Airframe shielding of engine radiated noise : a numerical approach

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DASSAULT AVIATION

Plan

- *Falcon jets specific background*
- *New prediction tools in Dassault Aviation*
- *Example of engine noise shielding*
- *Conclusion and perspectives*

Falcon jets specific background

- ***More and more stringent noise constraints around airports :***
  - depend on airports (the closer to dense inhabited areas, the stronger the constraints)
  - night curfews at some airports
  - fines if maximum authorized levels are not respected
- ***Our customers seek flexibility in term of day slots and operate at community aiports where the noise constraints are the strongest***

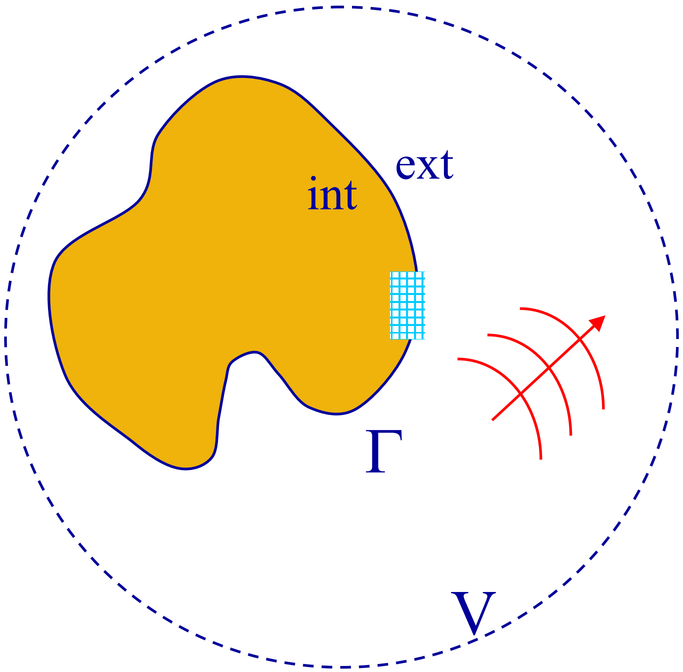
Challenge for engineers to cope with these requirements, noise criterion must be considered at early stages of A/C design

New prediction tools in Dassault Aviation

- ***Large effort to develop innovative noise prediction tools***
  - better handling realistic A/C configurations (nacelle geometry, fuselage and wing shielding …) ;
  - including acoustic treatment precisely.
- ***Applications***
  - Falcon aircrafts ;
  - SSBJ projects ;
  - military aircrafts.
- ***Current capacity***
  - engine noise shielding at A/C operating conditions ;
  - relative influence of shielding surfaces and acoustic treatment on the engine radiated noise.

Engine noise shielding

The Helmholtz equation is solved using surface discretization (BEM)



$$\Delta p + \frac{\omega^2}{c^2} p = 0 \text{ inside V}$$

$$\begin{cases} \dfrac{\partial p}{\partial n} = 0 \text{ on } \Gamma \text{ if hard wall} \\ or \ \dfrac{\partial p}{\partial n} = -\dfrac{i\omega p}{Z(\omega)} \text{ on } \Gamma \text{ if liner} \end{cases}$$

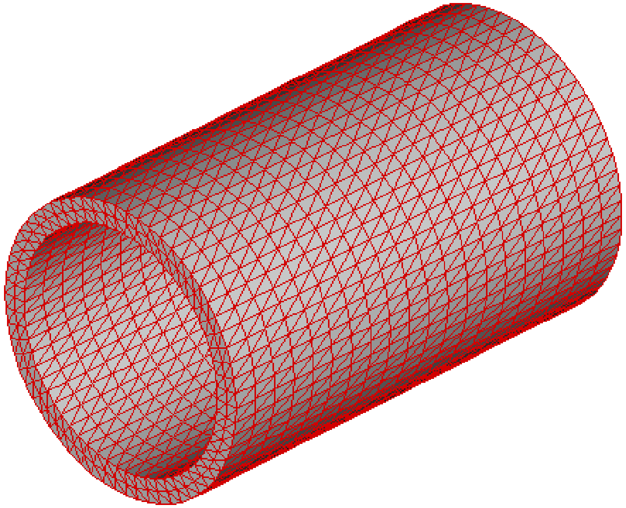
Outgoing spherical waves in the far-field (Sommerfeld condition)

