Aeronautical Engineering

By K Srinivas and Grant Steven

The department of Aeronautical Engineering at the University of Sydney was started in 1939 following the recommendation of Mr H. E. Wimperis, the Director of Scientific Research in the British Air Ministry. He was an outstanding scientist and administrator whose services had been made available to the Commonwealth Government.

The 1937 Secondary Industries Testing and Research Committee had foreseen that the aircraft industry in Australia employed British and American designs and did not have experimental or theoretical resources. The Committee, however, made no concrete recommendations because the 1939 visit by Wimperis was impending. Wimperis confirmed that Australia must find answers to its problems locally and should not depend on Farnborough or Teddington.

Wimperis made three specific recommendations. Firstly, he recommended that an aeronautical research laboratory should be established, and outlined what the main features of this should be. Secondly, he recommended that a Chair of Aeronautics should be created in one of the Australian universities. Thirdly, he recommended that an aeronautical research committee should be formed.

The Australian government accepted the first two recommendations (it remains unclear what they thought of the third) and decided that the Council of Scientific and Industrial Research (C.S.I.R.) should be directed to establish an aeronautical research laboratory. It was eventually established at a cost of £140,000. In 1941 the Aeronautical and Engine Testing Research Laboratory began operation at Fishermen's Bend, in close proximity to the Commonwealth Aircraft Corporation's plant in Melbourne. The laboratory became the headquarters of the Division of Aeronautics under the directorship of a Mr Coombes. Its objectives were to assist the RAAF and to undertake research on long range issues in aeronautics.

The organisation had four main sections: aerodynamics, structure and materials, engines and fuels and instruments. A wind tunnel was one of the first items of equipment to be installed in the new laboratory. It was designed by Dr G.N. Patterson, who came out from the Royal Aircraft Establishment, Farnborough, for this purpose. Today the laboratory stands as the Aeronautical and Maritime Research Laboratory governed by the Department of Science and Technology.

The Australian government also provided funds for the University of Sydney to establish a Chair for Aeronautical Engineering. The resultant Department of Aeronautical Engineering was incorporated into the Peter Nicol Russel School of Engineering. The newly established Chair was named after Lawrence Hargrave, one of the pioneers in Australian aviation.

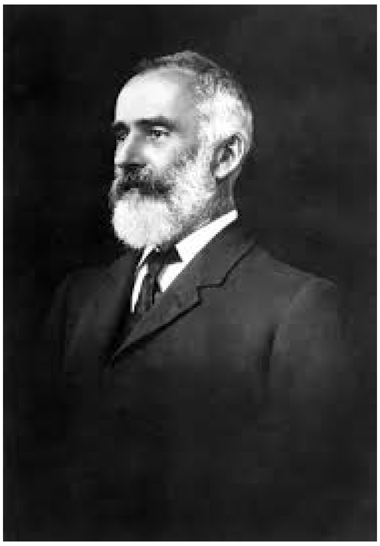

Figure 1 Lawrence Hargrave

Figure 2 Lawrence Hargrave and Alexander Graham Bell when they met in 1910

Hargrave (1850-1915) was a pioneer in aviation, an engineer and inventor. He chose to carry out his research into flying machines at Stanwell Park near Sydney where the winds were favourable to gliding and paragliding. Amongst other topics, he studied curved aerofoils with thick leading edges, rotary engines and box kites which gave a good length/diameter ratio for gliders. In an experiment with a train of four of his box kites, Hargrave was successful in lifting himself to a height of 16 feet. Use of box kites became widespread as a consequence.

Hargrave communicated his work to the Royal Society of New South Wales. Some of his papers and models have been exhibited in the foyer of the aeronautical wing of the AMME School. His work is said to have influenced Alexander Graham Bell of telephone fame, who also experimented with kites. They met at Bell's residence in Woollahra in Sydney in 1910.

Hargrave died in 1915, and although the Wright brothers are credited with the first human flight, Hargrave had accomplished much towards that goal. As well as the Chair in the Department being named after him in 1940, his picture has also appeared on the Australian twenty dollar note (1966 to 1994), and recently Qantas named its fifth Airbus A380 after him.

Arthur Veryan Stephens: First Lawrence Hargrave Chair of Aeronautical Engineering (1940—1956)

A. V. Stephens was appointed the first Lawrence Hargrave Professor in 1940. The primary responsibility of the new Department of Aeronautical Engineering was to supply aeronautical engineering graduates to various government departments, the RAAF, airlines and the aircraft industry of Australia.

In these early days the research of the Department was done in close liaison with the Aeronautical Research laboratories (ARL) at Fishermen's Bend in Victoria and the Weapons Research Establishment in Salisbury, South Australia. At that time, it was the only non-defence research laboratory and it was able to devote research to the fundamentals of aeronautics.

Figure 3 Professor A. V. Stephens

Figure 4 Cricket balls used by Stephens

A. V. Stephens, M.A. (Cambridge), FRAeS, brought the needed balance in theoretical and experimental research and in aircraft design. He had previously held joint appointments as Senior Scientific Officer at the British Royal Aeronautical Establishment at Farnborough and as a Fellow of St John's College, Cambridge. It was noted with pride at the time that Professor Stephens obtained interesting and valuable results with modest equipment.

Stephens carried out experiments in the wind tunnel to determine the side force on cricket balls which gives rise to swing, popular weaponry with bowlers. The balls he used have been preserved in the aerodynamics laboratory. This work has also resulted in the report *The late swing of a cricket ball*.

