

PROF. V. RADHAKRISHNAN

Prof. V. Radhakrishnan was born on 18th May 1929. He was the son of Prof. C. V. Raman and Mrs. Lokasundari Raman. After getting his B.Sc (Honours) degree from the Mysore University and working as a research scholar in Indian Institute of Science, Bangalore, for a short time, he went to the Chalmers University of Technology, Gothenburg, Sweden, and worked as *Research Associate in the field of Radio Astronomy* from 1955 to 1958. From 1959-1964 he was a senior research fellow in Caltech, Pasadena, USA, in Radio Astronomy. He then moved to the Division of Radio physics, CSIRO, Sydney, Australia, where he worked as a Principal Research Scientist till 1971. The next one year was spent by him in the Observatoire Meudon, in Paris. From 1972 he was the Director of the Raman Research Institute in Bangalore. He revisited Caltech from September 1980 to March 1981 as Sherman Fairchild distinguished scholar. From April to September 1989 he was Jublieum's Professor in the Chalmers University of Technology in Gothenburg, Sweden. He was a Fellow of the Indian Academy of Science in Bangalore and was a serving member of its council from 1971. He had wide ranging interest in Electronics, Astronomy, Astrophysics and Aviation. In addition he was keenly interested in sailing craft. He was married to Françoise-Dominique nee Barnard and had a child.

FLYING SLOWLY

V. RADHAKRISHNAN

I am sure that every human being has at some time or other wished he could swim like a fish and fly like a bird. Swimming, even if not quite like a fish, is relatively easily achieved almost anywhere in the world but flying is another matter. What I would like to talk about today are some interesting aspects of how man took to the air in the first place, their connection with recent developments in low speed aviation in the world, and also some personal experiences related to activities in India.

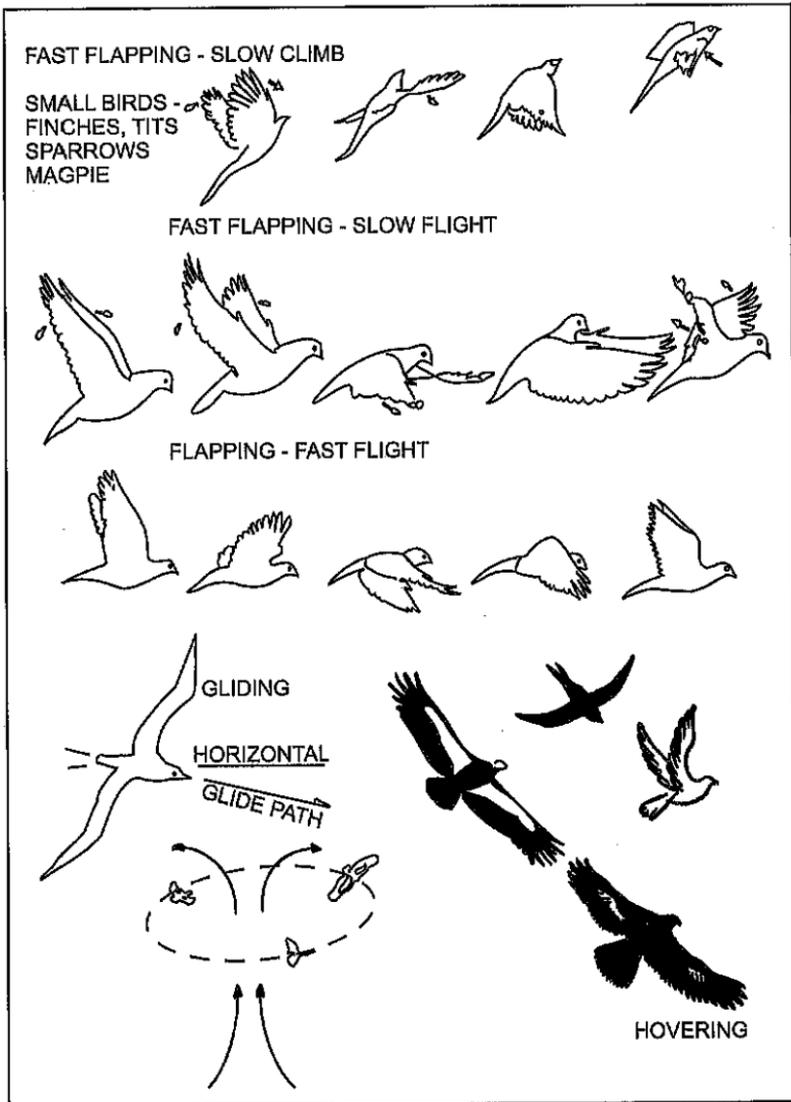
For all those who yearned to fly, like the pioneers in aviation, it was the birds that inspired them. But birds come in all sizes and shapes, and they fly in so many different ways. For example, the hovering of a humming bird sipping nectar from a flower while flapping its wings fifty times a second is very different to the stately cruising over the ocean of an albatross with outstretched wings locked open.

