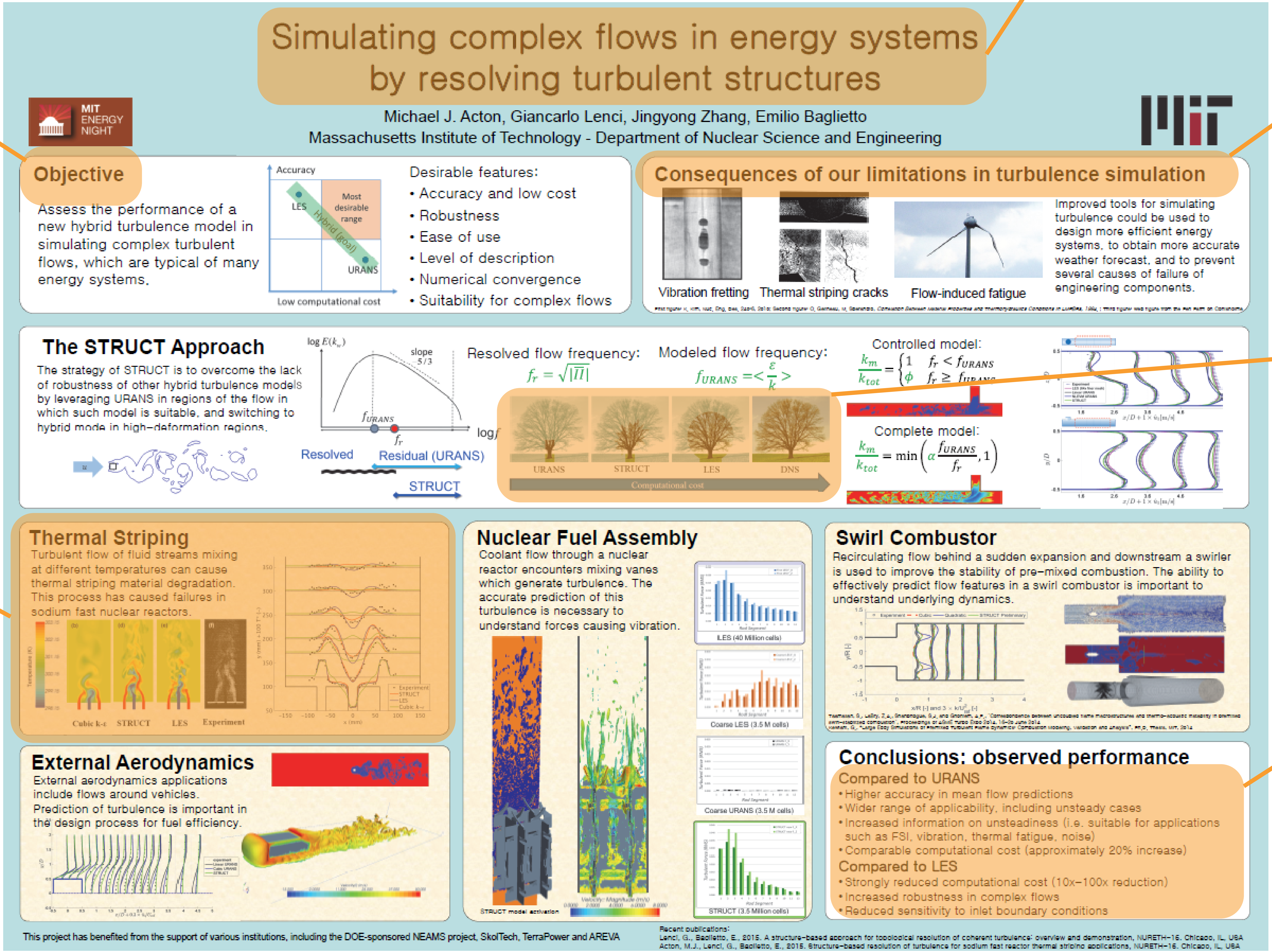
Simple, descriptive title

Large font section titles

Real world impact of research



Simulating complex flows in energy systems by resolving turbulent structures

Michael J. Acton, Giancarlo Lenci, Jingyong Zhang, Emilio Baglietto
Massachusetts Institute of Technology - Department of Nuclear Science and Engineering

Objective

Assess the performance of a new hybrid turbulence model in simulating complex turbulent flows, which are typical of many energy systems.

Desirable features:

- Accuracy and low cost
- Robustness
- Ease of use
- Level of description
- Numerical convergence
- Suitability for complex flows

Consequences of our limitations in turbulence simulation

Vibration fretting Thermal striping cracks Flow-induced fatigue

Improved tools for simulating turbulence could be used to design more efficient energy systems, to obtain more accurate weather forecast, and to prevent several causes of failure of engineering components.

The STRUCT Approach

The strategy of STRUCT is to overcome the lack of robustness of other hybrid turbulence models by leveraging URANS in regions of the flow in which such model is suitable, and switching to hybrid mode in high-deformation regions.

Resolved flow frequency: $f_r = \sqrt{|II|}$

Modeled flow frequency: $f_{URANS} = < \frac{\varepsilon}{k} >$

Controlled model:

$$\frac{k_m}{k_{tot}} = \begin{cases} 1 & f_r < f_{URANS} \\ \phi & f_r \geq f_{URANS} \end{cases}$$

Complete model:

$$\frac{k_m}{k_{tot}} = \min\left(\alpha \frac{f_{URANS}}{f_r}, 1\right)$$

Thermal Striping

Turbulent flow of fluid streams mixing at different temperatures can cause thermal striping material degradation. This process has caused failures in sodium fast nuclear reactors.

Nuclear Fuel Assembly

Coolant flow through a nuclear reactor encounters mixing vanes which generate turbulence. The accurate prediction of this turbulence is necessary to understand forces causing vibration.

Swirl Combustor

Recirculating flow behind a sudden expansion and downstream a swirler is used to improve the stability of pre-mixed combustion. The ability to effectively predict flow features in a swirl combustor is important to understand underlying dynamics.

External Aerodynamics

External aerodynamics applications include flows around vehicles. Prediction of turbulence is important in the design process for fuel efficiency.

Conclusions: observed performance

Compared to URANS

- Higher accuracy in mean flow predictions
- Wider range of applicability, including unsteady cases
- Increased information on unsteadiness (i.e. suitable for applications such as FSI, vibration, thermal fatigue, noise)
- Comparable computational cost (approximately 20% increase)

Compared to LES

- Strongly reduced computational cost (10x–100x reduction)
- Increased robustness in complex flows
- Reduced sensitivity to inlet boundary conditions

This project has benefited from the support of various institutions, including the DOE-sponsored NEAMS project, SkolTech, TerraPower and AREVA

Recent publications:
Lenci, G., Baglietto, E., 2015. A structure-based approach for topological resolution of coherent turbulence: overview and demonstration, NURETH-16. Chicago, IL, USA
Acton, M.J., Lenci, G., Baglietto, E., 2015. Structure-based resolution of turbulence for sodium fast reactor thermal striping applications, NURETH-16. Chicago, IL, USA

Good use of strong figures to illustrate key points. Poster is mainly figures!

Self-contained sections

Bulleted, easy to digest conclusions