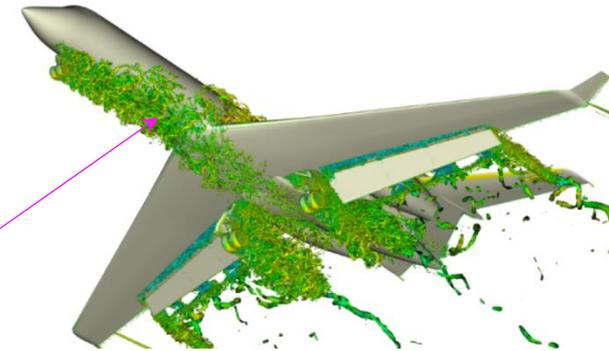


Fig.1-Junkers 52 aircraft

### 3. The case of present aircraft



L.G. noise is strongly reflected by fuselage



- In the case of present aircraft noise generated by jet and landing gear is strongly reflected by wing and fuselage to community

**Fig.2- Noise generated by jet and landing gear**

### 3. The case of present aircraft

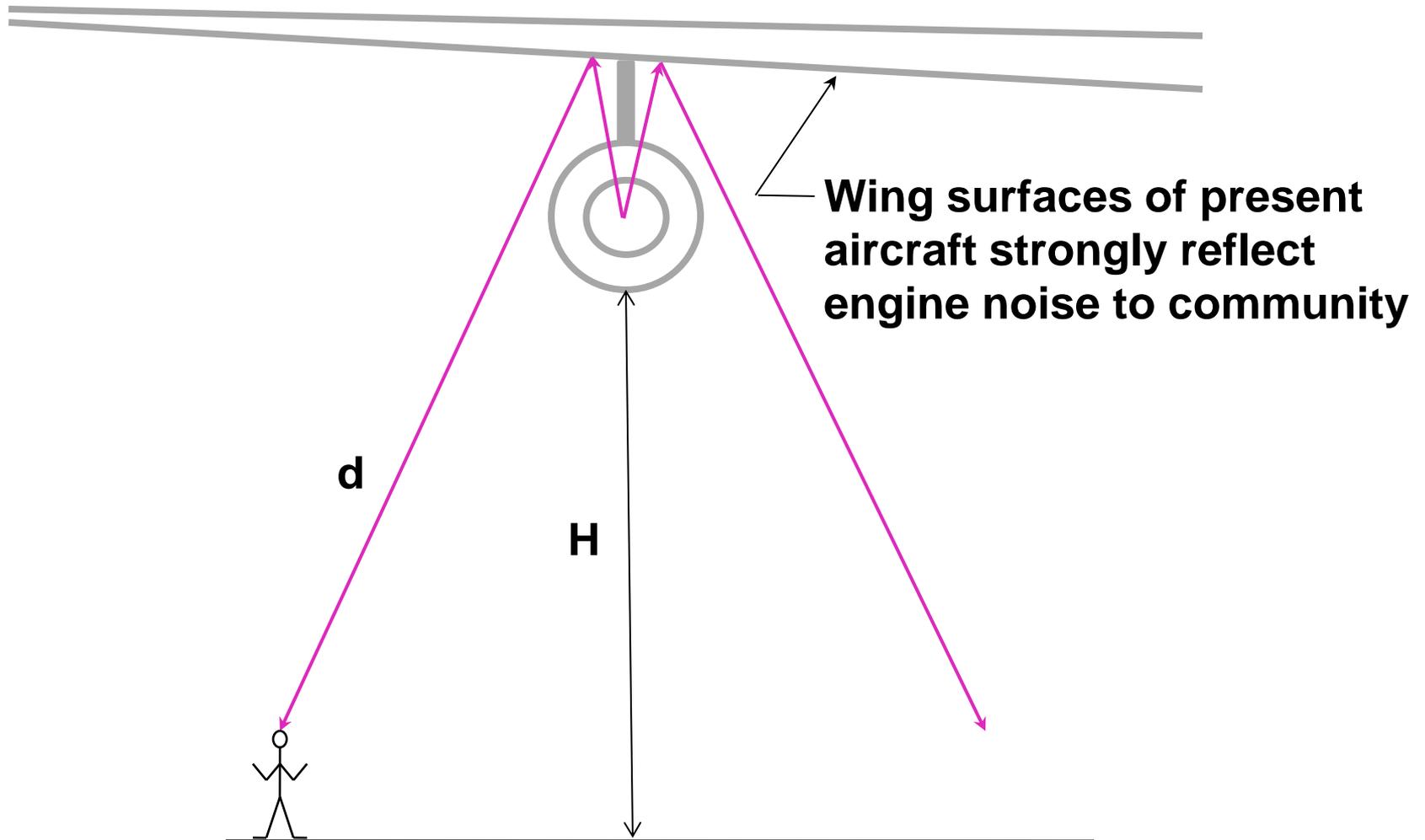


Fig.3- Not corrugated wing skin

## 4. Using of Junkers corrugated wing skin solution for noise scattering