There is nothing in Nature that man cannot learn from, but the lessons are not always easy and straightforward as we shall see. I shall divide the early experimenters in aviation crudely into two classes. The first looked for lessons to the flapping birds as there are no birds which do not flap at some time or other. But nobody ever managed to build a flapping machine with which one could take off from the ground, leave alone fly. It took a very long time to appreciate the extremely complicated action of a bird's wing in 'flapping' which was revealed only by modern ultra high-speed photography. So it is understandable that those adventurers who tied a couple of "wings" to their arms and tried to flap them up and down just fell on their faces.

Prof. Satish Dhawan, former Chairman of the Indian Space Research Organisation (ISRO) has made a deep study of bird flight and I refer anyone who wants to know more to his book* from which the illustration has been taken. The smart pioneers of aviation were those who were inspired by another kind of bird, also shown in the same illustration. These are what I would call soaring birds, which include vultures, kites and other large birds, who rarely flap their wings, but just go round and round effortlessly and apparently stay up forever. In due course, it became clear that they were

being held up by rising currents of hot air, which are also shown in the same picture. The birds sense these columns of rising air and circle round their centre's to stay in them.

* 'Bird's Flight' (S. Dhawan), Special Publication No. SP 9019
 October 1990. National Aeronautical Laboratory, Bangalore.



TYPE OF BIRD FLIGHT - flapping, gliding and hovering
 (Bird's Flight- S. Dhawan)

There can be situations particularly in mountainous regions when you have tremendously fast up-draughts. But in general, when it is not very hot, these currents, called thermals, go up very slowly at one or two metres a second – or walking speed. Any bird which is not flapping its wings but just gliding around within the column, must therefore have a downward vertical speed relative to the air which is no greater than the upward speed of the column; otherwise, it would soon be down on the ground. This means that the sink rate, the technical term for this downward speed, must be no more than just one or two meters per second.

The question this posed was how the bird could hang on to the air, which is all it has up there, to get such a low sink rate. Both the experimenters and the theorists knew that if you suspended a stone the weight of the bird from a parachute and made it big enough to have the same downward speed, it would be enormously larger than the wings of the bird, in fact, fifty to a hundred times the wing area. The obvious difference between the bird and the parachute was, of course, that the trajectory of the bird was not straight downwards but a shallow slope with a horizontal component of the speed many times the vertical. And the message that came through finally was that the high forward speed acting on the special shape of the wings produced an upward force that was large enough to support the weight of the bird against the acceleration of gravity. Theorists had great difficulty initially in dealing with this phenomenon, the proper understanding of which is at the heart of *aeronautics and all aviation*.

Airplanes have been around for only a hundred years or so, but man has operated sailing boats for thousands of years. As I learnt when trying to understand how sails work, there is an intimate connection between the types of forces produced by the wind on the curved surfaces of sails and those acting on the wings of an airplane due to its passage through the air. Aerodynamics and fluid mechanics which attempt to explain these forces had their beginnings with Newton. But it took over two centuries and many great minds both in Mathematics and Engineering to arrive at a reasonable understanding of the way sails and wings work. For the purpose of today's

talk however, the essence of these findings can be stated in the following deceptively simple form.

Aerofoils are objects shaped similar to bird's wings; when moved through the air at an appropriate angle they experience a force perpendicular to the direction of motion (lift) which can be many times (say 10 to 50) larger than the force in the line of motion (drag). This ratio is called the lift to drag ratio (L/D) of the wing and is a measure of its aerodynamic quality, the larger the ratio the better the wing. For a bird gliding down in still air without flapping its wings, the inverse of this ratio also gives the slope angle of the glide.