Cricket was not his only interest: Stephens was also passionate about yachts. John Blackler told the author:

> When he arrived in Sydney, the first thing Stephens looked for was a yacht. Then only he looked for a house to live in. He made it mandatory for the final year students to work on his yacht for a few weeks. We had to carry out this 'duty' twice a year in Rushcutters Bay, I think. The timing, usually four or five weeks before the final examinations, was such that students could not avoid participating.
>
> Many interesting incidents took place. Once I was given a kitchen knife from his house for spreading out rubber solution on to the deck. It broke during the process much to his (Stephens's) annoyance. He called me all the names under the sun. I had placed a tray of the rubber solution behind him. Without knowing he stepped into the bowl! It was a big hassle for him to remove his foot from the bowl and then to clean his shoe. Still, I passed the exams.

During the time that Stephens held the Chair, the Department could boast of many distinguished graduates. In 1989 at the fiftieth anniversary celebrations of the founding of the Department,, then Governor of NSW Sir James Rowland noted that out of the shadow of World War II, the Department of Aeronautical Engineering had maintained the highest of academic standards while turning out graduates who could underpin the business of aviation in Australia.

Some Notable Graduates

Alan Bolton was the first graduate from the Department of Aeronautical Engineering at the University of Sydney. He graduated with a BE Aero (2nd Class Honours) in 1940. He worked at the Commonwealth Aircraft Corporation as a Senior Design Engineer from 1940 to 1945, then Materials Engineer in 1946 and Assistant Production Engineer (Aircraft Division) 1946-1948.

Peter Stroud Langford AM graduated at the end of 1942 and worked at the Commonwealth Aircraft Corporation as Assistant Design Engineer until 1944, then as a Flying Officer in the RAAF in 1945. From 1946 until 1983 he worked at the Department of Civil Aviation, Transport and Aviation including periods as Director, Senior Assistant Director General and Senior Assistant Secretary of Airworthiness 1957-1975. He subsequently became Regional Director of Transport, Victoria and Tasmania until 1976, and then Regional Director of Transport, NSW until his retirement in 1983. He was President of the Australian Division of the Royal Aeronautical Society 1969-1971 and presented the

Lawrence Hargrave Lecture in 1975. He was awarded the Member of the Order of Australia in 1985 for services to Aviation Safety Standards in Australia.

Emeritus Professor P. Tom Fink AO CB CBE FTS FIEAust graduated in 1943. Tom worked in the Department with the CSIR Division of Aeronautics Group under Murray Evans until 1947, when he left for the near obligatory stint in the UK, for ten years of research and teaching, mostly in aerodynamics. He returned to the department as Reader in charge of Aerodynamics. He took the applied aerodynamics message to Mechanical Engineering and then Naval Architecture, in several professorial positions at the universities of Sydney and New South Wales. In the 1950's Tom advised Donald Campbell on his water speed record with *Bluebird*. In the early 1970s he provided technical advice on wind-tunnel tests and constant design modifications to Ken Warby for his attempt to better the water speed record with *Spirit of Australia*. From 1978 to 1986 he served as Head of the Defence Science and Technology Organisation.

Ronald John Yates AM graduated from Sydney University in 1944. He served in the RAAF, principally with the Aircraft Performance Units (ARDU). He was the first professional engineer employed by QANTAS, where he served for over 40 years, seven of which were spent overseas, mostly in the USA. His appointments varied from Performance and Structural Engineer to Director of Engineering and Maintenance and finally Chief Executive, the position from which he retired in July 1986. Since then he has remained very active in the corporate and public authority arena holding many positions.

Air Marshal Sir James Rowland AC KBE DFC AFC graduated from Sydney University in 1947. He served in the Royal Australian Air Force in World War II and later as an experimental test pilot and engineer, retiring as Chief of the Air Staff in 1979, the first graduate and engineer to hold that position. He was Governor of New South Wales from 1981 until 1989. Subsequently he became Chancellor of the University of Sydney from 1990 to 1991. He died in 1999 and was given a NSW state funeral.

Ian Sutherland graduated in 1948 and joined the RAAF. He served in Williamtown, Amberly, Laverton and Butterworth as an Engineering Officer and commanded Nos 478 and 482 Maintenance Squadrons. He served overseas in London and Washington and was appointed as one of the RAAF's Chief Engineers in 1985, rising to the rank of Air Vice Marshal.

Graeme Bird graduated in 1952 and became the third Lawrence Hargrave Professor of Aeronautics at the University of Sydney in 1964.

William Henry Wittrick MA (Cantab), PhD (Sydney), FAA, FRAeS, MIAS: Second Lawrence Hargrave Chair of Aeronautical Engineering (1956 – 1964)

Figure 5 1 Professor H. W. Wittrick

In 1956, when A. V. Stephens accepted the Chair in Aeronautics at Queens University of Belfast, Wittrick succeeded him as Lawrence Hargrave Professor of Aeronautical Engineering at Sydney. He was inevitably drawn into the affairs of the Faculty where his clear thinking and grasp of essentials were greatly appreciated. Over the years, he had built up a reputation among staff and students not only as a scholar and research worker but also as someone who had developed an excellent relationship with his small band of students both as a teacher and a friend.

Wittrick had little time for academic politics and even less for ponderous administrative procedures and interminable committees. He was nevertheless prepared to give time to devising a scheme for processing examination results that, for students with good aggregates, allowed certain compensations for shortcomings in a few subjects. This did much to quicken the progress of these students without in any way reducing standards. He also found time to take part in sport. As one of his colleagues of that time, G.A.O. Davies (now head of the Department of Aeronautics at Imperial College of Science and Technology) has remarked:

> Bill Wittrick had this [respect] in full measure in all fields, including the sporting one. Postgraduates found that guile is a powerful weapon on the squash court and a pretty potent one in the hands of a slow spinner on a turning wicket too.

