The Challenge of Non-equilibrium Turbulence

C. M. Velte[a], Azur Hodzic[a], Haim Abitan[a], Peder J. Olesen[a], Martin Schiødt[a], Simon L. Ribergaard[a] and P. Buchhave [b]

One of the most pressing challenges in the theory and modelling of turbulence is the mathematical description of non-equilibrium turbulence (NET). Surveying the field, we find that the approach to NET falls in widely different "families". We briefly describe the different methodologies, and, considering John Lumley's well known quote that we need to consider "the mechanism that sets the level of ***dissipation*** in a turbulent flow, particularly in ***changing circumstances***", we can distinguish between "rapid distortion theory", methods that modify the classical Taylor-Kolmogorov relation for equilibrium dissipation, approaches using Lie-theory to describe the path to self-similar conditions and even methods equivalent to classical non-equilibrium statistical mechanics.

Following this introduction, we describe some of our own theoretical and experimental results and conclude by describing our new experimental facilities that aim at a fully three-dimensional measurement of both large-scale energy containing structures and the smallest scales from the inertial structures and down well into dissipation dominated scales.

Equally important, we describe the theory framework developments that make possible the dynamic modal analysis of such flows in a robust manner. With these results, it will be possible to test the actual non-linear energy exchange mechanisms (whether following the Richardson cascade/local or non-local interactions) and how these processes are affected by the (controllable) degree of non-equilibrium of the flow. Hence, it will be possible to quantify the degree of non-equilibrium under various accelerations by direct measurements of the full instantaneous dissipation rate. At the same time, the processes that lead to that level of dissipation can be mapped out using analysis of the modal dynamics.

[a] Dep. of Civil and Mechanical Engineering, Technical University of Denmark

[b] Intarsia Optics, Sønderskovvej 3, 3460 Birkerød, Denmark

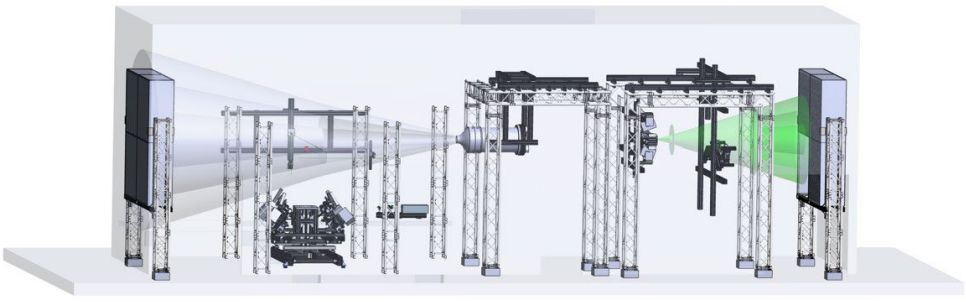

Figure 1. Drawing of the DTU Turbulence Research Laboratory Facilities.