Now the smart pioneers, as I said, spent their time watching the big birds, building gliding machines and learning to glide. And amongst the greatest and most celebrated of them were the Wright brothers. In fact, they spent years practicing with their glider to understand how one can glide down safely before attempting to install a motor and propeller on it for powered flight. One other crucial thing that the Wright brothers did was to add something that enabled control of the glider as it came down. The invention and perfection of this control system led to their final success in achieving the world's first manned, powered and controlled flight of a heavier-than-air craft. What they added were small control surfaces called ailerons, rudder and elevator. All of these were connected to cables or other mechanical means by which the pilot could move them and so control the aircraft. This scheme is absolutely basic, and all planes that you see today from little trainers to the big jumbo jets are controlled this way. It is called three-axis control, and the reason I draw attention to it will become clear as we go along.

Aeronautics has been advancing for a century in spectacular fashion. Apart from its vital role in military matters, the transport of people and cargo by air has become an essential part of everyday life in the more developed countries. Even in India, there is a tiny but significant fraction of the population whose life and work styles could not survive without air travel. But in spite of the overwhelming influence of aviation, there was something missing in the world scene and which suddenly appeared as a minor

revolution in the commercial jet liner age. This is the main topic of my talk today.

What didn't exist in spite of all the advances in aeronautics was a flying machine, as light and transportable as a bicycle, that one could foot launch, that was maneuverable and which could soar like a bird. In other words, a device with a sink rate less than the upward velocity that you find in thermals, of the order of a metre per second. Such a device, called a hang glider suddenly became possible, for two reasons. One, of course, was the advent of modern materials which are very strong, but very light like aluminum alloys, stainless steel cables and stabilized sail cloth, a kind of dacron that is used in sailing yachts. But the other reason that made the hang glider possible, as I see it, was an interesting throw-back to the pre-Wright brother's era.

Among the heroes of the last century, German engineer Lilienthal is now acknowledged as the father of gliding and one of the great pioneers of aviation. He had more than 2000 glides to his credit before he met his end on one of them in 1896. As he lay dying he is reported to have said calmly