It was therefore particularly appropriate that for some years Wittrick served as Senate representative on the Sports Union Committee.

An alumnus of the time, T. Murray Mansill, remembers the curriculum. In first year, students studied: Maths (2 levels); Physics (2 levels); Chemistry; Building Construction run by a chief engineer; Drawing at TECH, Harris Street, Workshop. Second Year subjects were: Technology (metallurgy, materials, steel making); Practical Mechanical Engineering – Merels and Diesel Engines. Only electrical engineering students did Advanced Maths and Physics, and Structural Engineering and Strength of Materials were all civil oriented. Third Year studies involved Aircraft Structures (taught by Wittrick), Aerodynamics, and it was a short year stressing practical training, maybe at Qantas. Fourth Year included Aircraft Design and Supersonics, the thesis went on until the Professor was happy, and examinations involved a three hour written exam.

Mansill remembers that the classes were 'schoolish', and felt that teachers had a good knowledge of the students. In his estimate, maths had still not caught up with computer developments and Australia lagged behind the US by about five years in teaching.

In 1960 Wittrick visited the College of Aeronautics at Cranfield and other universities and industrial organisations, first in the USA under the sponsorship of the Carnegie Corporation, then in Canada and European countries.

On appointment to the Chair, Wittrick began to take a more active part in the national research programme in aeronautics. He became a member of the Australian Aeronautical Research Committee, charged with the task of advising the Minister of Supply who led the aircraft factories and Aeronautical Research Laboratories in Melbourne. In 1961 Wittrick was invited by the Minister to become chairman of this committee. In 1962 he was appointed one of the three Australian representatives on the Commonwealth Aeronautical Advisory Council, responsible for co-ordinating aeronautical research throughout the Commonwealth.

In 1964, at age forty-two, Bill Wittrick had been nearly twenty years in the same department and was obviously ready for some new challenge. To his colleagues he frankly expressed the view that it would be a good thing for the vitality of his department if he were to move on. He had made outstanding contributions to the fund of Australian research that had been recognised by special awards and notably by his election to Fellowship of the Australian Academy of Science in 1958. He had played a full and active part in all aspects of university life and was currently Dean of the Faculty of Engineering. His acceptance of the Chair of Structural Engineering at the University of Birmingham was a matter of great regret to his University of Sydney colleagues.

A. V. Stephens had instigated the department's interest in research into Aircraft Structures and Wittrick was invited to undertake this task. Aircraft structure had previously been treated as any civil engineering structure such as a metallic bridge. The wing was a series of ribs held in place by metal spars and wrapped in cloth or thin metal. The skin did not contribute to the strength or stiffness of the wing. With the advent of semi-monocoque construction, typified by the Hawker Hurricane of 1935 whereby the skin became part of the structural strength, the method of analysis of a wing had to be different.

With this background, Wittrick quickly established research collaborations with DSTO Aeronautical Research Laboratories. In the eleven years before his appointment to the Lawrence Hargrave Chair, Wittrick established an international reputation for himself as a resourceful and original researcher in the theory of aircraft structures and undertook the following studies.

Now that the aircraft skin was an active member contributing to strength, stress concentration around the holes was an important consideration and reinforcement was needed to reduce it. In 1953, following the Comet aircraft disaster, Wittrick employed the analytical methods developed in Russia by Muskhelishvili to predict the stress concentrations around reinforced holes of ‘rounded square’ and ‘rounded triangular’ shapes in aircraft fuselage. For part of this work Wittrick was awarded the Orville Wright Prize of the Royal Aeronautical Society. Wittrick and his associate Glyn Davies made important contributions in the fundamental areas of thin walled structures for aerospace concerning areas of stress diffusion round holes, stress distributions around holes and buckling of thin panels of various shapes and topologies. This was all prior to the advent of digital computers.

With the development of the commercial aircraft around 1960, there was an increased demand for strength and safety. Buckling became an important consideration. Stiffeners called stringers were placed along the wing and fuselage. Wittrick made a major contribution to this area by employing approximate methods due to Courant and Rayleigh-Ritz to develop eigenvalue solutions for stiffened orthotropic plates under combined loading. The Wittrick – Williams algorithm was the result.

Higher speeds required led to the development of sweptback wings at about the same time. Analysis became more complex. Wittrick was able to obtain solutions and demonstrated that there was a coupling between flexure and twist and the effect of root restraint. This became his Ph.D dissertation. This was no mean task when the only aid then available was the mechanical hand-operated calculating machine! It is now felt that his adoption of the well-established assumption of rigid line-of-flight ribs was not appropriate for swept wings, because it markedly exaggerates the coupling between torsion and flexure. It did, however, highlight a novel structural phenomenon. This acted as both a trigger and a spur to those who then recognised the need for a more exact analysis.

Prompted by his other studies, Wittrick returned to buckling in early 1950. He was able to develop elegant solutions for the buckling of orthotropic and isotropic rectangular plates under various biaxial loading and boundary conditions and contributed substantially to the associated literature.

Wittrick showed interest in other areas such as the stability of a heated bimetallic disc and was able to generate an exact solution to the stability of a non-elastic system. He studied the theory of crossed flexural pivots which finds an application in balances. In addition in collaboration with Professor Y C Fung, he studied the boundary layer at the free edges of a thin cantilever plate under large deflexion.

