Science & Technology Facilities Council

www.stfc.ac.uk

Shock-Wave/Boundary Layer Interaction control using Spark-Jet and Micro-Vortex Generator

Jian Fang[1], Guang Yang[2,3], Yufeng Yao[4], Chaoqun Liu[3], Lipeng Lu[2]

[1]Scientific Computing Department, STFC Daresbury Laboratory, Warrington WA4 4AD, United Kingdom

[2]National Key Laboratory of Science and Technology on Aero-Engine Aero-Thermodynamics, School of Energy and Power Engineering, Beihang University, Beijing, 100191, China

[3]Department of Mathematics, University of Texas at Arlington, TX 76019-0408, USA

[4]Faculty of Environment and Technology, Department of Engineering Design and Mathematics, University of the West of England, Bristol BS16 1QY, United Kingdom

Objective & Conclusion

We present Large-Eddy Simulation of two control devices: active control by SparkJet and passive control by MVG. It is found that both methods can greatly alleviate the separation. Flowfield analysis shows that the streamwise counter-rotating vortex generated by the two devices might be the common control mechanism.

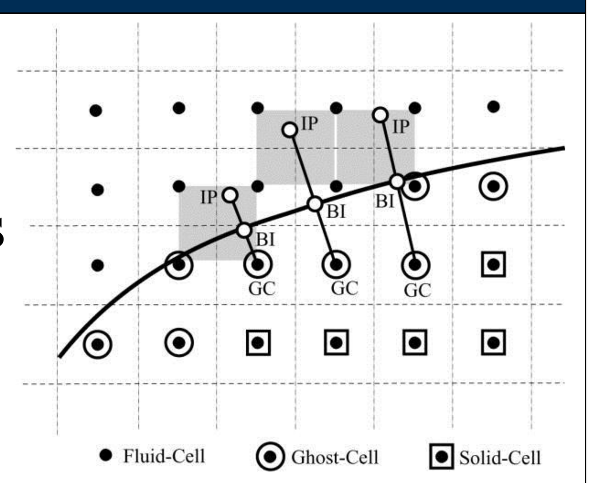
Numerical Methods

In-house SBLI code

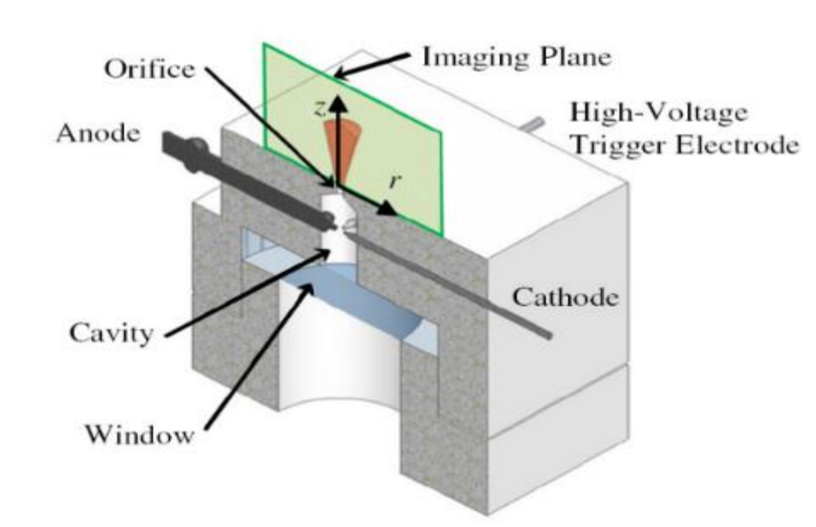
- **Fourth-order** Central Difference
- **Entropy Splitting** for Convective terms
- **Laplacian Form** for Viscous terms
- SGS model : **Mixed Time Scale**
- Inflow BC : **Digital Filter Method**