$$p = p_{inc} + p_{sc}$$

p_{inc} is the input (source term), p_{sc} is the unknown

Engine noise shielding
Finite element discretization

P1 shape functions : $p_{sc}(\vec{x}) = \sum_{j=1}^{N} p_j N_j(\vec{x})$



ex : Hard wall case

$$\int_{\Gamma} \left(\frac{\partial p}{\partial n}\right)_{\text{inc}} (\vec{y})\, N_{\text{i}}(\vec{y}) dS(\vec{y}) =$$

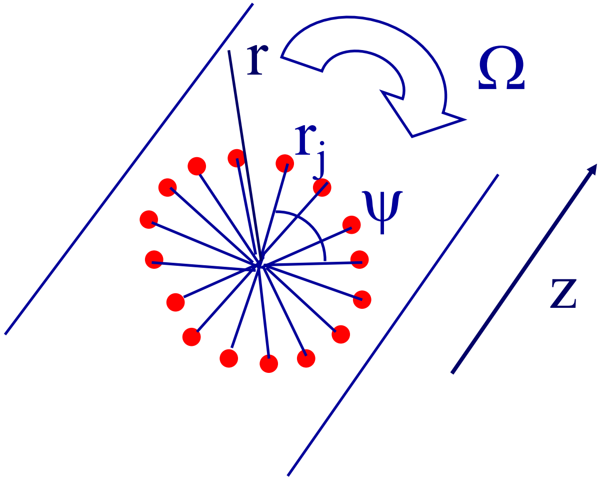
$$\sum_{j=1}^{N} \left(\iint_{\Gamma} G(\vec{x}-\vec{y}) \overrightarrow{rot}_{\Gamma} N_{\text{i}}(\vec{y}) \cdot \overrightarrow{rot}_{\Gamma} N_{\text{j}}(\vec{x}) dS(\vec{x}) dS(\vec{y}) \right.$$

$$\left. + k^2 \iint_{\Gamma} G(\vec{x}-\vec{y}) N_{\text{i}}(\vec{y}) N_{\text{j}}(\vec{x}) \vec{n}_x \cdot \vec{n}_y dS(\vec{x}) dS(\vec{y}) \right) p_j \quad \forall i, j = 1, \ldots, N$$

$$AX = B \quad \text{with} \quad X = \left(p_j\right)_{j=1,N}$$

Engine noise shielding
Acoustic sources

Incident pressure field generated by modal monopoles or dipoles



$$p_{\text{inc}}(r,z,\psi,t)=\sum_{m=-\infty}^{+\infty} Q^m(r,z)e^{im(\Omega t-\psi)}$$

Ex : dipoles

$$Q^m(r,z)=-\frac{1}{4\pi^2}\int_0^{\pi}\frac{\cos(m\psi')}{R^3}z(1+ikR)e^{-ikR}d\psi'$$

$$R=\sqrt{r^2+r_j^{\,2}-2rr_j\cos\psi'+z^2}$$

Engine noise shielding
SPECTRE 90 in house code

- ***Very fast and robust BEM implementation :***
  - modular approach ;
  - accurate numerical scheme ;
  - parallel matrix assembly.
- ***Out of core linear solver : problem size is only limited by disk storage capacity (current capacity > 200000 dof) ;***
- ***Efficient external pre and post processing in MATLAB environment.***

Engine noise shielding

Comparison of noise levels emitted by the side and central engines of a Falcon aircraft