Establishment of a Computer Facility at the University of Sydney in 1956 (Silliac) gave a boost to department research. Wittrick readily used this for his studies into swept-wing structures, stress concentrations around holes in shells and plate bending.

Graeme Bird: Third Lawrence Hargrave Chair of Aeronautical Engineering (1964-1990)

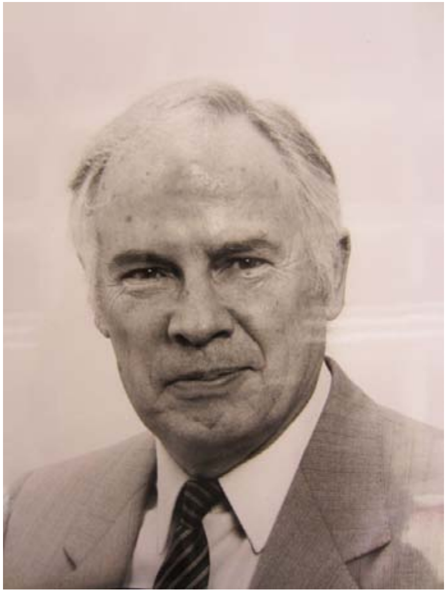

Figure 6 **Prof G. A. Bird**

The third Lawrence Hargrave Professor was Graeme Bird (1964-1990) who also started as a student in the department. He had graduated with a first class honours degree in 1952 and worked as a scientific officer at the Department of Supply until 1959. He then returned to the Department to lecture and undertake research leading to a PhD. He rose quickly through the academic ranks and was appointed Professor and Head of Department in 1964.

During his time as Professor he had periods as visiting scientist or Professor at the University of Manchester, Caltech, Imperial College, NASA Langley and the Max-Plank Institute for Stroemungsforchung. He is a Fellow of the Australian Academy of Technological Sciences, the Institution of Engineers and the American Institute for Aeronautics and Astronautics and the American National Engineering Foundation. In 1990 he was awarded the NASA Distinguished Scientist Award, one of the few non-Americans to be so honoured. His research has been in the field of molecular gas dynamics, whereby the behaviour of gases at low and not so low densities are simulated by emulating them as individual molecules together with all their chemical and mechanical behaviour. He wrote the authoritative book, *Molecular Gas Dynamics and the Direct Simulation of Gas Flows*, Clarendon, Oxford (Second Edition, 1994).

Bird pioneered the direct simulation Monte Carlo (or DSMC) method, widely used for the modeling of gas flows through the computation of the motion and collisions of representative molecules. Computation at the molecular level is necessary for studies in rarefied gas dynamics (or RGD) because the transport terms in the Navier-Stokes equations are not valid in this flow regime. The essential characteristic of a "rarefied" flow is that the molecular mean free path is not negligible. This means that many applications involve normal and high density flows with very small physical dimensions. The method was originally used for simulation of rarefied gas flow around re-entry vehicles. Graeme remembers that one of the early presentations he made resulted in this massive work. It led to a number of years of consultation work for NASA.

Graeme Bird retired in 1990. According to Alan Fien,

> Graeme was extra-ordinarily good as a head and almost an ideal. He did not micromanage the events in the department. Decisions were reached by discussions. Nothing was ordered from above.

Alan Fien had become a student in the department in 1959 and was lecturer from 1965-1994. He describes the department at the time as a "Professor factory". Almost everyone who joined it went out as a Professor there or somewhere else. John Manly became a Professor at the Queensland University; Tom Fink became a Professor at the Department of Mechanical Engineering, University of Sydney and later moved to University of New South Wales, Kensington as a Dean; Glyn Davies became a Professor at Imperial College, London; by 1961 Manly had gone off to La Trobe as a Professor.

During this period, the department closed down the ARL attachment. In 1965 there were three members of staff – G. A. Bird, Alan Fien and Glyn Davies. G. P. Steven joined the staff in 1970. At that time, Grant Steven recalls:

> For the first two years of the undergraduate programme the students followed the same curriculum as that of Mechanical Engineering, with Maths, Physics, Chemistry and Statics in first year follows by all the *–ics* in second year, Solid Mechanics, Fluid Mechanics, Thermodynamics and Dynamics. In the final two years of the programme the hard aeronautics subjects were taught. This structure allowed for students from interstate and the Australian Defence Force Academy (ADFA) to join in the third year without any difficulties.
>
> The third year provided the basic foundation to aeronautical engineering with aerodynamics, aircraft structures, flight mechanics and control. In the final year of the programme there was advanced aerodynamics, advanced aircraft

> structures, advanced aerodynamics and propulsion together with more aircraft design. Additionally there were several electives in gas, dynamics, continuum mechanics, rotary wing flight and control plus others.
>
> I especially remember the continuum mechanics elective because it taught the complex variable solutions to 2D stress analysis based on the text of Muskellishvilli.

During Bird's term as Lawrence Hargraves Chair, others who joined the Department staff were Tom Thompson and Ed Poppleton. The department operated for a long time with the following academic staff: Professor Graeme Bird, gas dynamics; Tom Thompson, senior lecturer, low and high speed aerodynamics and supersonics, propulsion; Ed Poppleton, senior lecturer, flight mechanics and low speed aerodynamics; Alan Fien, lecturer, structural mechanics, aircraft design; Grant Steven, lecturer, structural analysis; John Blackler, part time lecturer, aircraft design.