With Immersed Boundary Method

"Ghost-point" based shape interface IB

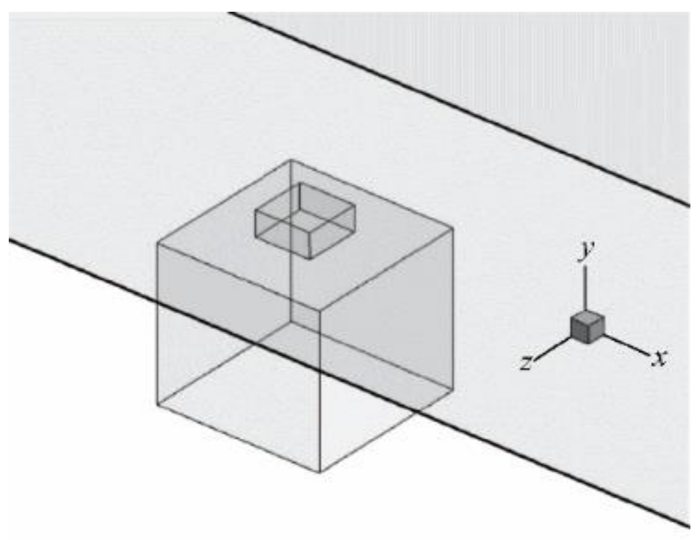


Active Control by SparkJet



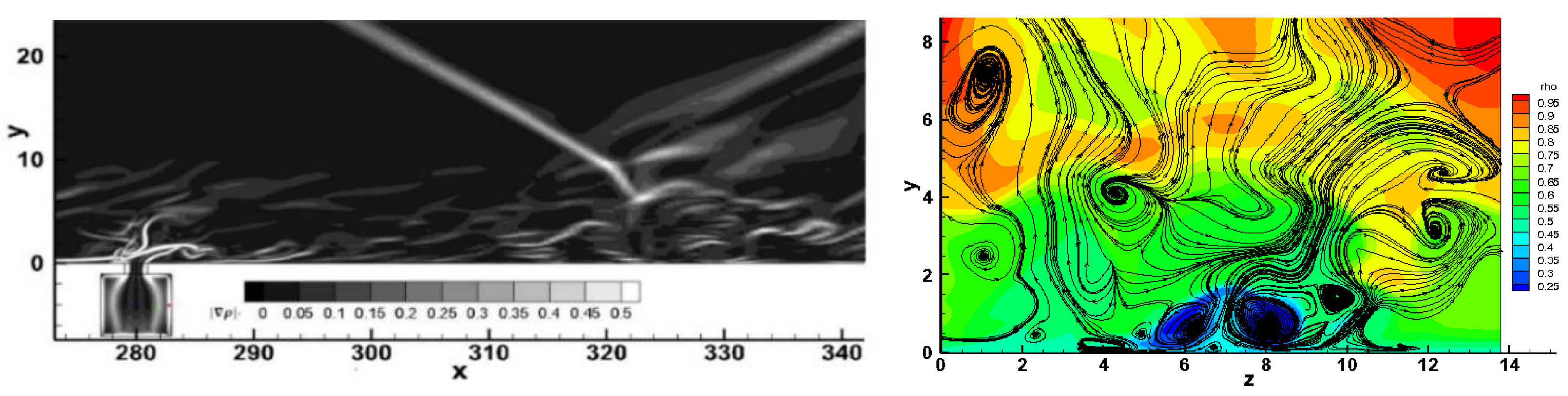
SparkJet Actuator

High voltage between electrode produce spark discharge, the heated gas would ejected from the above orifice into main flow.

