Closed-loop turbulence control is a rapidly evolving, interdisciplinary field of research. The range of current and future engineering applications has truly epic proportions, including cars, trains, airplanes, jet noise, air conditioning, medical applications, wind turbines, combustors, and energy systems.

We review successful control studies of flows around airfoils and bluff bodies at high Reynolds numbers in experiments and simulations. These studies achieve beneficial changes of the mean flow (0 Hz) for lift enhancement or drag reduction via suppression of an instability at a natural frequency by exciting instabilities at lower or higher frequencies. This strongly nonlinear interplay between vanishing, natural, and actuation frequencies is incorporated in a generalized mean-field model and exploited for control design. It cannot be described in any linear(ized) model.

Building on these results, we pursue a model-based strategy for closed-loop manipulation of broad-band turbulence dynamics, i.e. the control of a rich kaleidoscope of such nonlinear interactions. This strategy starts with robust control-oriented low-order Galerkin models. Using these models, the first and second moments are predicted with statistical closures employing finite-time thermodynamics and maximum entropy concepts. These closures incorporate natural and controlled dynamics, i.e. enable fully-nonlinear infinite horizon control. The ultimate goal is a general mathematical theory for turbulence control in experiments.

The talk comprises joint work with Boye Ahlborn, Marek Morzyński, Robert Niven, Gilead Tadmor, Michael Schlegel, the former Collaborative Research Center SFB 557 'Control of complex turbulent shear flows' at TU Berlin and Institute PPRIME (Poitiers, France).

Bernd Noack develops closed-loop flow control solutions for cars, airplanes and transport systems — in an interdisciplinary effort with Institute PPRIME (Poitiers, France), the groups of M.W. Abel, H.-C. Hege, M. Morzyński, R.K. Niven, C.O. Paschereit, M. Schlegel, G. Tadmor and other colleagues. One key for efficient turbulence manipulation is a novel concept of attractor control — synergizing reduced-order modeling (ROM) for fluid flows, nonlinear dynamics, statistical physics and control theory.

Since 2009, he has been Director of Research CNRS at Institute Pprime and was awarded with an ANR Chair of Excellence. Past affiliations include TU Berlin, UTRC, Max-Planck Society, German Aerospace Center and University of Göttingen. He has co-authored more than 100 publications, 2 patents and 1 book on ROM and flow control. Dr. Noack’s research achievements have been acknowledged by German, French, European, American and even Australian honors — including the 2005 Richard von Mises award from the International Association of Applied Mathematics and Mechanics (GAMM).