In the late 1960s and early 1970s in the Department of Aeronautical Engineering an FEA (Finite Elements Analysis) code called Dismal (<u>DIS</u>placement <u>M</u>ethod for <u>S</u>tructural <u>A</u>nalysis) had been developed as part of the PhD project of Russel Keys supervised by Alan Fien. The code was based on the Displacement Method or the Assumed Displacement Method of Structural Analysis whereby a displacement is defined within each finite element ensuring compatibility with adjacent elements. The Principle of Minimum Potential is invoked to establish equilibrium of the whole structure.

The Dismal code was sponsored by the Federal Department of Civil Aviation and was designed specifically to analyse aircraft type structures where a thin skin is integrated with a framework of stringers, ribs, frames and longerons. Thus it contained shell elements and rod elements. A special feature of Dismal was the ability to detect if the stresses in the thin skin (either compressive direct or shear) would be sufficient to cause local buckling and if so the effective elastic properties were reduced and a re-analysis undertaken to determine the post-buckling stiffness of the whole structure. Dismal ran in a batch mode on the University's Control Data CDC 6600 computer using punch cards to define the structure. Each node was defined on a single card and each element's connectivity was defined on a single punch card. Thus the setting up of an FEA model could take several days in front of an IBM 29 card punch machine.

The subsequent 10kg box of card had then to be transported across campus to the computer centre where it was put in a queue to be run overnight. Rain was to be avoided at all costs. The next day one returned, fingers crossed, to retrieve the box of cards and hopefully a print out of the results. The print out came on A3 perforated, folded paper with a listing of all the data, then the displacement results and then a list on the element results, all the stresses etc. One tiny mistake in aligning the holes on the punch card meant a day's delay. Such errors were common since the input deck was fixed format.

At that time the Department of Aeronautical Engineering was housed in the south eastern corner of what is now the John Woolley building. The whole building was shared with Mechanical Engineering.

Figure 7 Eastern exterior of the Aeronautical Engineering building. The top bay window was the Lawrence Hargrave Professor's room. The lower row of windows on right looked in on the large wind tunnel.

Figure 8 Modern photograph of the room that was the Aeronautical Engineering lecture room in 1970

In 1974 the department then moved to Darlington Campus (Chemical Engineering and Electrical Engineering had already moved). The Department of Aeronautical Engineering retained the wind tunnel while the Department of Mechanical Engineering retained the water tank built by Bob Halliday. Grant Steven recalls that:

The Department consisted of about ten offices, two workshops, one electronic, the other a machine shop and fitting shop, a library, two laboratories, one small and general purpose, the other contained the 7 x 5 foot low speed wind tunnel with mechanical balance.

The department maintained a small workshop for a number of years until it merged with the one for the School of Aeronautical, Mechanical and Mechatronic Engineering (AMME). Until 1978, Jim Burnett and Kevin Pippin were the heads of this workshop. Since then Greg Cumberland has been in charge, rendering a valuable service to the staff of the department.

Figure 9 Staff and students in 1986

Nick Pitsis and John Curtis served as technical officers for many years. Nick Pitsis operated the wind tunnel, assisted others and performed his own experiments. John Curtis helped Graeme Bird in setting up experiments regarding reflection of shock waves in low density media. Len Stellema was in charge of electronics.

At this time, Heads of Department reported directly to the Vice Chancellor. There was no need to please or take orders from the intermediate. Because of this the department had its views heard and responded to by the bureaucracy. The Deans of those days were elected from among the academic staff of the faculty. This has changed to an “Inverted Pyramid” managerial style.

Long ago, it was felt that it was not necessary to have both the departments of Aeronautical Engineering and Chemical Engineering at the University of Sydney as well as UNSW. The idea was to transfer one of the departments to the other. Though this was considered seriously, it failed to materialise. The next proposal was a merger of Aeronautical Engineering with Mechanical Engineering at the University of Sydney. This almost happened in 1983, but thanks to the intervention of the Chancellor of the University, and of then

Governor of NSW Sir James Rowland, the merger was aborted. The idea again surfaced in 2000 and merger seemed obvious.

In the past, people from industry provided teaching on aircraft design. Actually, they did more than teaching - they provided stimulus. Lew Gardener and Stan Shafston (both from Hawker de Havilland), and John Blackler, a consulting Engineer, provided significant contribution from outside. It is known that this is important for accreditation from the Institution of Engineers. Nowadays, funds may be difficult to provide for these services. On the other hand faculty of Medicine have specialists serving as fractional staff. Students and the departments have benefitted from these. It may be noted that in Germany and USA engineering managers of large companies are also Professors in universities. Says Blackler, “These lectures brought to students many anecdotes and inside stories of many incidents, mainly of disasters. These helped students retain their interest in the subject and even entertained them.”

Flying Camps were a speciality of the department to promote the motto – “As an Aeronautical Engineer one should like aeroplanes and one should like flying.” Once a year camps were held in Camden, Hawkesbury, Maitland or Newcastle. Dan Newman, a pilot himself, took a special interest in this. Alan Fien also participated. Students and staff camped for a week or so and undertook flying. This was popular, continuing into the late nineteen eighties.

Despite this, the image of an engineer changed drastically. Computers became a universal solution to all engineering problems. John Blackler (who made many helicopter models) recalls, “A certain professor came to me and asked – what can your model do that a good computer program cannot?”

