Numerical simulation of the noise and interactions of a supersonic twin jet configuration

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Context and objectives
During lift-off, the hot, supersonic jets exhausting from the rocket engines of space launchers produce acoustic pressure fluctuations which are high enough (up to 180 dB) to damage the launch pad and the payload. Predicting the corresponding pressure levels requires taking into account interactions effects between the different jets, including acoustic shielding, interaction noise and twin jet resonance [1, 2]. The present post-doctoral work aims at characterizing these effects in a simplified twin, free jet configuration using high-fidelity numerical simulations.

Jet parameters
They are close to those of the MARTEL experiment [3]:
- Mach number $M_j = u_j/c_j = 3$, overexpanded conditions
- Total temperature $T_0 = 2000 \, \text{K}$
- Twin jet separation $h = 2.8D$, with $D$ the jet diameter
- Reynolds number $Re_D = \rho_j u_j D/\mu_j = 200000$

Numerical methods
The large-eddy simulations (LES) are carried out by solving the compressible Navier-Stokes equations using high-order finite differences with low dispersion and low dissipation [4].

Three cylindrical meshes are used:
- two narrow cylindrical grids, one for each jet
- one large cylindrical grid overlaying the others

The flow variables are passed from one grid to another using Lagrangian interpolation of order $N = 10$, e.g.

$$\rho(r, \theta) = \sum_{i=0}^{N} \sum_{j=0}^{N} l_i(\theta) l_j(\theta) \rho(r_i, \theta_j)$$

Preliminary results
Static temperature (left) and pressure fluctuations (right)
- Single jet
- Twin jet
color scales: 293 K to 1000 K (left) and $10^5 \pm 20000 \, \text{Pa}$ (right)

Conclusion and perspectives
- A CFD code able to accurately simulate the flow and sound fields of supersonic twin jets has been developed.
- Future work will focus on the characterization of interaction effects, and notably on the influence of the nozzle spacing $h$.