1. Introductory remarks

Flow control is a key issue for the improvement of the next generation of airplanes, cars and energy generation for a safe and clean environment. The purpose of this Lecture Series is to give the fundamentals of fluid mechanics, turbulent characteristics of flows in view of control, stability and control theories.

The recent advances in control strategies, sensors and actuators for open as well as closed loop will then be presented, including low energy plasmas for flow control. Illustrations of successful control for industrial situations, transition, mixing enhancement, drag reduction, vectoring, jet and cavity noise and combustion will be discussed to enhance the applicability to the various fields of research of the attendees.

1.1 Some industrial/environmental requirements

A wide range of potential applications exists for active flow control.
In terms of applications, much of the focus and investment is on the aeronautical sector, while, in fact, both marine and automotive sectors offer vast energy savings. As stated by Morrison and Bonnet in the introduction to [IUTAM 2008], John Kim pointed out that worldwide ocean shipping consumes 2.1 million barrels of oil *per annum* whereas the airline industry only uses 1.5 million. It is therefore somewhat ironic that several effective methods are known for reducing skin-friction drag in water flows but little work in air. However, it suggests that more investment should be targeted towards drag reduction of ships and road vehicles.

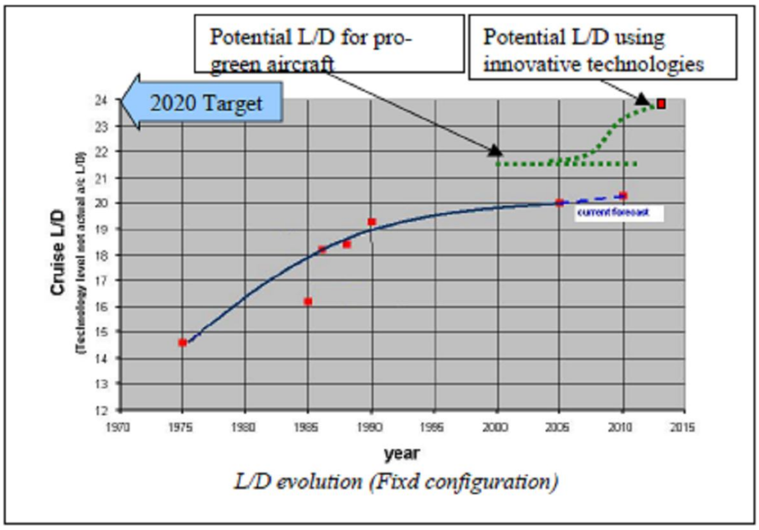
Let us consider two typical domains in which flow control can be considered as key issues: the aeronautical and automotive domains.

1.1.1 Aeronautical domain.

In 2001, the Advisory Council for Aeronautics Research in Europe, ACARE, recognised "the challenge of meeting increased demand whilst reducing the environmental impact of operating". ACARE set some demanding environmental targets:

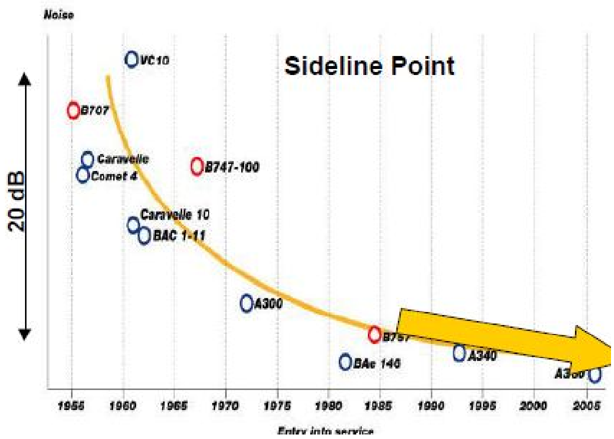
- A 50% cut in CO_2 emissions for new aircraft entering service in 2020 relative to year-2000 aircraft
- An 80% cut in NOx emissions for new aircraft entering service in 2020 relative to year-2000 aircraft
- A reduction in perceived noise by 50% for new aircraft entering service in 2020 relative to year-2000 aircraft .

If we observe the evolution of the last 30 years in term of performances, many progresses have been made by optimizing the shapes for less drag and higher lift. The simple extrapolation of the actual performances leads to a lift/drag value of order of 20.5 in 2020 when the target from ACARE 2020 is 24 as shown on the next figure (Abbas and Bieler 2008).



Evolution of the lift/drag ratio for commercial airplanes (ACARE document)

As far as noise reduction is considered, in 40 years 20 dB (100 times less noise) have been reduced for commercial airplanes as shown on Fig. 1.2. From that figure it appears that the last 10 EPNdB will be quite difficult to obtain.



Evolution of the perceived noise for commercial airplanes (ACARE document)

The ACARE 2020 targets have largely been adopted by the European airline industry. The challenge of achieving 50% reduction in fuel burn implies a wing/fuselage drag reduction of about 20%, an improvement in engine efficiency of about 20%, with the remainder coming from improved traffic management. In theory, arrays of microjets, dimples, pimples or other actuators combined with suitable sensors and control systems could produce substantial reductions in drag. Whether this is possible or not remains an open question. An estimate for the number of sublayer streaks present at any one time on the fuselage of an Airbus A340-300 in cruise is 10^9, and shows the scale of the problem for active control. Clearly, advances in the