The department used to have about ten or twelve students every year. Of these some were on deputation from the Air Force, one or two were from government departments, invariably there used to be a couple of students from Indonesia. Some of the latter have risen to very high ranks in the Indonesian Army or Air Force. John Blackler remembers:

> In the past we used to have students who were exposed to some hardware, especially those from the farms, and these became very good engineers. Sometimes we got students who asked funny questions. Once they were asked to make bigger bolts for a certain combination. One student asked whether the nuts also should be made bigger!
>
> There was one woman student long ago [Audrey Fakes] and none after her for a long time. Of course, now we find many girls joining the department as students. However, there has been no female academic as yet.

Unlike some of the other universities, the University of Sydney used to have three terms of nine weeks each. Alan Fien remarks:

> This was a very efficient system considering both the energy levels of the teachers and brain capacity of students. In the thirteen week system the last three weeks are spent in completing the assignments and reports and many times are a waste of time.

The examinations, too, were held distinctly. One of the universities had a week or so of examinations where the students had two papers every day. This was mainly a memory dumping exercise. Contrary to this, at the University of Sydney we used to have a day's gap after every exam to allow the students to prepare themselves. In the early days, assignments were mostly the laboratory work reports and were hardly marked. They did not count toward the grades.

G. P. Steven: Fourth Lawrence Hargrave Chair of Aeronautical Engineering (1990-2000)

Figure 10 **Professor G. P. Steven**

Grant Steven began his engineering career at fourteen years of age as an apprentice fitter and turner in John Brown's shipyard in Clydebank, Scotland. A trade certificate was gained in 1964 in conjunction with the undertaking of an engineering degree at Glasgow University. This led to a scholarship to undertake research at Oxford University leading to a DPhil award in 1970. For the final two years at the Department of Engineering Science at Oxford, Grant held the position of Junior Lecturer.

Steven described his arrival in Australia in 1970 as follows:

> I arrived in Australia on the fifteenth of October and first stepped foot in Melbourne at 11.50 AM. This time sticks in my mind as, at that first footfall the ground shook and there was a loud explosion and dust rose a kilometre away where the Westgate Bridge had just fallen down, the worst industrial disaster in

> Australian history. The Morison Technical Report into the failure, apart from identifying the cause of the failure noted that advanced structural analysis methods would have provided sufficient results that would have prevented the accident happening.
>
> So after that auspicious start, the sail to Sydney was uneventful and we were met by Professor Graeme Bird and his son Nick at Woolloomooloo docks a few days later. After settling into a Sydney University apartment in Drummoyne my first day at Sydney University was October twentieth.

After taking up his position as lecturer, Grant introduced experiments in structural engineering:

> I noticed that there were extensive laboratory sessions in aerodynamics and supersonics in 1970 but no structures laboratory sessions. This I considered a serious omission and set about resolving it with the design and implementation of ten experiments to illustrate the basic theories and applications in structural behaviour and analysis. My motivation for this effort was based on my two years as Laboratory Demonstrator/Junior Lecturer in the Department of Engineering Science at Oxford University, undertaken in conjunction with my doctorate research. There I observed the improvement in outcome of the graduates when they felt confident that the results of analysis were backed up in real life through the design and implementation of experiments. Some of the experiments that were designed were: Shear Centre of Open Thin Walled Sections, Bending of an Unsymmetrical Beam, Bending and Shear of an Aircraft Spar and Bending and Torsion of a Thin Walled Tube.

Grant became Department Head in 1984, and in 1990 he was appointed Professor. During his time at the Department there were several sabbatical breaks with visiting professorships at Glasgow, Swansea, Harvard, Oxford and Dalien Universities. He produced over three hundred academic papers and several research books. Much of the research undertaken has been in the fields of numerical methods, especially the Finite Element Method (FEA) method for structural analysis, structural design and laboratory testing. Recently the research has focused on new methods for achieving the optimum design of a structure for its many varied environments. This work has borrowed computational techniques from observations of evolutionary processes in nature. Grant Steven is a Fellow of the Australian Academy of Technological Science and Engineering and the Institution of Engineers. Since leaving the chair in 2000 he has been Professor of Engineering at the University of Durham. He is also a Professor Emeritus in the School of Aerospace, Mechanical and Mechatronic Engineering.

When Grant Steven first became Head of Department, he accumulated a very active group of youngsters alongside his staff Alan Fien, John Blackler and Doug Auld. Among the new recruits over a number of years were K. Srinivas, K. C. Wong, Dan Newman, Osvaldo

Querrin (now at the University of Leeds), Llyong Tong and Peter Gibbens. Consequent to the resignation of Helen Cottome, Yvonne Witting became the secretary.

Figure 11 Staff and post graduate students in 1997
Top Left: Toby Payton, Ben Stockwell, Greg Cumberland, Bill Higgs, John Blackler, Ben Grocholsky, Dan Newman, Qing Li, Manuel Garcia, Justin Talbot-Stern, Rohan Pinto, Liyong Tong, Chris Mellen, Ping Tan, Wei Li, Hugh Stone, Mike Xie, Kee Chonn Wong, Greg Riviere, Jai Madhani, Yvonne Witting, Grant Steven, K Srinivas, Osvaldo Querin, Doug Auld

Keeping up with the times, personal computers entered the department and changed the course of teaching and research. Many new areas of research opened up such as Monte Carlo method, already mentioned as the pioneering work of Graeme Bird.

D. J. Auld developed several codes based on Panel Methods and Vortex Lattice Methods to compute aerodynamic fields and forces. These have substantially added to the quality of teaching of Aerodynamics.