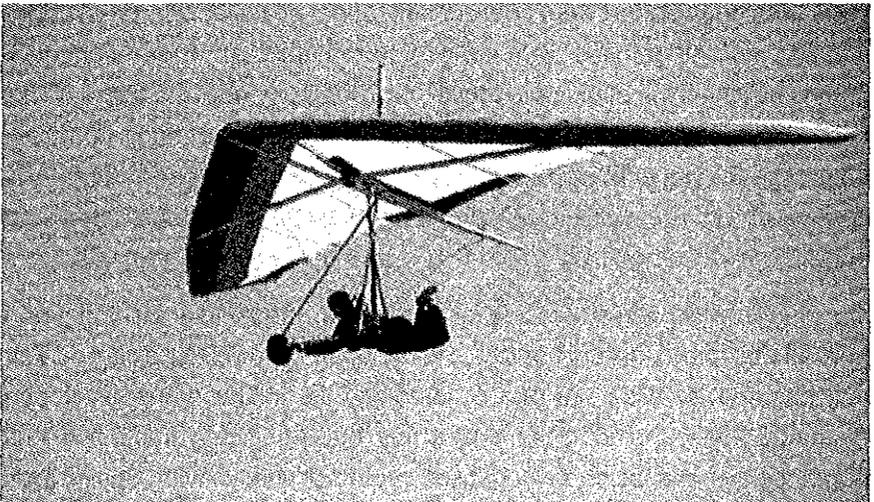


FIGURE 1 An early type of Rogallo Hang Glider

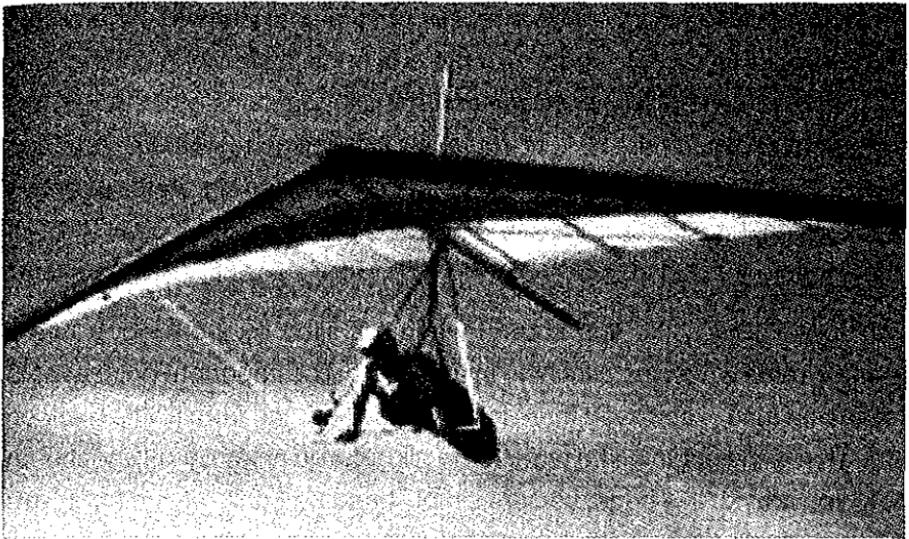


FIGURE 2

A modern Hang Glider

that sacrifices must be made. Lillenthal's and all of those other early gliders were controlled by shifting your weight with respect to the centre of effort of the wing. In other words, all that the pilot did was to move his body with respect to the contraption which could have been a sail or a box-kite or whatever. One did not manipulate any parts of it as in fact the Wright brothers did in their three-axis system. The modern hang glider also works on this early principle of weight-shift and does not have any controllable aerodynamic surfaces. And this happened in the middle of the jet age when you would have thought that no one in his senses would advocate, or build, or fly a machine which had no controllable elements.

The trigger for the development of modern hang gliders was an idea of a man called Rogallo who worked for NASA. He thought up what he felt was a very clever kite system. But nobody paid any attention to him, and finally he and his wife went and took out a patent. Much later, NASA paid him an enormous fortune because they thought they would use his device to bring spacecraft down instead of the parachutes that were normally used. Apparently NASA spent a lot of money before finally scrapping the idea as unworkable. The drawing from his patent looks incomprehensible and I

have never been able to understand its functioning. But when the patent expired around 1968, a whole new generation of latter-day pioneers took up the idea, built Rogallo kites and jumped off mountains with them. A few of them died but others rapidly improved the design to make it safer and better, and this process of improvement has been going on for over two decades now.

Fig 2 shows what an early Rogallo hang glider looked like. The fabric on it was loose, and could flop around when not filled by the wind. It had a control frame which the pilot held in his hands. The important point to note is that the man is strapped there in a harness hanging from a little hook on top. That is the origin of the term "hang glider". You are not firmly anchored in it, you are not in a cage, you are simply hanging free from the top of this glider. Note also that the sail is a single surface and not three dimensional. As I have already explained, it has no controllable parts. This sort of thing will fly and did fly. Many people jumped off cliffs with just this sort of machine, and as I said a few of them died. These gliders had a low sink rate and so could soar in good thermals, but they didn't have a very high lift to drag ratio. In other words, their forward speed wasn't very great and in a sense this helped when coming in to land, because you will be landing on your feet and you don't want to be tearing along when you hit the ground. So it was a low performance device but it suddenly made the experience of flying possible and affordable to hundreds and later tens of thousands of enthusiasts.

A modern hang glider is a great improvement over the Rogallo kite. It has long thin aluminum battens which are inserted into pockets in the wing to give it an aerodynamic shape. The leading edge is not a thin sheet any more, but a nicely rounded three dimensional object. In other words, it has an aerofoil shape with a double surface of cloth both above and below for a good fraction of the sail. It is a very simple but elegant construction, and the fabric in a modern hang glider is under tension and not floppy as in the Rogallo. Even though there are no surfaces that you can control, the whole wing is flexible in a very special way. When you shift your weight to one side

or the other to turn it, the wing loading on different parts of the sail changes and the sail modifies itself in such a way to both initiate a turn and also to stabilize it. It coordinates roll and yaw by itself like a bird, something that conventional airplane pilots must do with the controls.

It is the simplicity and affordability of hang gliders which made the sport spread like wild fire in the US, Europe and Australia and created enormous numbers of a new class of aviator. The only comparable revolution was the invention of the wind surfer which was to the yacht what the hang glider was to the airplane. It is the craft sailed by the greatest number of sailors in the world today and it is for exactly the same reasons namely simplicity, portability and a very low price. Remarkably, the materials used - aluminium alloy or carbon fibre and stabilized sail cloth - are the same, as is the fluid mechanics which describes their performance.

The stalling speed of free flying hang gliders can be as low as 20 kms per hour and typical speeds 30-40 kms per hour. They are very safe and maneuverable in calm weather or steady winds but they are not meant to be used in gusty or turbulent conditions. One learns to fly these gliders by running down gentle slopes with them. With the right kind of instruction, and people to catch you when you fall, you go from gentler to steeper and steeper slopes and you get airborne for longer and longer times, and gradually you learn to control the device. If you persevere long enough you should get to the stage when you can jump off a cliff, catch a thermal and soar for an hour or two or till you get cold and tired.

