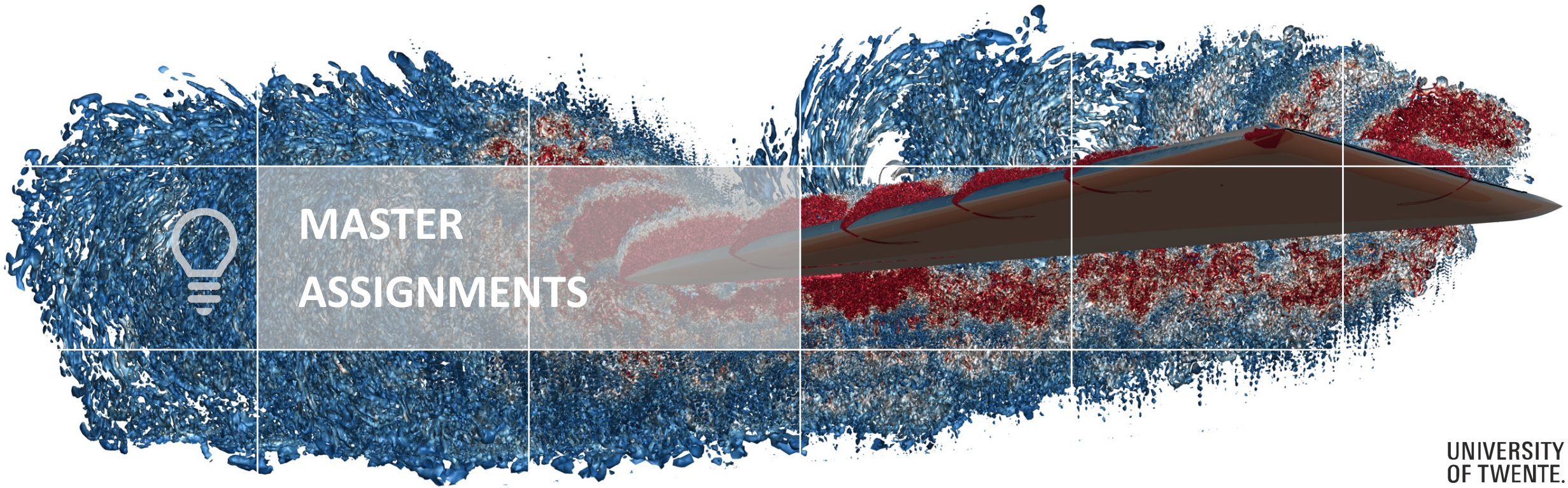
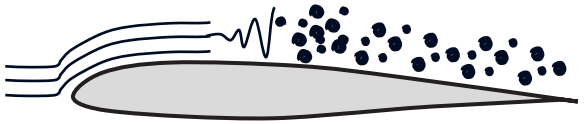
Transition-Transport Modelling:

1) Implementation and Assessment of Algebraic Transition Models

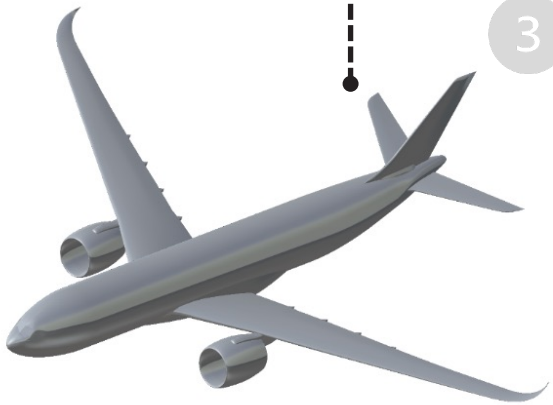


LAMINAR-TURBULENT TRANSITION AND ITS PREDICTION



1 The laminar-to-turbulent transition is the process of a **laminar flow becoming turbulent.** Depending on the mechanism this process is caused by instabilities growing exponentially and eventually turning the flow into a chaotic, turbulent state.

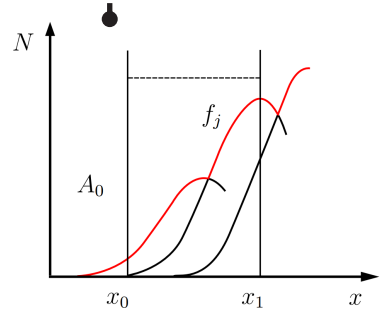
2 For many applications in aerodynamics it is essential to consider the laminar-to-turbulent transition and to know in which region this transition is happening. For this purpose, a wide range of methods exists that enable the **prediction** of the transition at different levels of fidelity.



$$\frac{\partial(\rho\phi)}{\partial t} + \nabla \cdot (\rho\, \boldsymbol{u}\phi) = \mathcal{P}_\phi + \nabla \cdot ((\mu + \mu_t)\sigma_\phi\, \nabla\phi)$$

3 A class of methods pioneered by Menter and colleagues in the early 2010s are known as local (correlation-based) transition-transport models [1]. They adhere to the principal of being fully compatible with modern computational fluid dynamics software, offering additional advantages such as robustness and user-friendliness. However, a drawback of these methods is that they may sacrifice accuracy in pursuit of these benefits.