In 1989 K. Srinivas joined the department and continued his work on Finite Volume Methods to compute transonic flow over aerofoils and through turbomachinery cascades. Several concepts in TVD (Total Variation Diminishing) and LED (Local Extremum Diminishing) schemes were developed and tested out for inviscid and viscous transonic flows. Srinivas also developed Space Marching Schemes for supersonic and hypersonic flows. In 1998 a collaboration started with Dassault Aviation in France. The main aim was to perform multi objective design optimisation of Aerodynamic shapes using what are today called Evolutionary Algorithms (Genetic Algorithms). The outcome was the Hierarchical Asynchronous Parallel Evolution Evolutionary Algorithm, which has been shown to be considerably faster than the basic Genetic Algorithm. The procedure has been used to optimise a variety of aerodynamic shapes including wings and fuselage. The method was also extended to include uncertainty in input data to perform a Robust Design.

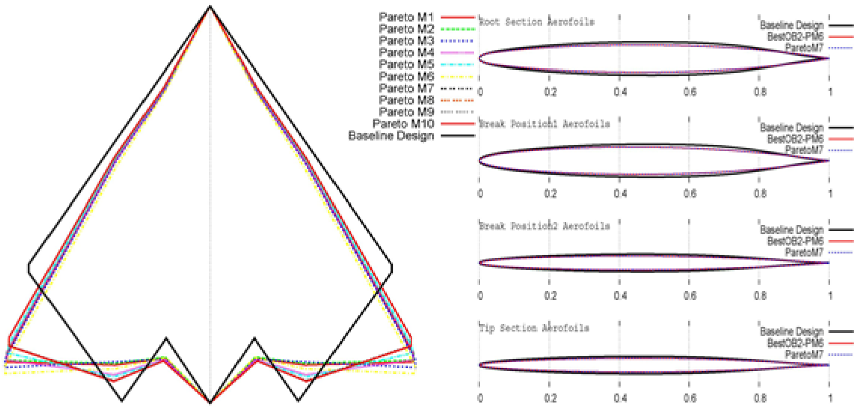

Figure 12 Optimised aircraft wing, cross section at different locations shown

The interest of Srinivas was diverted to biomedical engineering and he became involved in the design optimisation of coronary and cerebral stents using the principle of Exploration of Design Space. A three dimensional stent to cure a cerebral aneurysm was developed as a part of a PhD program. This design is now being tested at Macquarie University for a real patient geometry. Studies on rupture of aneurysms and distribution of liposomes in tumours are in progress.

Figure 13 Optimised stent for an Aneurysm

Another research area was the Strand computer software, first developed by Grant Steven and Doug Auld and academics from the University of New South Wales. An independent company was formed, subsequently developing and marketing a series of DOS and Unix based Finite Element Analysis (FEA) programs. In 1996 the company commenced work on a completely new software development specifically for the Windows platform. This product was released in 2000 and was named Strand7. Some high-profile applications of Strand7 include the optimisation of the "Water Cube" Beijing National Aquatics Centre for the 2008 Beijing Olympics, the "Runner" sculpture that was placed on top of Sydney Tower during the 2000 Sydney Olympics and the Terminal 2E roof, Charles de Gaulle Airport.

While he was Chair, Grant Steven also built a strong Finite Element Method (FEM) school which undertook Evolutionary Structural Optimisation (ESO). In the words of Greg Cumberland, who headed the departmental workshop from 1978 to 2000 (and subsequently that of AMME School):

> After Grant came to power, experimental activity in the department got a boost. We procured the big computer in the workshop which is still in operation, and

then we had the Numerically Controlled Milling Machine. Lots of other machinery came in. Many students took up experimental and/or developmental work for their thesis. The pinnacle was in 1998 when we were asked to fabricate a model of a Jumbo Jet about 15 metres long by KLM airlines. Everyone in the workshop got involved and celebrated when the work was completed. It was a job well done.

Figure 14 Students graduating in 2000

Back Row:	Quan Nguyen, Jean Paul Ballard, Luke Trotter, Claudio Natoli, James Ward, Glen Debnam, Gerard Kurilowich, Adrian Atkins, Leighton Aurelius, Akilan Krishnamoorthy.
Centre Row:	Ahmad Ismail, Melvin Leow, Jenny Hunter, Paul Salerno, Stojan Karlusic, Sheree Wahba, James McManus.
Front Row:	Yong Yi, Taniel Boyadjian, Julia Tims, Sandra Hannah, Andrew Dropmann, Ping Tan (PhD).

The Present Day

The year 2014 marked the seventy-fifth birthday of teaching and research in Aeronautics at the University of Sydney. The anniversary was celebrated on a grand scale on July 4, 2014 with daylong presentations and a dinner. Many of the retired academic staff and present staff were present along with numerous alumni including Bill Downes and Neville Fakes who graduated in 1942. Some of the leading men of the Australian Aeronautics scene including G. A. Bird, Peter Smith (well known industry figure), Tony Carolyn (CEO of Hawker de Havilland), Ken Anderson (DSTO), and Ian Irving (CEO, Northrop Grumman) spoke on the occasion.

We operate under a new umbrella today, namely, School of Aerospace, Mechanical and Mechatronic Engineering (AMME). The current academic team consists of Douglas Auld, K

C Wong, Llyong Tong, Peter Gibbens, Xiaofeng Wu, Dries Verstraete, Gareth A. Vio and Ben Thornber.