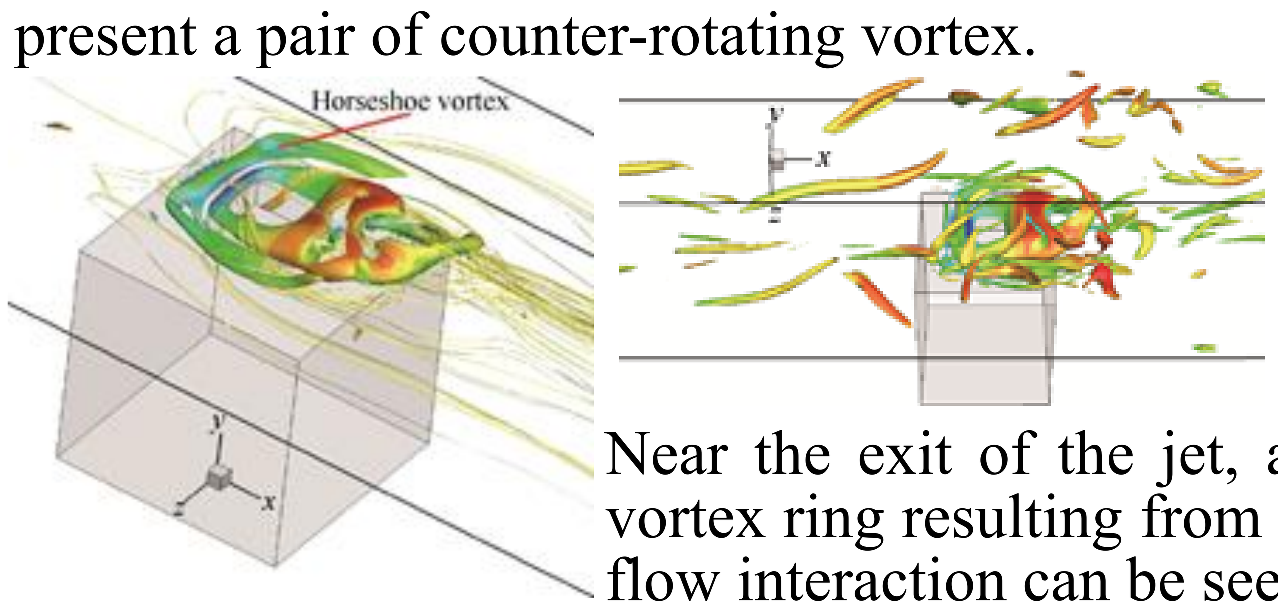


Computational Model

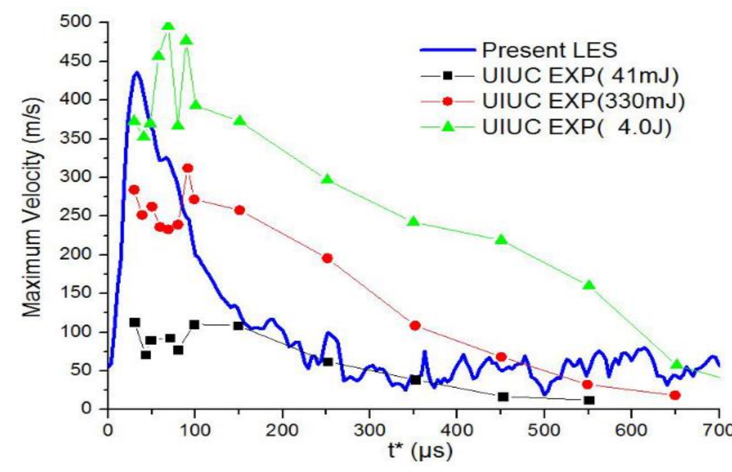
Actuator model represented by a cubical cavity and neck, electric spark heating energy modeled by adding a source term in energy equation.



Numerical schlieren in the symmetry plane shows the blast wave in the cavity and jet near the orifice. Density contour and streamlines on a streamwise slice downstream the actuator present a pair of counter-rotating vortex.