Fig. 2-Aircraft with corrugated wing skin on pressure side, over engines

# 4. Using of Junkers corrugated wing skin for noise scattering

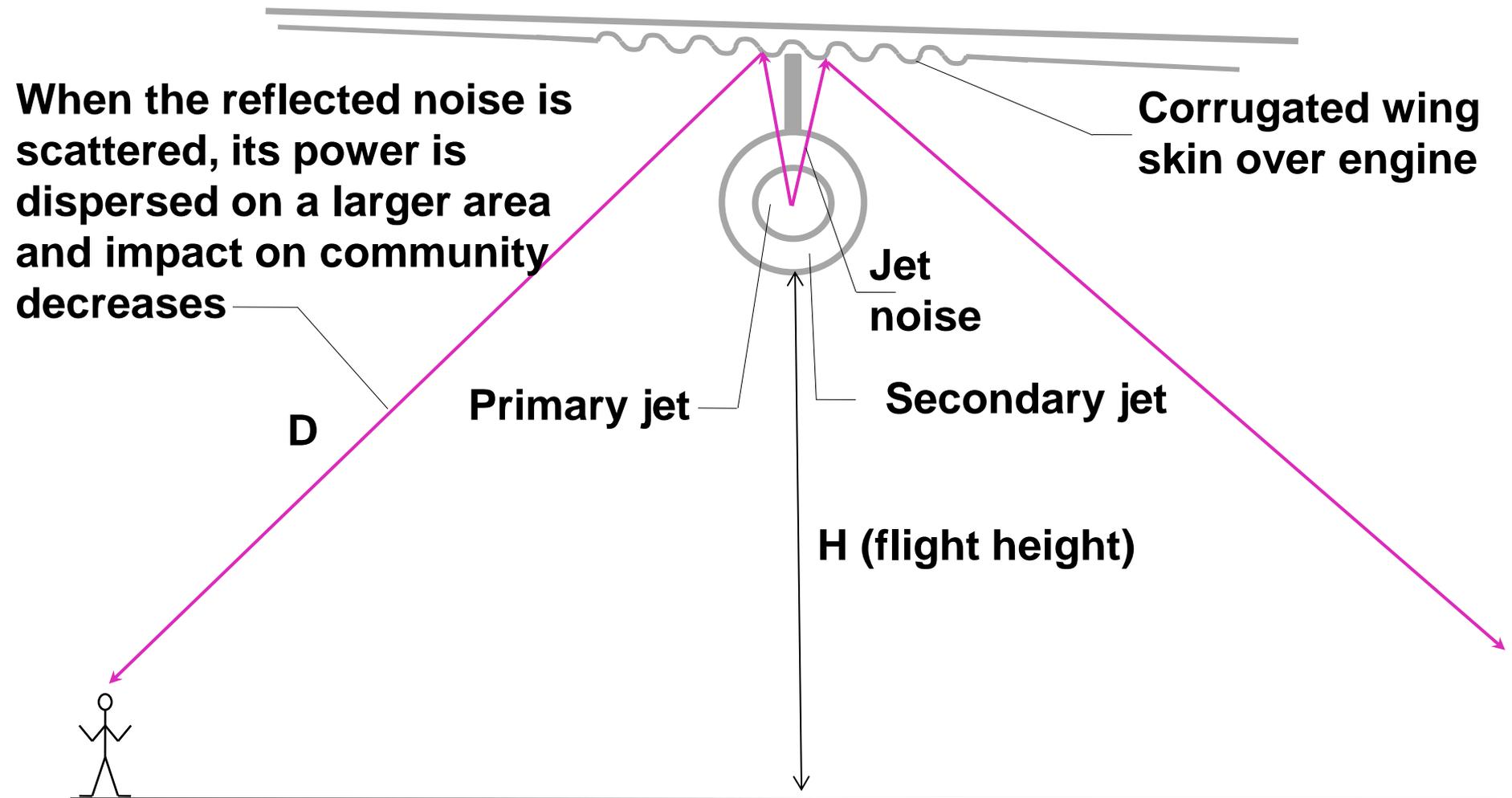
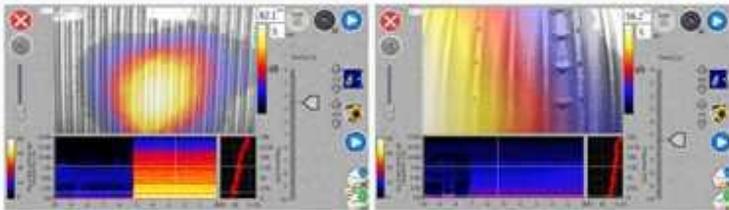
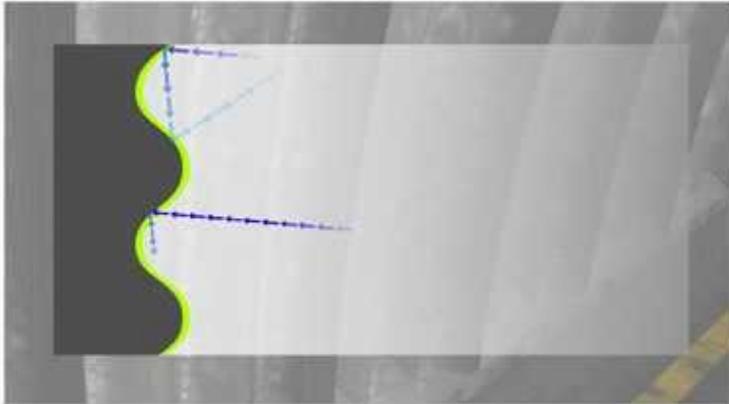


