A Visual Introduction to Turbulence and its Prediction in CFD

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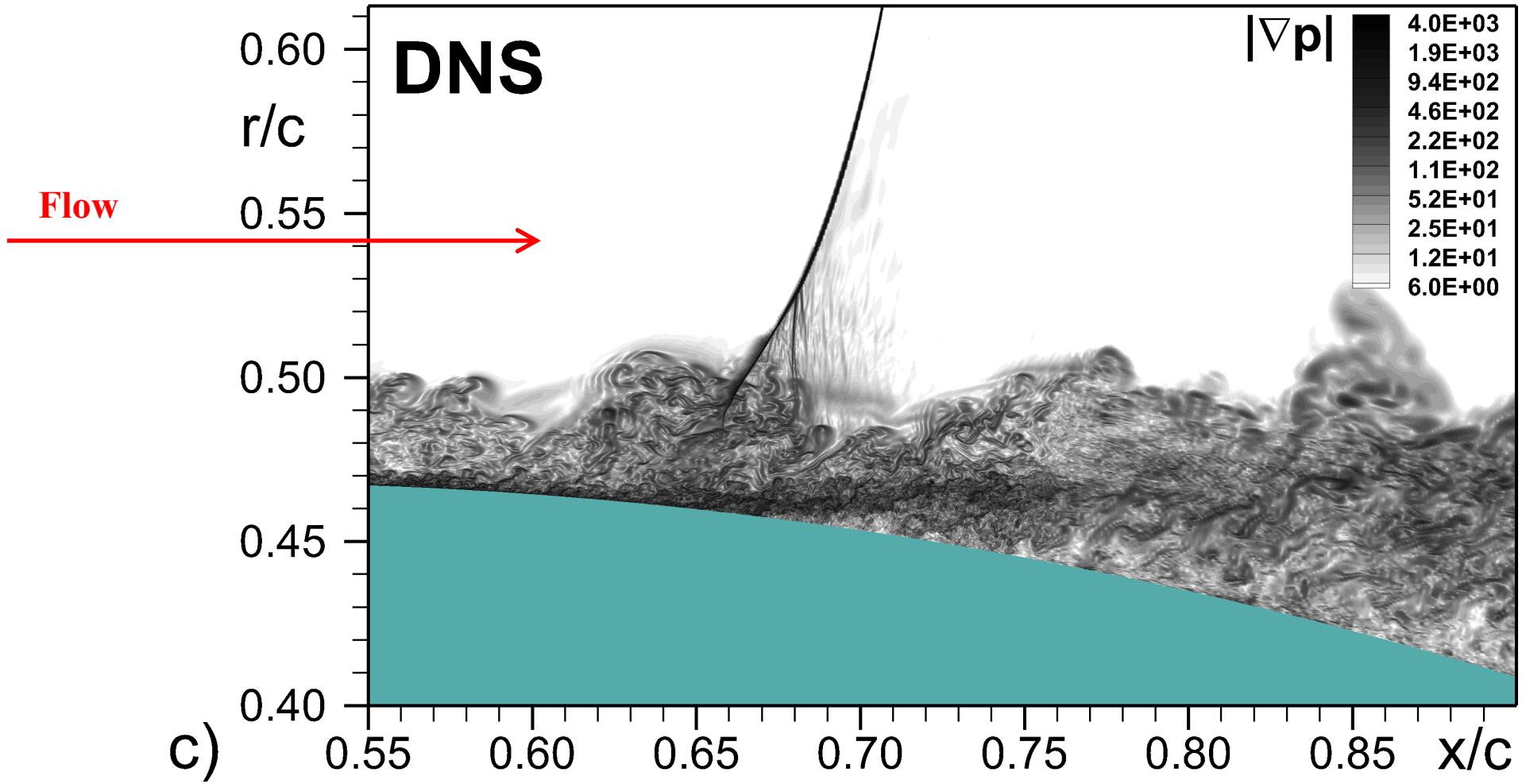
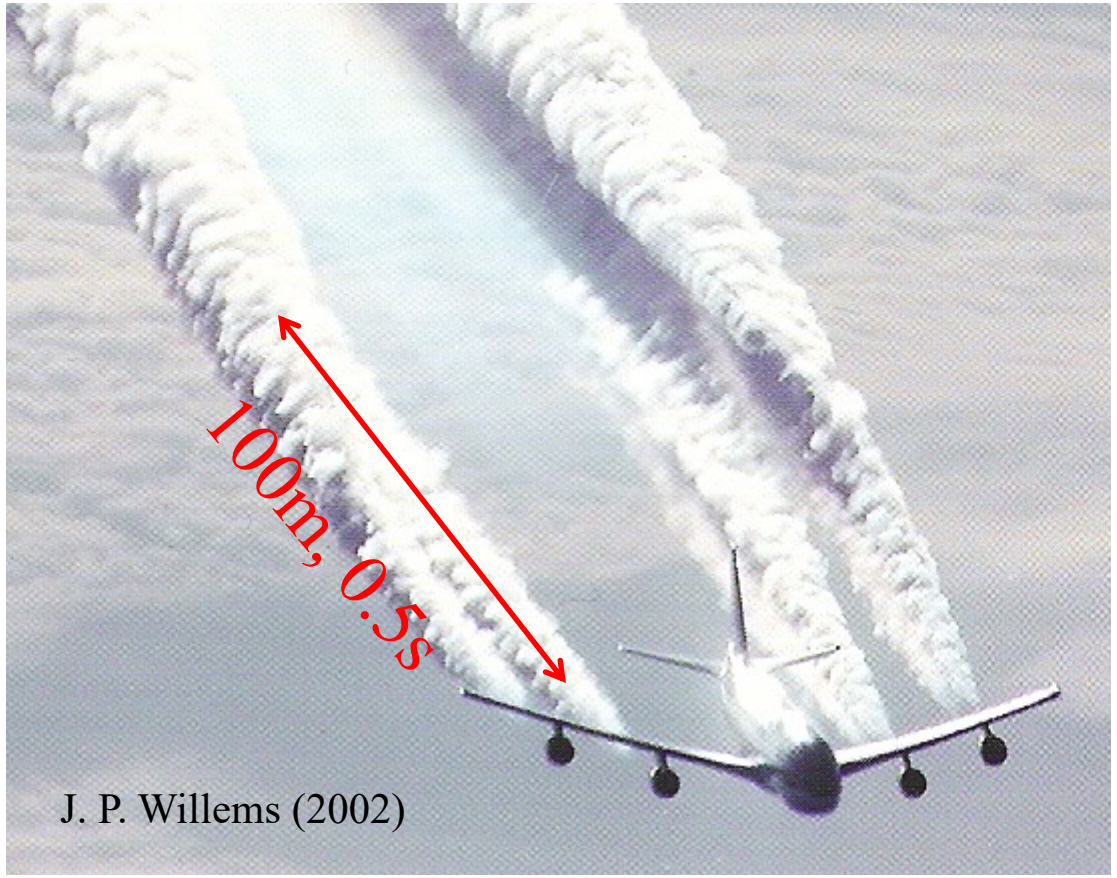
Direct Numerical Simulation of a Turbulent Boundary Layer