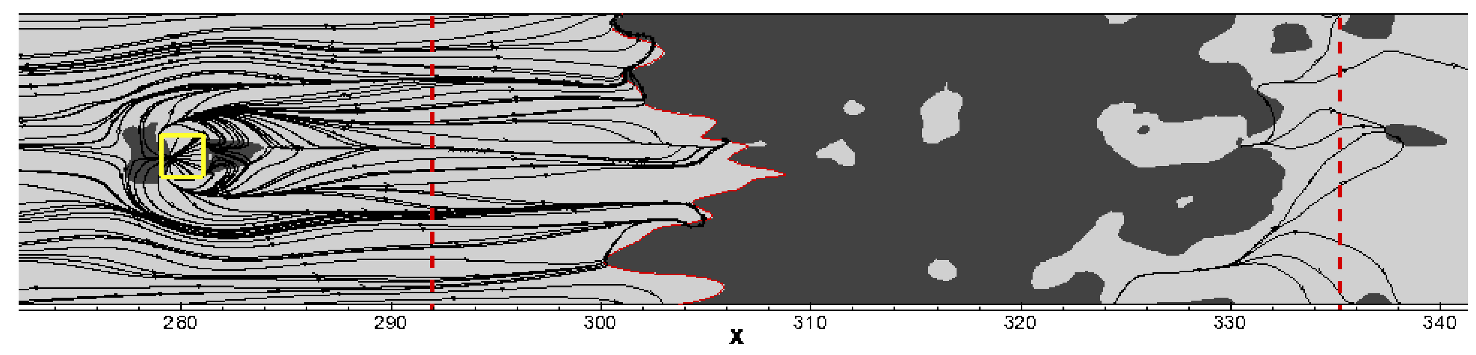


Near the exit of the jet, a rectangular vortex ring resulting from the jet/cross-flow interaction can be seen

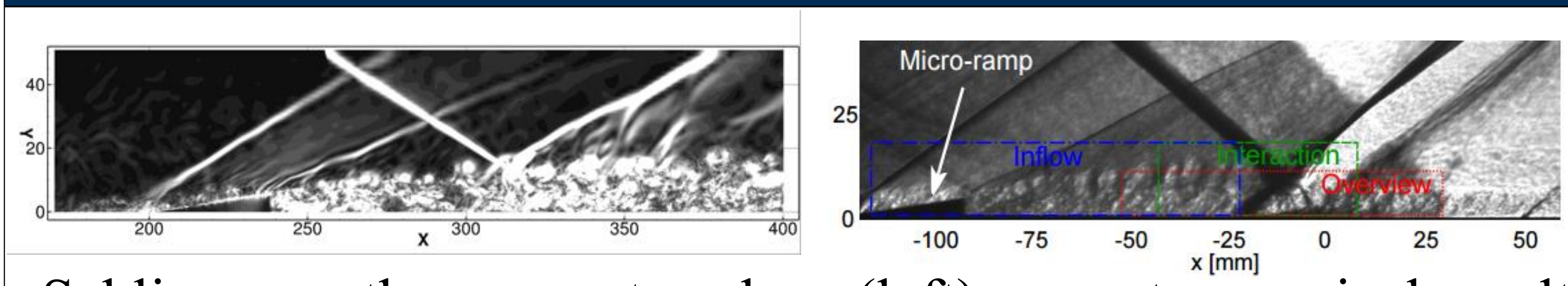


Maximum jet velocity matches well with the experiment.

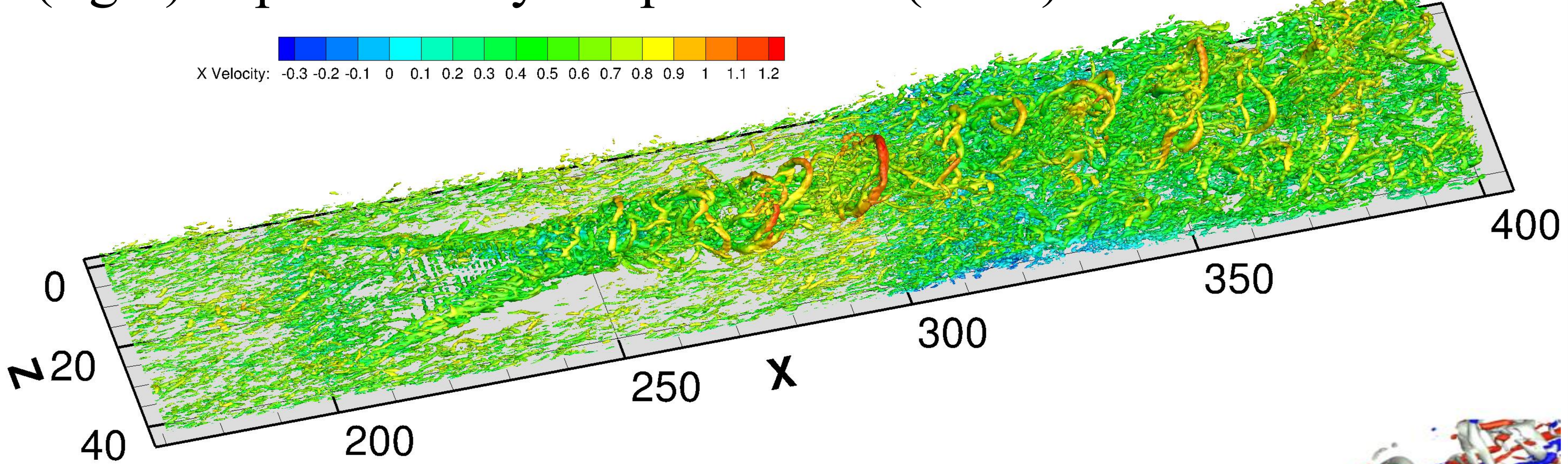
The flow separation (black zone) is suppressed by the SparkJet against the baseline case without control (red dashed line)