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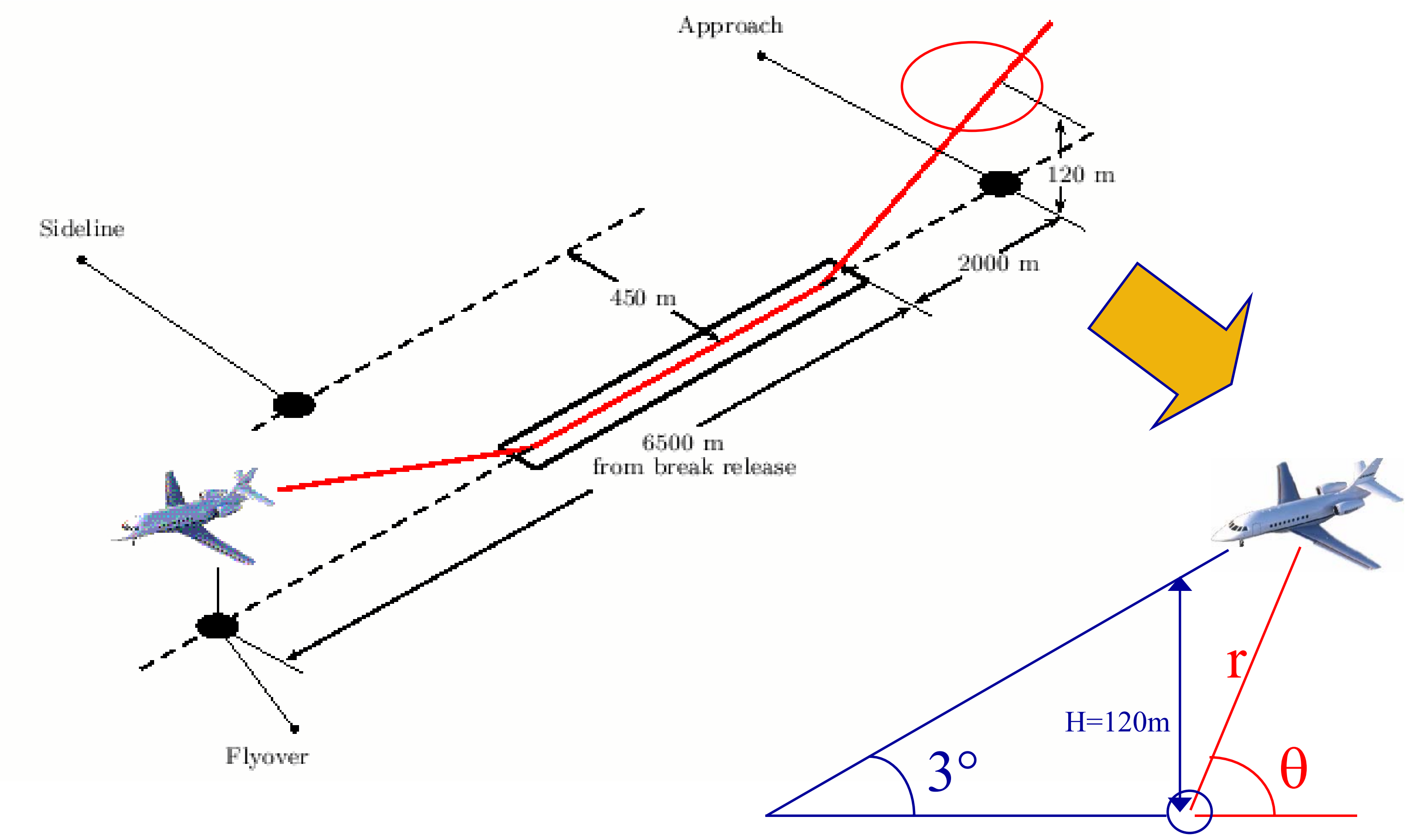
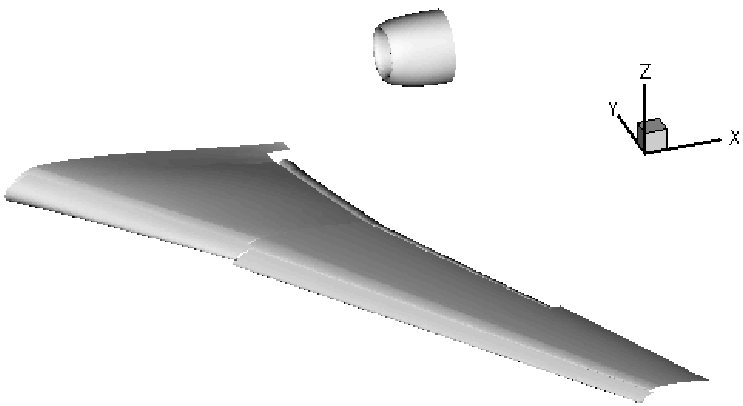
Assumptions for numerical predictions :