Fig.4 – The case of corrugated wing skin over engine

# 5. Experimental facts

- The problem of noise scattering produced by corrugations is very complicated [1]
- In some practical cases (corrugated auto-tunnels) a 30% noise reduction was measured [2] (fig.5a)

Corrugates Steel Plate Noise Barrier Tunnel  
Diffused Reflection



Verification by Sound Camera Video Technique  
(Acoustic Camera, Noise Indicator, ACOEM, Germany)



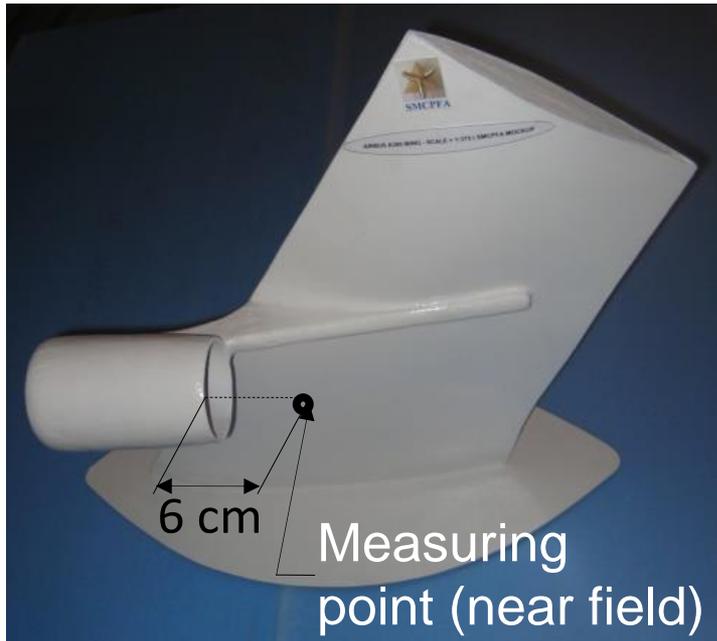
**Fig.5a – Noise reduction in corrugated tunnels [2]**

[1]-Jean-Marie Chesneau, Armand Wirgin, Reflection from a corrugated surface revisited, 1994