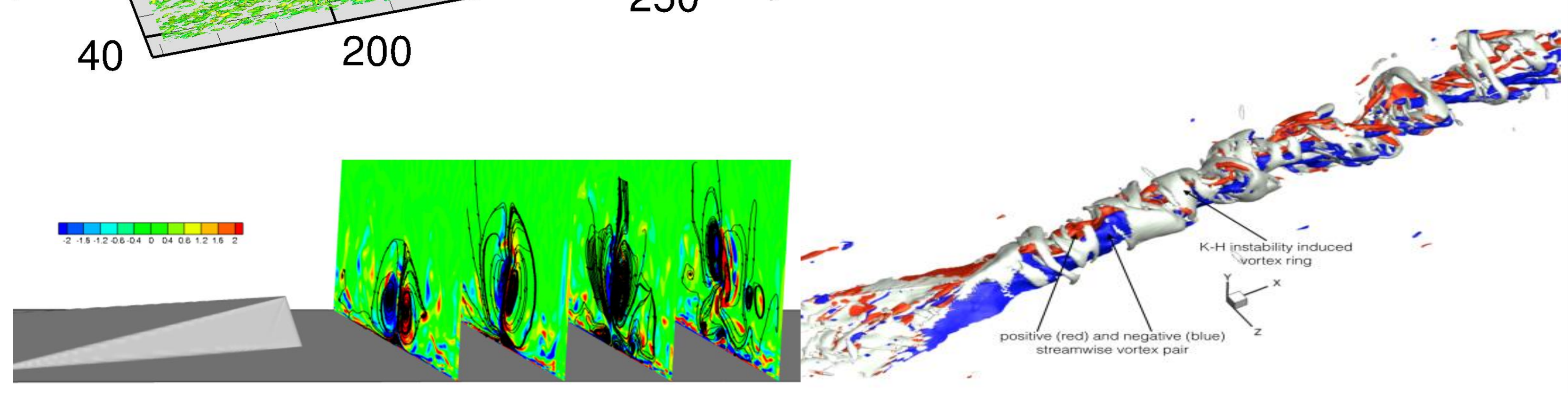


Passive Control by MVG

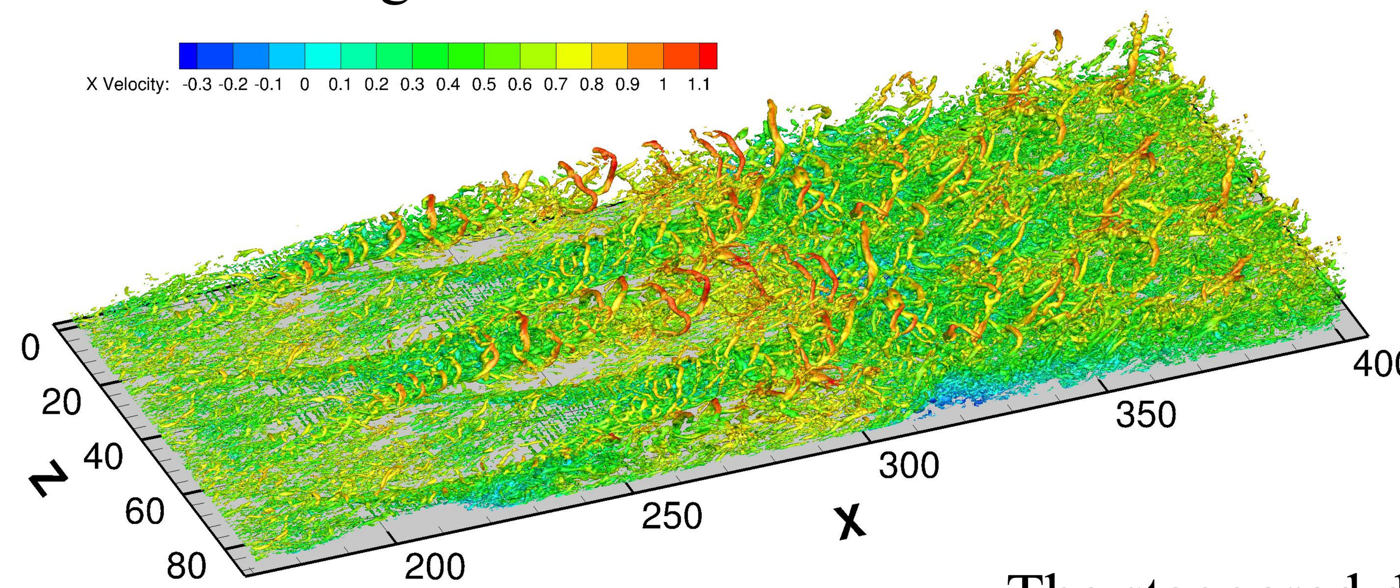


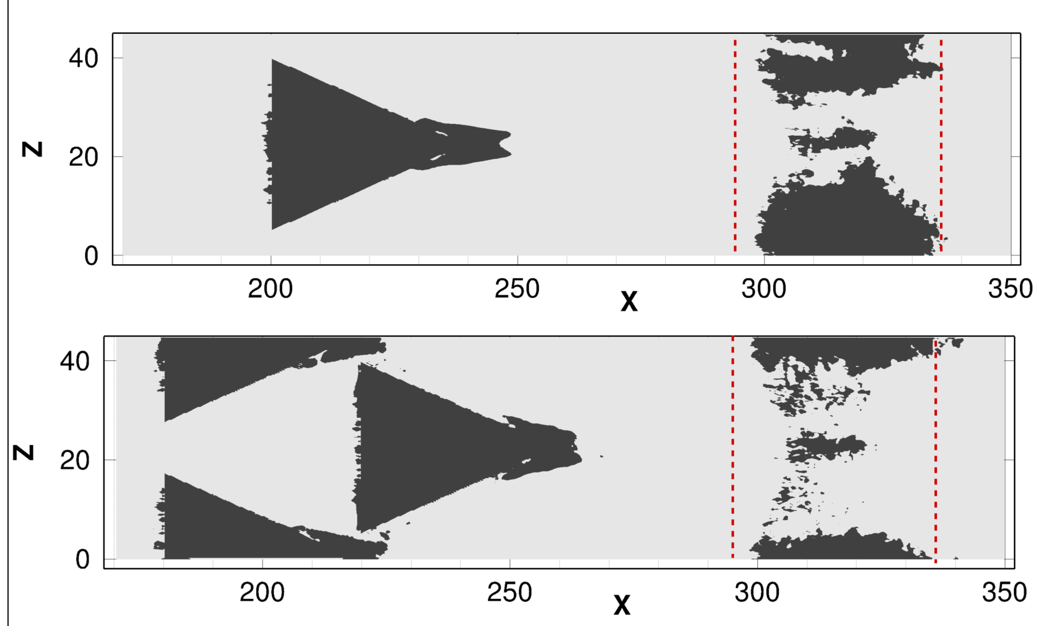
Schlieren on the symmetry plane (left) current numerical result (right) experiment by Giepman et al (2014)





Downstream MVG, the vortex trail is generated due the K-H instability of the free-shear layer. The streamline downstream MVG shows that the vortex trail actually consists of two counter-rotating vortices





The staggered double-row MVG generates a stronger vortex tail and causes a greater interaction with the shock-wave. Therefore it has a larger effect in suppressing flow separation downstream (black zone of the left figure).

This work is supported by the UK Turbulence Consortium (EPSRC Grant No. EP/L000261/1) and National Natural Science Foundation of China (No. 11302012). The simulations were run on the UK High Performance Computing Service ARCHER.

Science & Technology Facilities Council | 北京航空航天大學 BEIHANG UNIVERSITY | UNIVERSITY OF TEXAS ARLINGTON | UWE BRISTOL University of the West of England