

NASA/NY SPACE GRANT UNDERGRADUATE RESEARCH PROGRAM

Cornell University

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Fluid Dynamics Research Laboratories

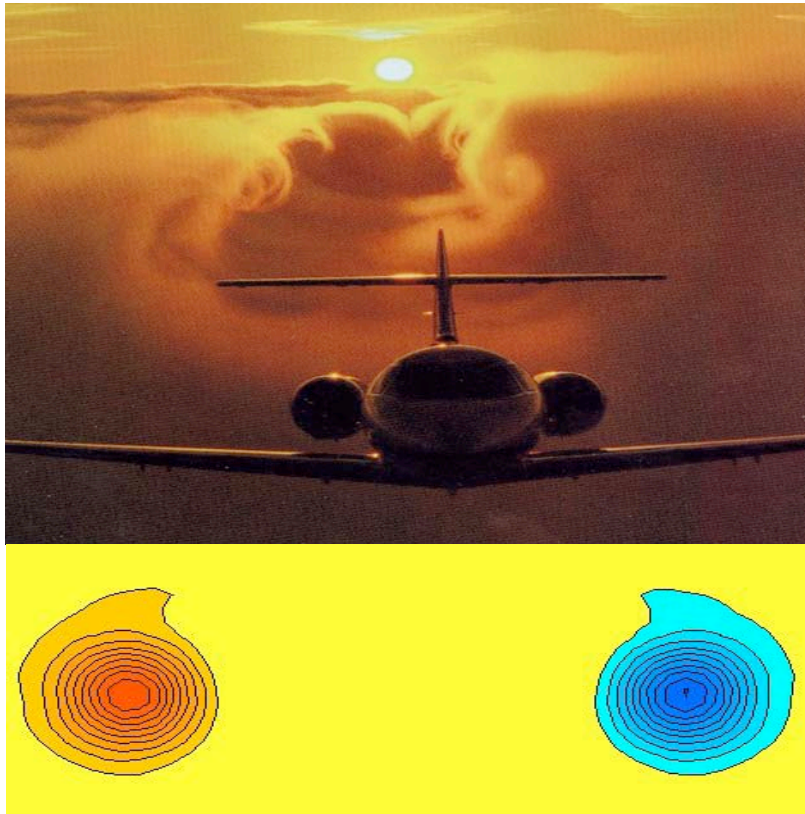
Novel Flow Visualisation -- Aircraft Vortex Wakes -- Vortex-Induced Vibration