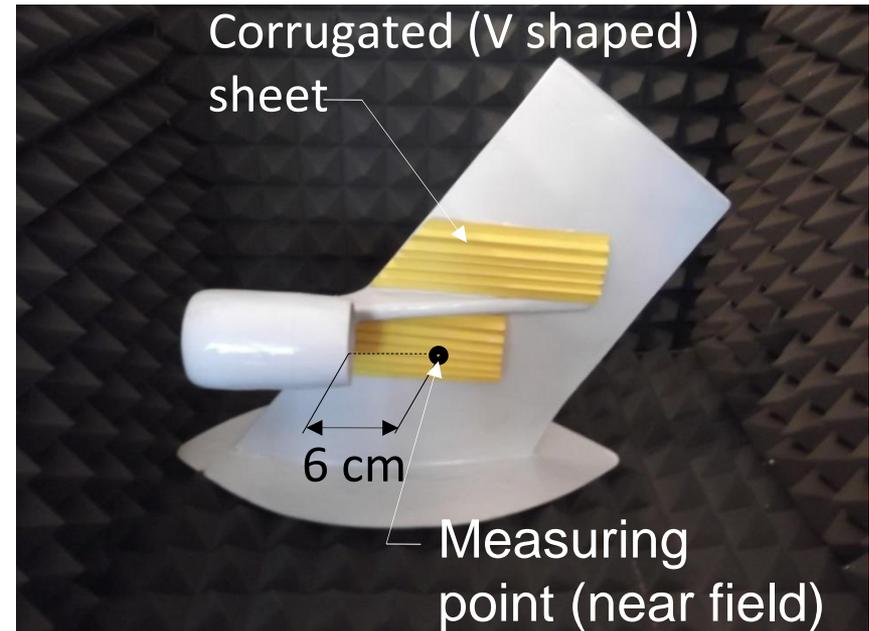
[2]-<http://www.fixoninc.com/>

# 5. Experimental facts

- Experiments at very low scale (1:375) on an Airbus A380 mock-up shown a 4 dB noise reduction when a corrugated (V) shaped sheet was applied on the pressure side of wing (fig.5b).



**Measured noise without V shaped sheet reflector: 82 dB(jet noise + wing reflection)**



**Measured noise with V shaped sheet reflector: 78 dB (jet noise + wing reflection)**

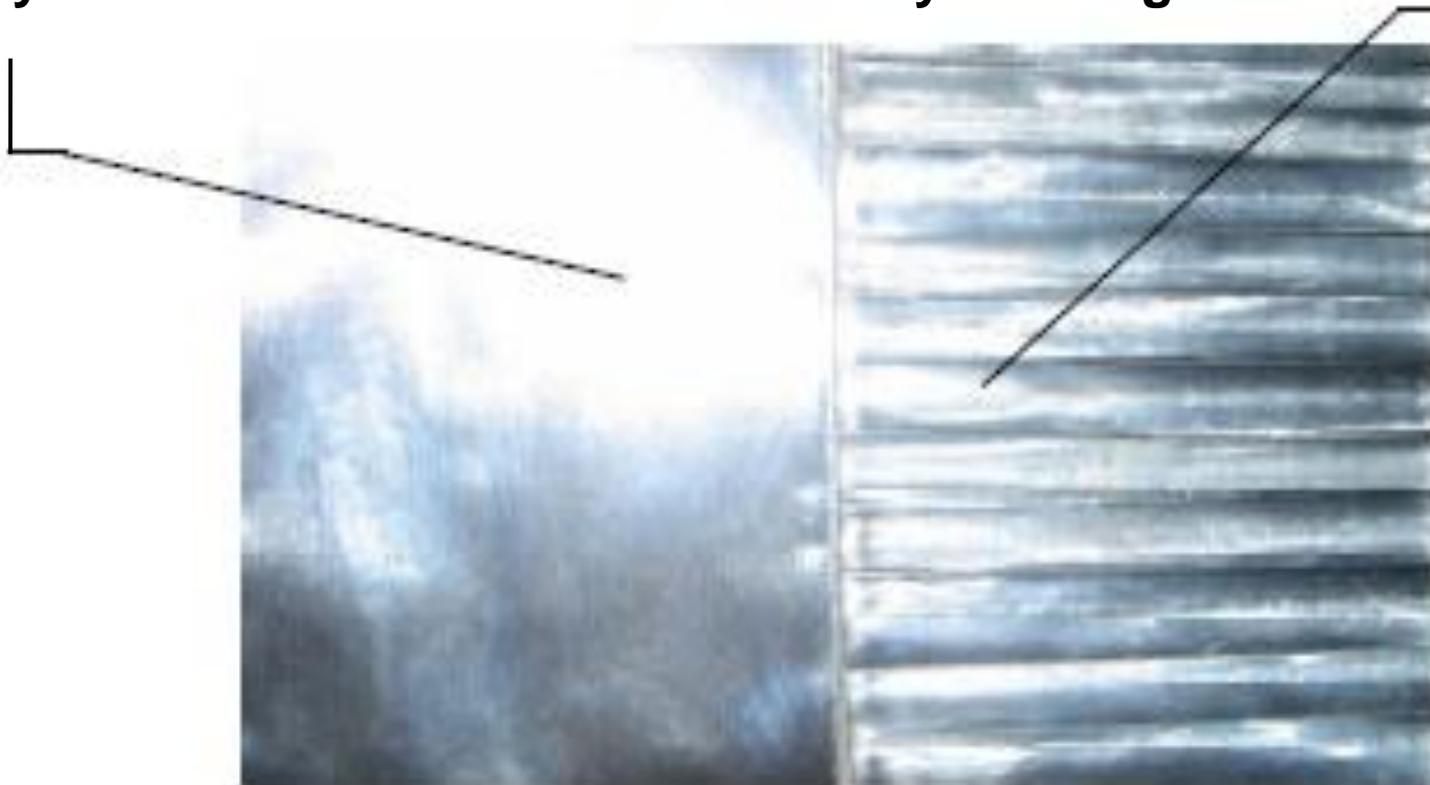
**Fig.5b – Noise reduction by a corrugated (V shaped) pressure side (Airbus A380-scale 1:375)**