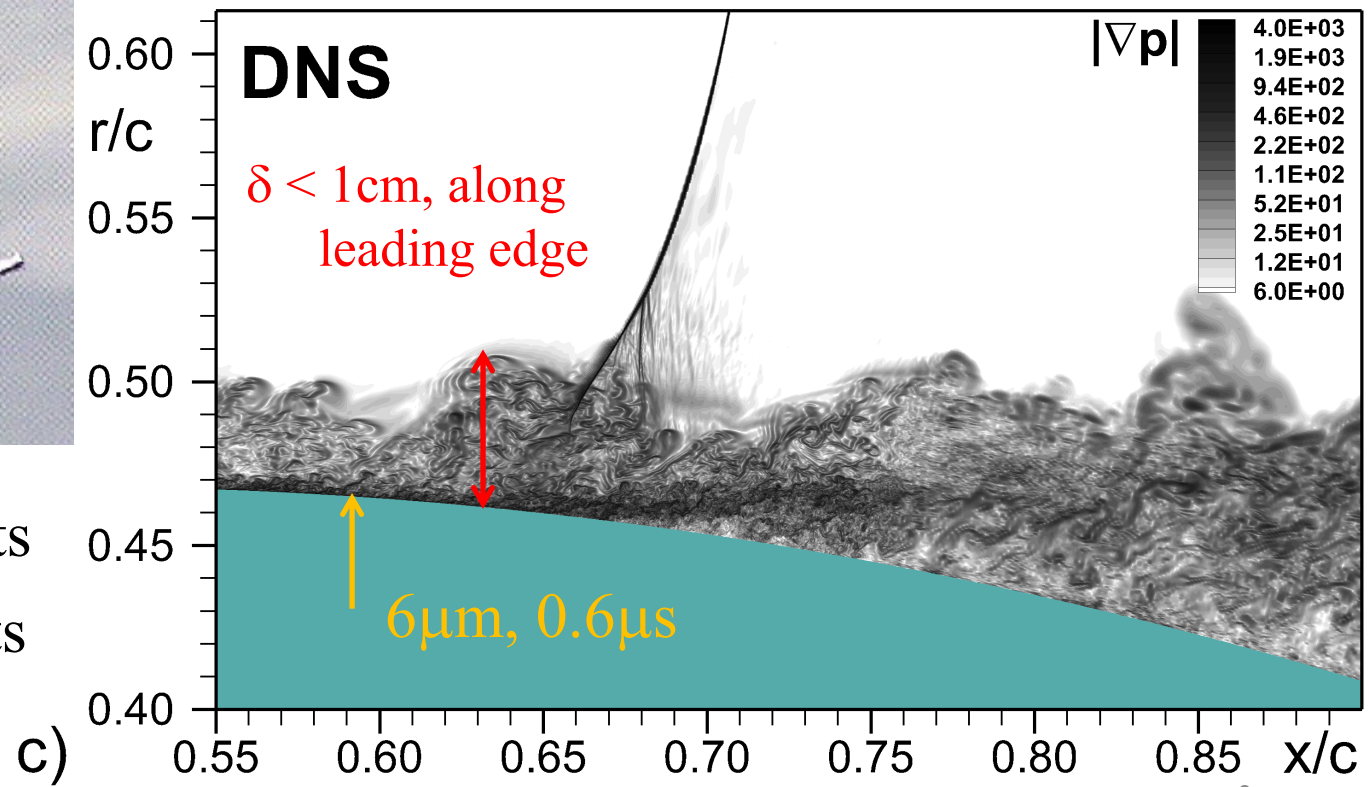
- Work of Strelets group, in St. Petersburg, funded by Boeing
- Solution of the Navier-Stokes equations with billions of grid points