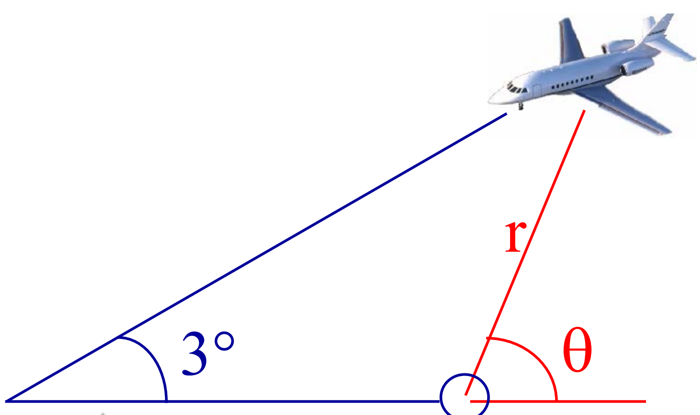
- only one frequency is considered : fan blade passing frequency (BPF) = 2.5 kHz ;
- acoustic treatment in the inlet for the side engines ;
- no mean flow effect ;
- all the comparisons are made relatively with the same dipole sources, only the geometries or the acoustic treatment differ ;
- the engine aft radiation is not considered ;
- only cut-on modes are taken into account, all carrying the same amount of energy ;

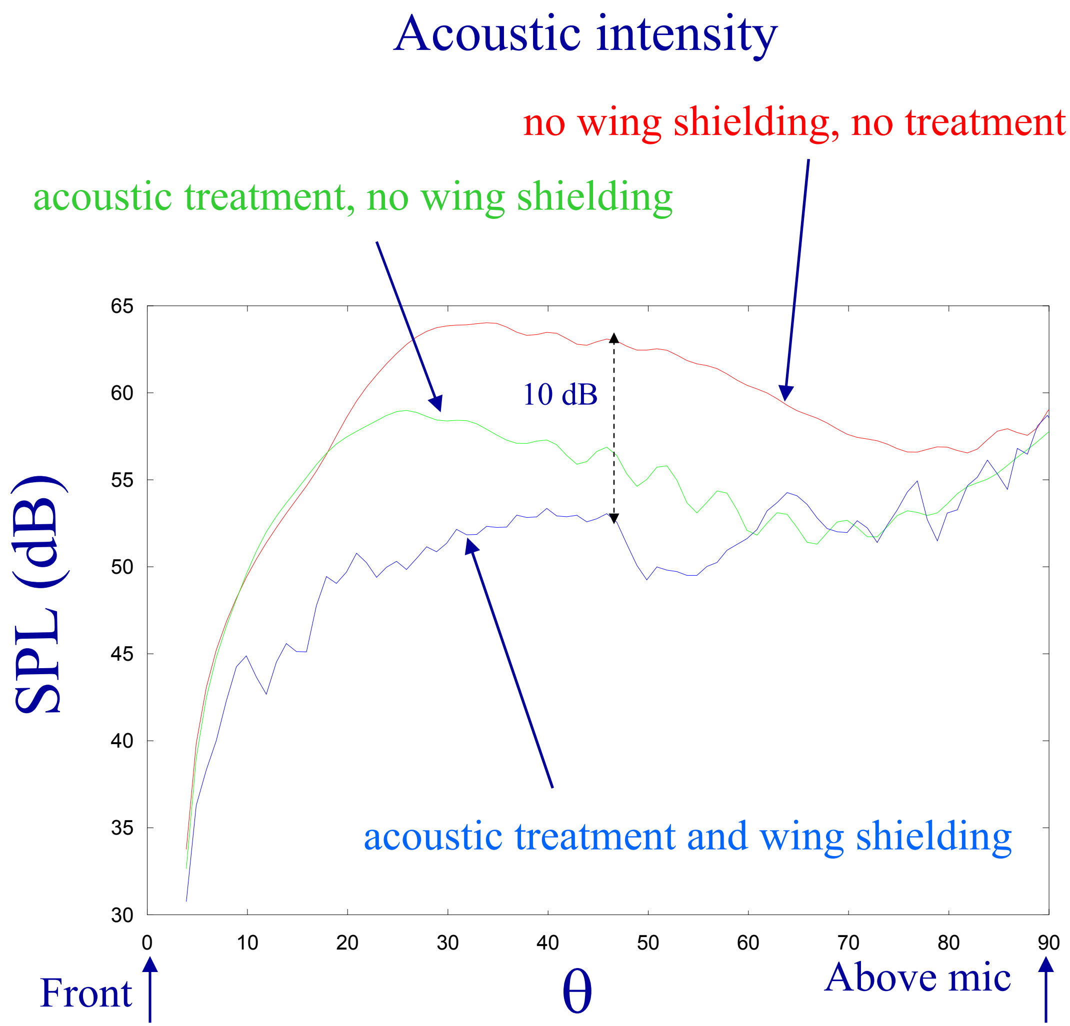
- ***noise directivities are computed along a reference flying path at approach :***