# 5. Experimental facts

- Intuitive experiments were done using a concentrated light source. These experiments shown that the light is dispersed after reflection by a corrugated surface and its intensity decreases accordingly.

Reflection of concentrated light source by a flat reflective surface

Dispersion of concentrated light source by a corrugated surface



**Fig.5c – Intuitive experiment done with concentrated light reflected by a flat and a corrugated surface**

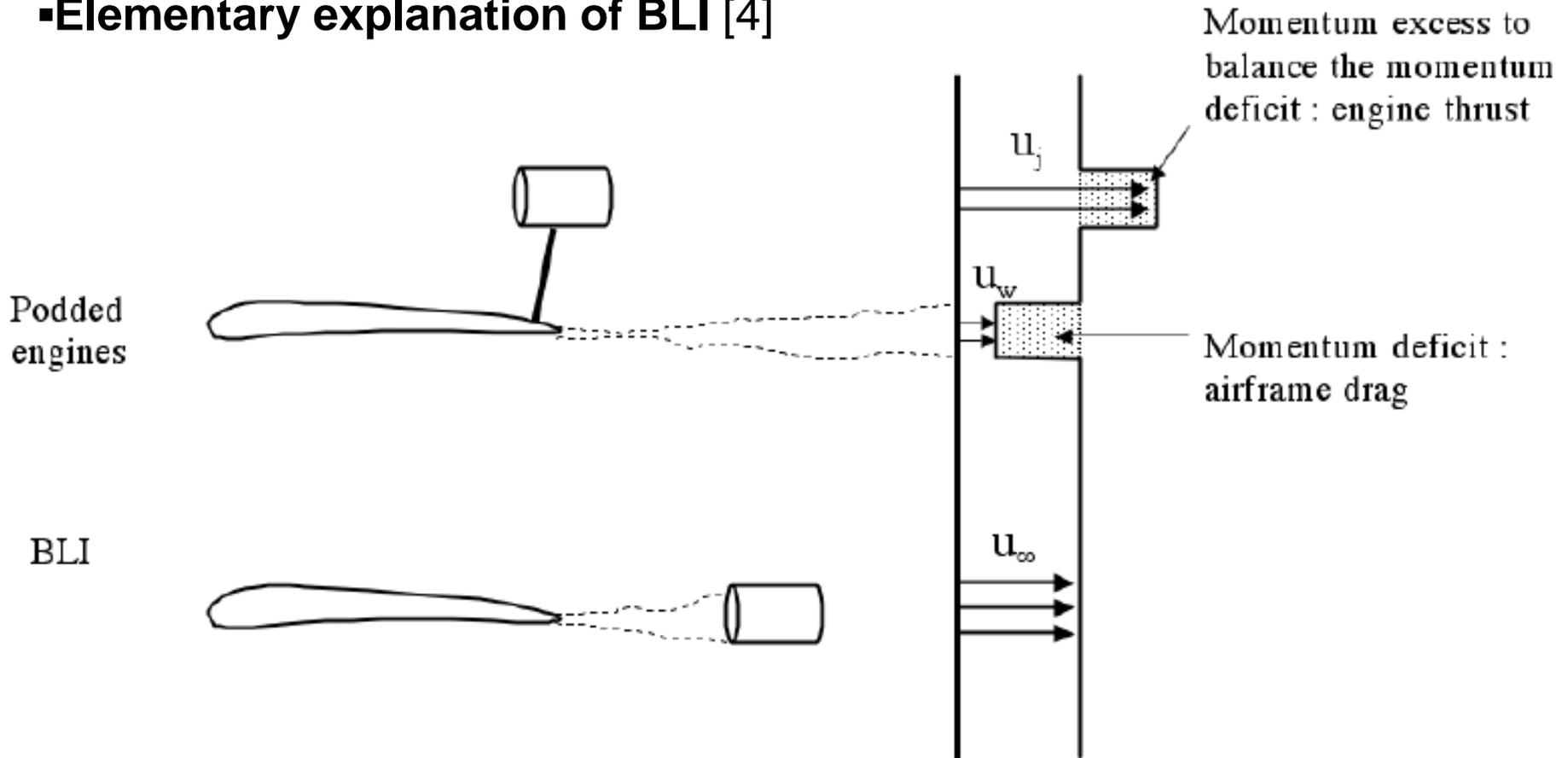
# 5. Experimental facts

- **Some experiments were done digging small longitudinal grooves aligned with the free-stream [3] in a body.**
- **These experiments shown that aerodynamic drag can be reduced (!) with 10%...20% when groves/corrugations are applied.**
- **In this way, corrugation of wing and fuselage skin leads simultaneously to noise reduction, dynamic drag reduction and aircraft strength increasing.**

[3]-A. Baron and M. Quadrio, Some preliminary results on the influence of riblets on the structure of a turbulent boundary layer, International journal of heat and fluid flow, 14(3): 223-230, 1993

# 6. The case of BLI

## Elementary explanation of BLI [4]



$$F_{engine} = \dot{m}(u_j - u_\infty) = \dot{m}(u_\infty - u_w) = D_A \quad F_{engine} = \dot{m}(u_j - u_w) = \dot{m}(u_\infty - u_w) = D_A$$

$$P_{no\ BLI} = \frac{\dot{m}}{2}(u_j^2 - u_\infty^2) = \frac{F}{2}(u_j + u_\infty)$$

$$P_{BLI} = \frac{\dot{m}}{2}(u_j^2 - u_w^2) = \frac{\dot{m}}{2}(u_\infty^2 - u_w^2) = \frac{F}{2}(u_w + u_\infty)$$

[4]-A. P. Plas, M. A. Sargeant, V. Madani, D. Crichton, E. M. Greitzer, T. P. Hynes, C. A. Hall, Performance of a Boundary Layer Ingesting (BLI) Propulsion System, 45th AIAA Aerospace Sciences Meeting and Exhibit, 8 - 11 January 2007, Reno, Nevada

## 6. The case of BLI

- In the case of BLI, corrugation of fuselage in the front of engine can be used for fan noise scattering