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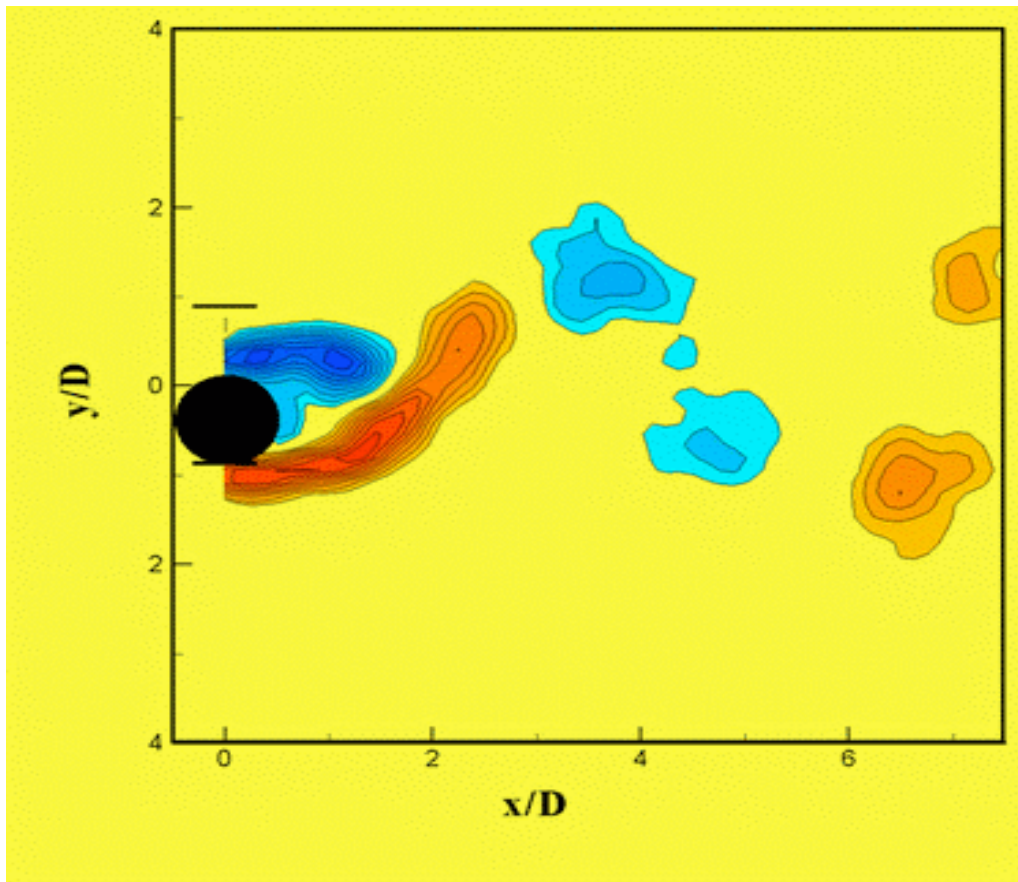
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- **FACILITIES:** We have built a novel Computer-controlled XY Towing Tank, a 26-foot Water Channel and also a Vortex Generator Facility, all of which will be used to visualise the trailing vortex wakes of aircraft, and to make discoveries in Vortex-induced vibrations in a set of projects suitable for bright undergraduate research ! This work follows from successful Summer projects over several years.
- **PAST NASA FELLOWSHIP WINNERS:** *Many of my students from the NASA Space Program are in PhD programs and have won NATIONAL fellowships for graduate degrees. One of my students is heading for the Churchill Fellowship this year ! 19 past NASA students working in the Fluid Dynamics Labs have gone on for graduate degrees, 14 of whom embarked on PhDs at Stanford, Princeton, Caltech, Cornell and others.*
- **THE AIRCRAFT WAKE PHENOMENON:** is an *extremely* important problem to the US Air Force, and the FAA, since it concerns flight safety, where the vortex wake of one aircraft can be a hazard to other manoeuvring aircraft. Our approach is both visual and exciting in that fluid motions can be very beautiful, as well as important from the standpoint of fundamental vortex instabilities and turbulence. The vortex instabilities are like the wavy patterns that you see in the sky known as contrails (condensation trails). We have also become extremely interested in the fundamental process of vortex merging. Much of our work is being published in the top journals, and we have discovered the physical mechanism for the merging of two vortices, and explained this for the first time. The counter-rotating vortex pairs also exhibit fascinating phenomena, and we have discovered, again for the first time, that a short wave instability exists that involves a distinct phase relationship between the two principal vortices - it is immensely beautiful too ! Incidentally, it is the long wavelength instability that you generally see making periodic patterns along aircraft contrails in the sky. We are very excited by the physics and beauty of these phenomena, and they are extremely important to understand, with a view to purposefully breaking up the vortex wakes from aircraft, so to remove their hazard.



- **RESONANCE FOREVER ! THE VORTEX-INDUCED VIBRATION PROBLEM.**

We will utilise our unique XY Towing Tank at Cornell, and study the relationship between vortex dynamics and the forces on bodies that they produce. One of our discoveries in this field has led to many international presentations and a great deal of excitement - we have found that below a (almost magical) critical value of the mass of a vibrating body, the formation of vortices in the wake can induce body vibration over an infinitely wide regime of flow velocities. You are used to the concept of resonant vibration when the forcing frequency (in this case due to asymmetric pressure distribution on the body, coming from the asymmetric vortex formation) is close to the natural frequency of the structure. In our case, we have resonant vibration when the forcing frequency can be 300 times the natural frequency !! In fact, to take this further, we have resonant vibrations at infinity times the natural frequency, and the strange thing is that we have actually proven this right there in our labs !! We are busy with several people in the research group working on this and other related problems, and we would be delighted to have further bright graduate and undergrads join us. I should also mention that we have been working on the concept of NEGATIVE DAMPING - and have some radical results which should clear up some controversy that has existed for the last 30 years. As a result of these projects and their many published papers and seminars, Prof C.H.K. Williamson has been invited to write a review book on the field of "Vortex-Induced Vibrations", which has just been completed. This is all REAL research for the undergrad, we need to know the answers, and it will be a lot of fun too.



- **DPIV TECHNIQUE (Digital Particle Image Velocimetry).**

EXCITING DEVELOPMENT OF THIS FRONT-LINE TECHNIQUE IS NEEDED AS A PART OF THE PROJECT. DPIV is a modern technique which enables us to determine the velocity and vorticity fields in 2D slices of a fluid, using the motions of neutrally-buoyant fluorescent particles. It is part of our *Fluid Image Processing Centre*.

These projects will give the student exposure to research computational analysis, design of a fluid mechanics experiment, the use of various flow visualisation techniques, image analysis, video and also fluid mechanics instrumentation in challenging and important problems. The tools gained by the student will be exceedingly useful to future work in fluid mechanics and aerospace.

These projects will also set up the student for applications to grad school and other careers of course!

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