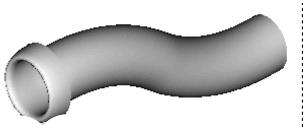
Side engine : effect of acoustic treatment and wing shielding

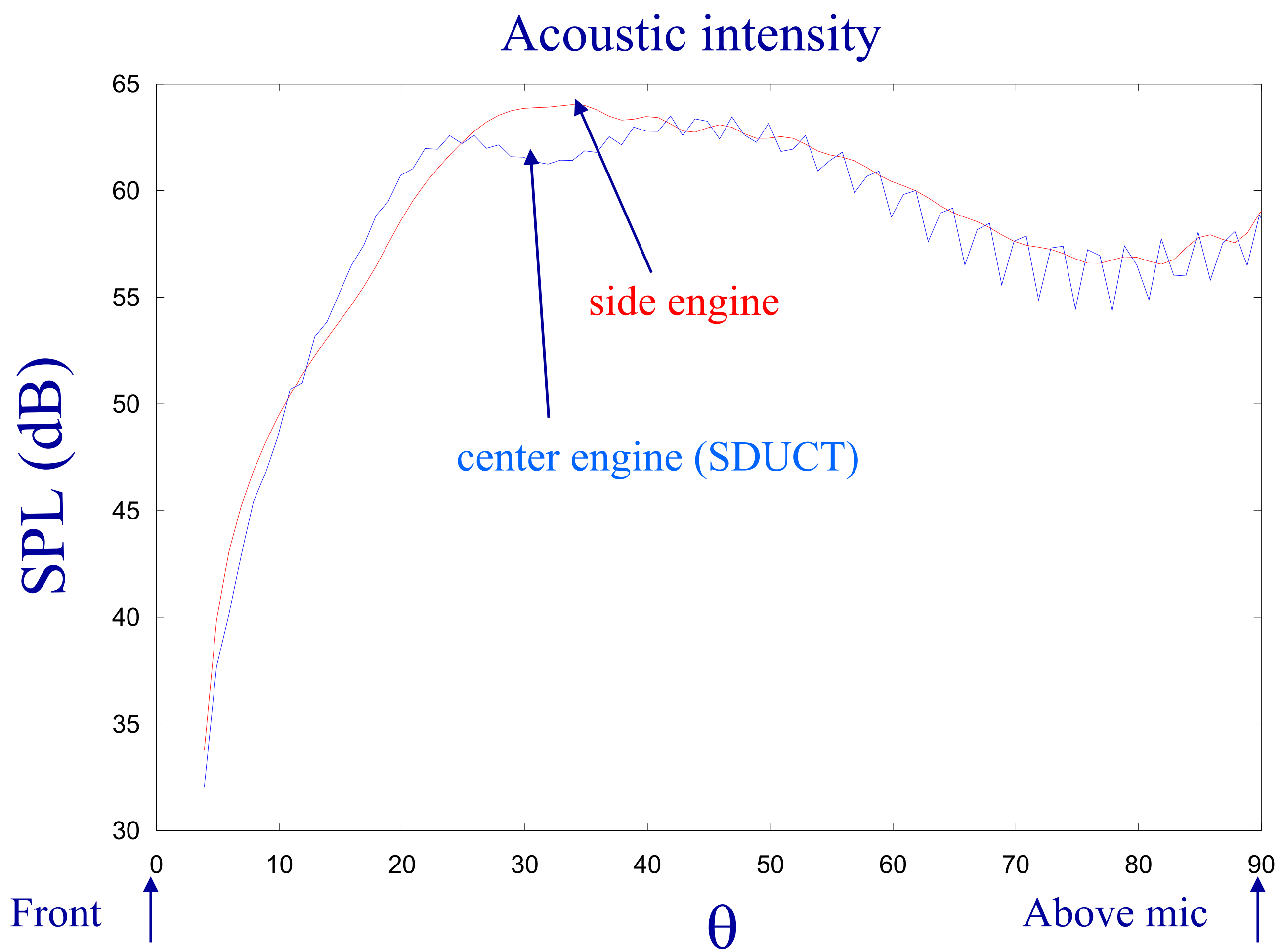






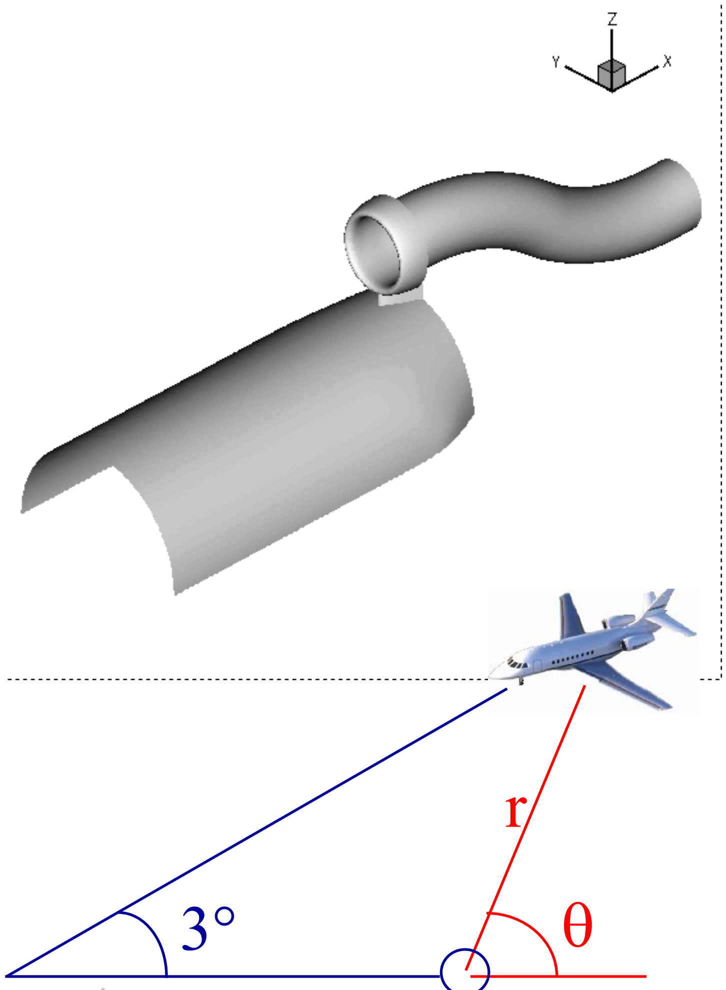
Effect of central engine nacelle geometry