4 The first model of this class was carried out by Menter and colleagues leading to the so-called $\gamma-\mathrm{Re}_\theta$ model [1]. The model is based on empirical data using the so-called Abu-Ghanam and Shaw transition criterion. Models that are based on linear stability theorey + e^N method have been developed e.g. by Coder et al. [2] and Ströer et al. [3,4].



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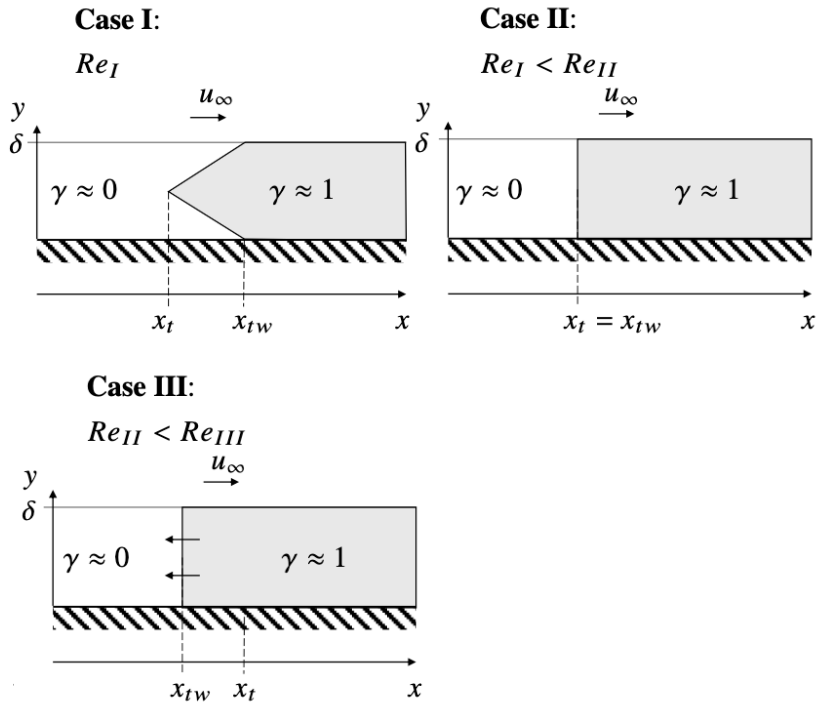
ASSINGMENT 1 *Implementation and Assessment of Algebraic Transition Models*

Research questions:

Is it possible to set the transition-onset position in a grid-point local and stable manner without using an additional transport-type equation?

- **Problem description:**
  - *Most transition-transport models use an additional transport-type equation to set the transition-onset position in a grid-point local manner.*
  - *This equation is usually called the γ equation (which is a pseudo-physical variable in reference to the physical intermittency).*
  - *This is challenging because the γ equation insetself might affect the transition-onset position as shown by Ref. [4], cf. Figure right.*
  - *Therefore, it is desired to find a way to set the computed transition-onset position without affecting it, and at the lowest cost possible.*



Source: Ref. [4]

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- **Tasks in this assignment:**

  - ✓ *Implementation of the algebraic (i.e. 0-equation) model by Menter [5].*
  - ✓ *Implementation of the γ model of Menter [6] (using the transition criterion of the 0-equation model or another one).*
  - ✓ *Determination of suitable test cases.*
  - ✓ *Evaluation of the integral transition criterion and determination of the analytical transition onset position for these test cases.*
  - ✓ *Comparison of all models (i.e. γ equation and the algebraic formulation) regarding their ability to set the transition onset position.*

Piqued your interest?

Reach out!

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REFERENCES

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[2] Coder, J.G., andMaughmer,M.D.,"Computational Fluid Dynamics CompatibleTransition Modeling Usingan Amplification Factor Transport Equation," AIAA Journal, Vol. 52, No. 11, 2014, pp. 2506–2512. doi: 10.2514/1.J052905.

[3] Ströer,P.,Krimmelbein,N.,Krumbein,A.,and Grabe,C.,"Stability-Based Transition Transport Modeling for Unstructured Computational Fluid Dynamics Including Convection Effects", AIAA Journal, Vol. 58, No. 4, 2020, pp. 1506-1517. doi: 10.2514/1.J058762.

[4] Ströer, P., Krimmelbein, N., Krumbein, A., & Grabe, C., "Galilean-invariant stability-based transition transport modeling framework," AIAA Journal, Vol. 60, No. 7, 2022, pp. 4126-4139.

[5] Menter, F. R., Smirnov, P. E., Liu, T., & Avancha, R, "A one-equation local correlation-based transition model," Flow, Turbulence and Combustion, Vol. 95, 2015, pp. 583-619.

[6] Menter, F. R., Matyushenko, A., Lechner, R., Stabnikov, A., & Garbaruk, A., "An algebraic LCTM model for laminar–turbulent transition prediction," Flow, Turbulence and Combustion, Vol. 109, No. 4, 2022, pp. 841-869.