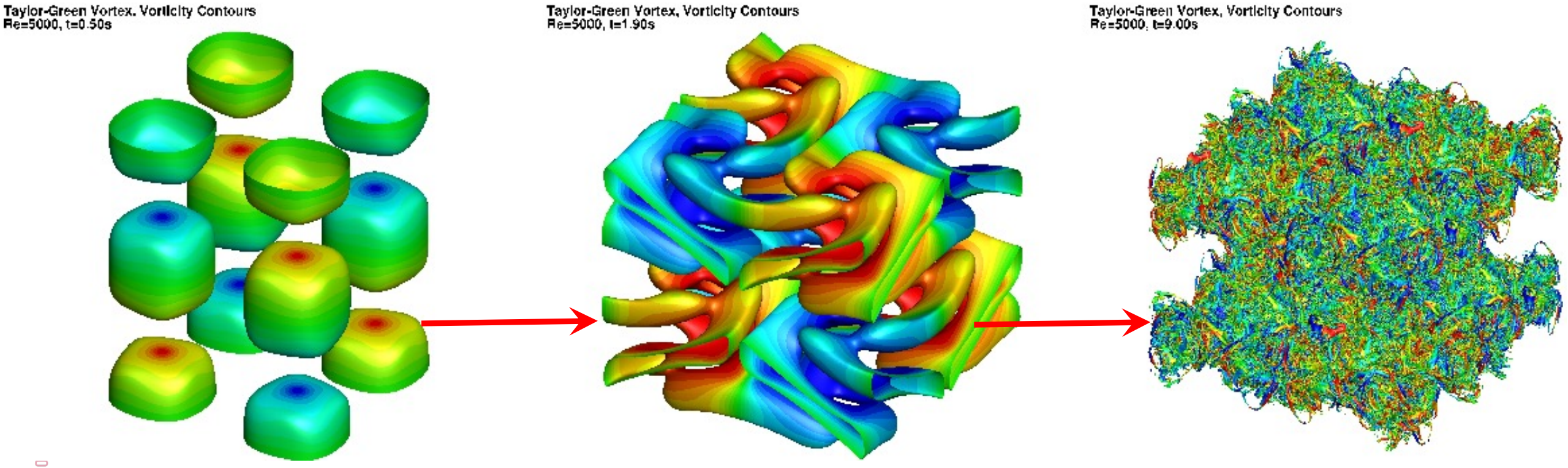
The Range of Scales of Turbulence Around an Airliner



- Brute-force approach: ~ 10^{24} grid points
- Largest simulations today: ~ 10^{10} points



The Energy Cascade in Turbulence



- Taylor-Green Vortex DNS by Beck and Gassner, 2012. Periodic geometry
- The Navier-Stokes equations “turn potatoes into spaghetti”
- In 1941, Kolmogorov had a simple theory, predicting the “$k^{-5/3}$ spectrum”
- Reynolds number is 1600, compared with 10 million for airplane boundary layer

Reynolds-Averaging of a Turbulent Flow Field

- Work of Strelets group
- Large-Eddy Simulation (LES) calculates the flow field on the left. 3D, unsteady
- The Reynolds-Averaged Navier-Stokes (RANS) method calculates the flow field on the right
- It's Turbulence Modeling, here 2D, steady, symmetric, smooth