Fan noise is scattered by the corrugation of fuselage

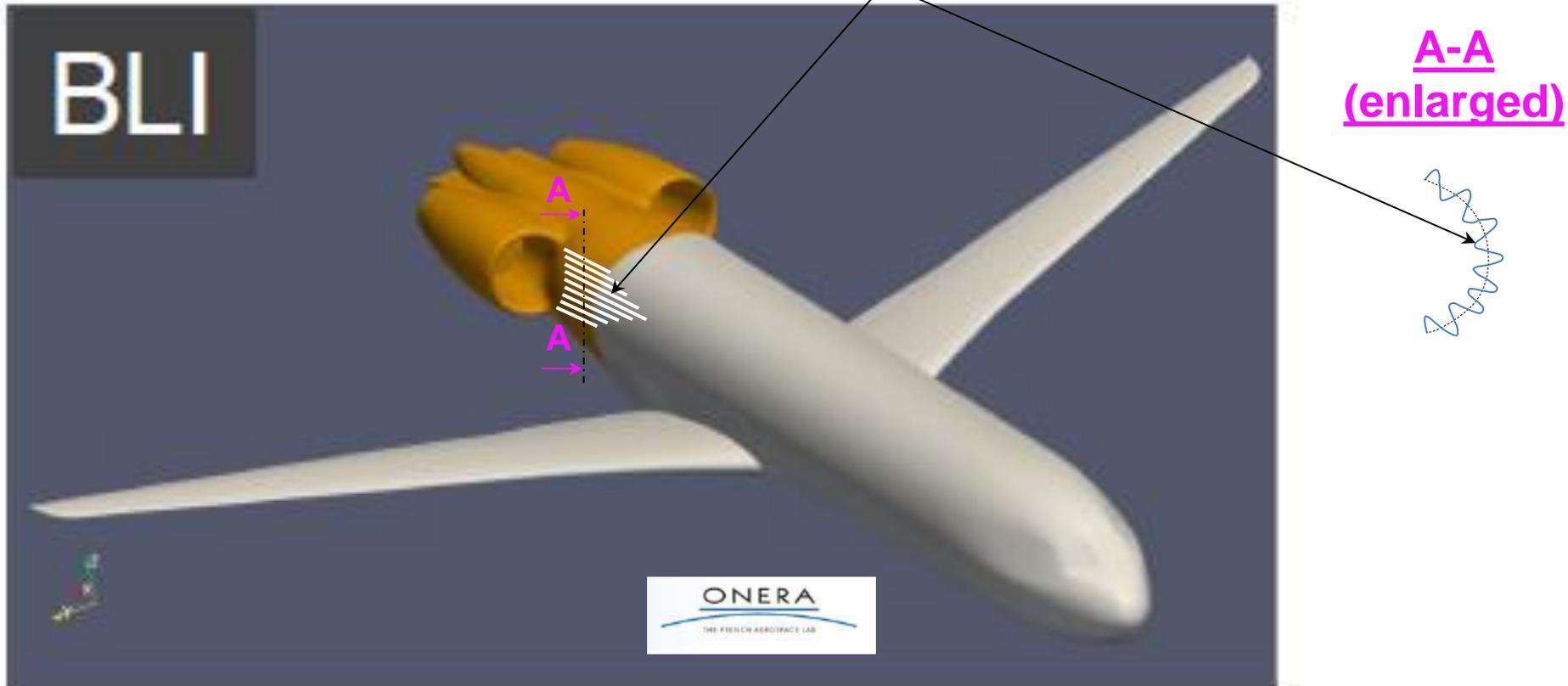


Fig.6 – Combined ONERA BLI solution with Junkers corrugations for fan noise reduction

# 7. Discussion on re-using of Junkers solution at future European aircraft

In future, reusing of Junkers solution can lead to:

- Reduction of total aircraft skin mass
- Increasing of aircraft strength
- Reduction of fan noise reflecting to community (fan noise, compressor noise, core noise, jet noise, airframe noise, LG noise) due to scattering of noise by corrugated wing and fuselage skin
- Reduction of aerodynamic drag

Using of Junkers corrugated skin on the lower side of aircraft fuselage and wing



# 8. Conclusions

- Using of wing corrugated skin over the engines leads to scattering of noise reflected to community by wing
- Measurements in corrugated auto-tunnels shown a 30% noise reduction inside tunnels due to scattering. Experiments done at very low scale Airbus wing (scale 1/375) shown that jet noise reflected by wing decreases with 4 dB in near field.
- Intuitive experiments done with a concentrated light source shown that reflected light is strongly scattered by a corrugated surface.
- For BLI solution issued by ONERA, the fan noise can be scattered if the fuselage skin is corrugated in the front of engines
- Re-using of Junkers solution on future European aircraft (mainly on the bottom side of aircraft) is productive for noise reduction, strength increasing ('crash resistant aircraft') and reduction of aerodynamic drag.