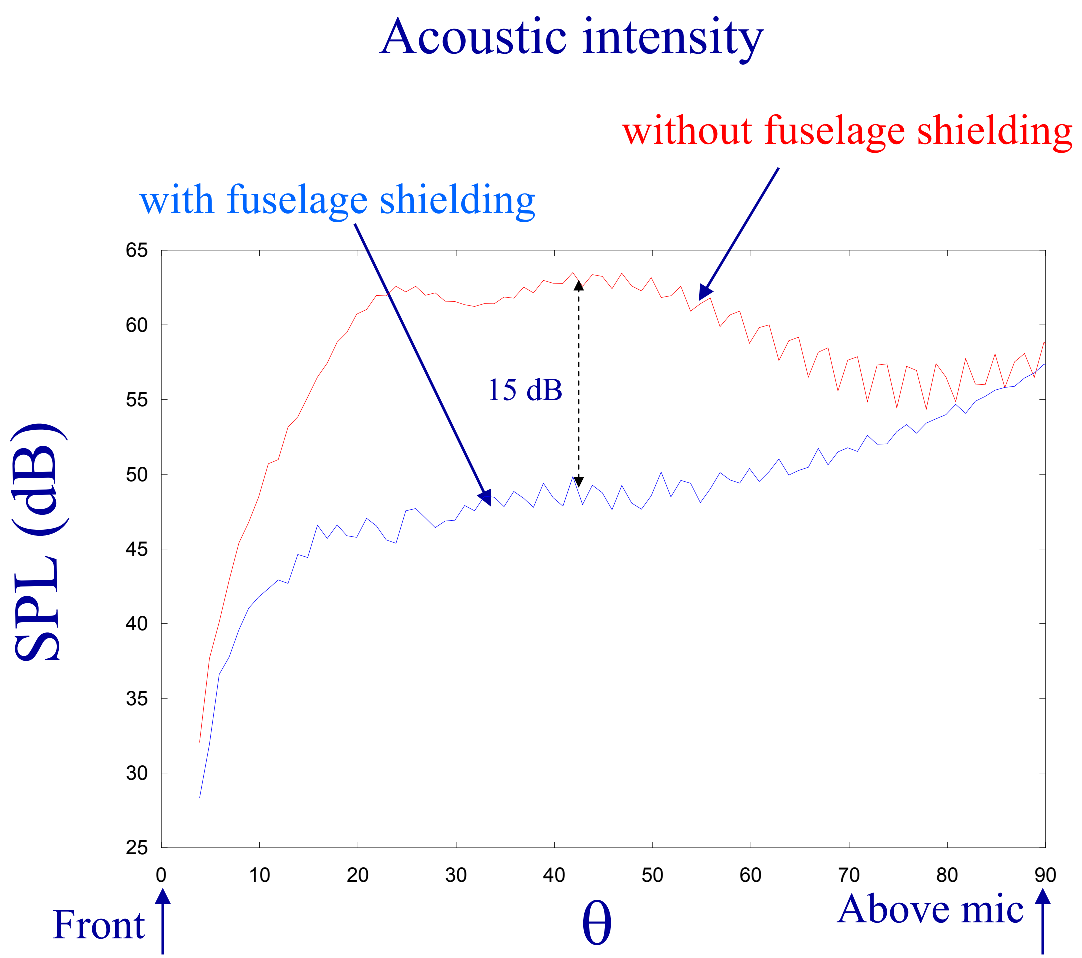




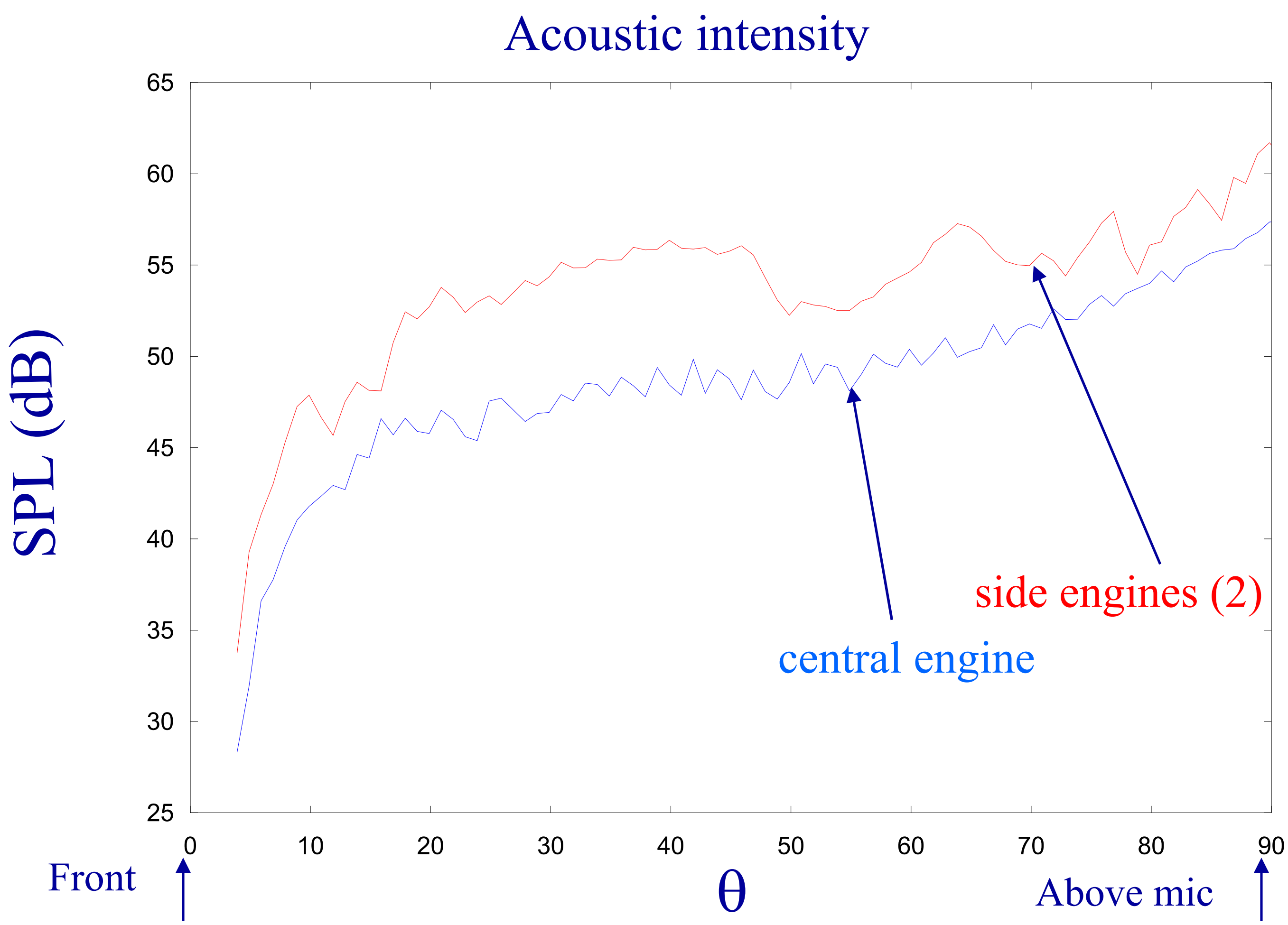
Small effect of SDUCT geometry on noise radiation

Central engine : effect of fuselage shielding (no treatment)





Comparison between side engines radiation and central engine radiation (with shielding and acoustic treatment)



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Conclusion and perspectives

- ***Efficient implementation of BEM in SPECTRE 90 code ;***
- ***Preliminary application to a FALCON aircraft : engine noise airframe shielding :***
  - The additional length of the center nacelle (Sduct) has a very small effect on the acoustic levels (compared to shielding effects and acoustic treatment effect) ;
  - At the approach condition, the center engine is less noisy without treatment than the side engines with treatment (strong fuselage shielding of the center engine radiation).
- ***Results to be compared with experimental data (static and flight tests);***
- ***Investigation of new engine installation concepts in progress (ex : NACRE project).***