Figure 15 Pre dinner drinks, 75th Anniversary dinner

Figure 16 Ian Irving (CEO Northrop Grumman) addressing dinner guests

Gregory Chamitoff: Fifth Lawrence Hargrave Chair of Aeronautical Engineering (2012-)

Figure 17 Gregory E. Chamitoff

The current Lawrence Hargrave Professor is Greg Chamitoff, a NASA astronaut appointed to the post in 2012. He flew to the International Space Station on STS-124, launching 31 May 2008. He was in space for 198 days and returned to Earth 30 November 2008 on STS-126. He served as a mission specialist on the STS-134 mission, which was the last flight of Endeavour and delivered the Alpha Magnetic Spectrometer.

Greg has a B.S., Electrical Engineering from California Polytechnic State University, 1984, M.S., Aeronautical Engineering, California Institute of Technology, 1985, Ph.D., Aeronautics and Astronautics, Massachusetts Institute of Technology, 1992, M.S., Planetary Geology (Space Science), University of Houston–Clear Lake, 2002. He has received many medals and honours including California Astronaut Hall of Fame, NASA Distinguished Service Medal and NASA Exceptional Service Medal.

In 2014 the Aerospace Engineering courses included:

First Year

Materials 1; Introduction to Aircraft Construction & Design; Introductory Aerospace Engineering; Mechanical Construction and Introduction to Mechanical Engineering.

Second Year

Aerospace Performance and Operations; Space Engineering 1; Thermodynamics and Fluids; Mechanics of Solids 1; Materials 1; Engineering Dynamics; Instrumentation; Mechanical Design 1

Third Year

Aerodynamics 1; Propulsion Aircraft Structures 1; Aerospace Design 1; Aerospace Technology 2; Flight Mechanics 1; Aerospace Management; Space Engineering 2

Fourth Year

Rotary Wing Aircraft; Aerodynamics 2; Aerospace Structures 2; Aerospace Design 2; Flight Mechanics 2; Space Engineering 3; Honours Thesis A,B ; Engineering Project A, B.

In the early days, only twenty-five percent of students finished high school and only ten percent of the students went to university. Thus, a very small fraction came to university and those that came in were of a high calibre. Engineering, however, has maintained a good cut off in TER so that as a result the quality of students is maintained. However, teaching and assessment in high schools have changed and today students have higher expectations. In addition, what they learn has changed. In 2015, the big change from previous years is that there are now many elective courses. Today there is more mathematics in all of the courses. Of course, the advent of the computer has effected a big change in the course content and manner of teaching.

Apart from ongoing research and teaching in areas previously mentioned, there are a number of new initiatives. The first year students now have the opportunity to assemble an aeroplane, Jabiru, which is also sold commercially, a venture undertaken by K. C. Wong. Perhaps there is no other university in the world where the first year undergraduates build an aeroplane in their very first year of study.

Figure 18 Students building Jabiru

The department now also has its own Flight Simulator due to the efforts of Peter Gibbens. Its key features include: "Variable Stability" allowing for any aircraft type to be simulated; capacity for the manipulation of aerodynamic characteristics or physical aircraft geometry in real time; it features an Instructor Operating Station with Variable Stability Module; is Weather, Failures and Ground Model Capable; and is an effective Teaching and Research tool in Flight Mechanics and Visual Systems (3rd and 4th year).

Figure 19 Students and staff in the flight simulator

The Unmanned Aerial Vehicles (UAV) Research Group has one of Australia's largest and most active team of robotic aircraft researchers, comprising up to ten academics and research students. Originally developed to provide flight research platforms in support of the department's various research activities, the UAV's are also used to enhance skills in airframe design and fabrication, flight instrumentation, flight control systems, and operational aspects of UAVs. They form the basis of technology demonstrators for many aspects of

Aeronautical Engineering, and are now also being used to explore commercial applications for autonomous flight vehicles.

Space engineering has been one of the very successful programs introduced during recent years. Key areas include orbital mechanics, space vehicles, ground station infrastructure, space avionics and space robotics.

The DSMC (Direct Molecular Simulation - Monte Carlo Method) gas flow simulation has now progressed to the stage of being a useful tool for solving a large range of aerodynamic and aerospace problems. Some of the projects now being undertaken in the school using this method are: simulation of flow separation in near continuum region; Rankine - Hugoniot weak/strong shock reflection solutions; Nano-Fluid Simulations; and investigation of stability of low Reynold's number flows.

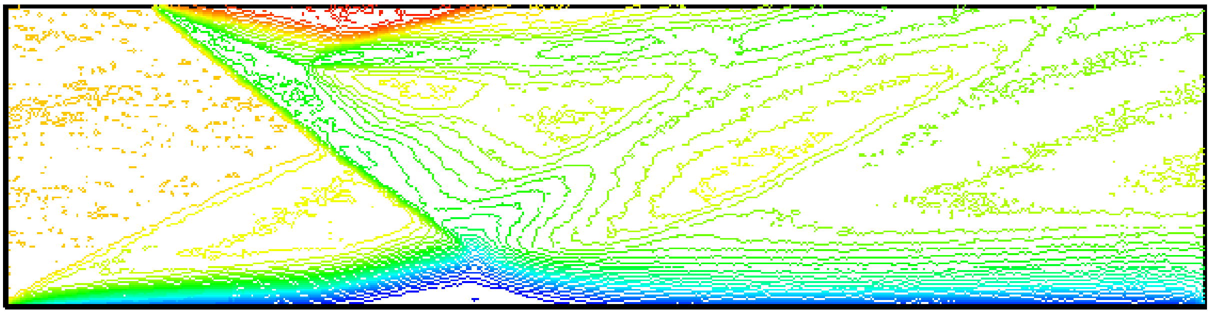

Figure 20 Shock boundary Layer Interaction, Mach Contours

Acknowledgement.

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