Just as in wind surfing, you need to be very fit, or should have learnt to operate these sports, so I don't fly free flying hang gliders, but I did get a ride once on a glider big enough for two people to hang from. We jumped off a steep cliff on Nandi Hills, near Bangalore, and the flight lasted for only two or three minutes. But after this experience I decided that this was something that should be encouraged in our country, where other types of flying are either prohibitively expensive or inaccessible or both.

Towards this end one set up is a series of projects funded by the Aeronautics Research and Development Board of the Ministry of Defence. I

have been the so-called Principal Investigator in these projects but in all of them the key person has been a Frenchman by the name of Joel Koechlin who was the one I jumped off the mountain with. He came to India overland from Europe many years ago and decided the moment he walked into India that this is where he was going to live. An ace pilot and designer of hang gliders; he has been the chief consultant and test pilot in these projects and also my guru in weight-shift control. All my previous experience in flying was with conventional aircraft which used three-axis control.

Our first effort was towards the design and development of hang gliders for training, several of which were manufactured locally. Following this was an exercise in organizing training schools on suitable slopes in the Nilgiri hills which we also did, with the project paying for all the expenses of the trainees.

The second phase in the hang glider revolution was the attaching of a small motorcycle or similar engine to a seat with wheels, the whole contraption hanging from the same hook on the hang glider to which the harness for the pilot used to be attached. Almost miraculously, one now had a true flying machine, smaller, lighter and more elegant than that of the Wright



A Powered Hang Glider

Brothers, with which one could take off, cruise around and land with complete control on any open field. Dozens of such designs were produced in the last fifteen years or so, particularly in Europe and manufactured in large numbers. This next and major step was a more than interesting one for me because I could now participate instead of just encouraging others. We too got into the game and three such models of "powered hang gliders" were produced since 1987 and several tens of them can be found all over the country today. The smallest were single seaters powered by the 250cc YEZDI Road King engine and the biggest long-range two-seater cruising machines were powered by imported 500cc Rotax Aero engines.

A couple of years ago we decided to do a little tour to really check out the reliability of these machines in cross country flight. We covered a 1000 kms. in a week and at the end it wasn't clear whether it was the machines we were testing or the endurance of the pilots. Unlike in conventional aircraft, one is exposed to the weather, and worse, in weight-shift machines one has to exert considerable force to control the craft when the air is turbulent. An extended flight in non-ideal conditions can be exhausting and one is grateful to be down and safe on the ground again. On the other hand, when the weather is right, there is no aircraft which can compare with the hang glider in imparting the sheer joy of flying. One of my friends who was a Chief Test Pilot and has spent the last forty years piloting every type of aircraft from trainers to jet fighters and helicopters to heavy transports claims that *what he enjoys flying most are the hang gliders developed in the project*. A joy-ride in such a machine, open as it is with no cabin to make you feel cooped-up, is an unforgettable experience not to be missed if you have the chance. Apart from the fun of sport flying, powered hang gliders have found use in reconnaissance, wild life surveys, aerial photography specially of urban areas, and agricultural spraying, the last particularly in Russia.

The project has provided a lot of fun and excitement. But I would be giving a very false impression if I did not mention at least some of the many difficulties encountered along the way. The design and manufacture of

craft intended for operation on land, at sea and in the air form a hierarchical sequence in terms of the reliability and quality control required for safety in operation. It took us years of persistent effort, for example, to be able to procure alloy tubes which would have the right composition, and conform to specifications in size even within the same batch. The tests and modifications required to convert engines made for motorcycles to aero performance and reliability was a saga in itself. The development of light but strong wheels was another story. The only item, that we failed miserably to find an Indian substitute for was the dacron sailcloth. As the strength of this fabric was literally a matter of life and death, there was no choice but to import it.

As anyone who has tried would know, it is not easy to manufacture something of international quality in India. The system seems almost designed to thwart you at every step. To create something excellent in spite of all the difficulties is the achievement of the small scale industry called Rajhansa Ultralights Private Ltd., in Mysore which has to date produced over two hundred hang gliders of both the free flying and powered varieties. Now the technical difficulties have been overcome and we have these flying machines which are both good and inexpensive. As often happens in our country, the bureaucracy has now stepped in. The desperate struggle we are going through at this moment is to overcome new regulations and restrictions which have been imposed by different ministries of the Government. Unless we succeed, this activity which has taken so much effort to grow will be killed and all the progress made so far wiped out. Meanwhile, we are still flying and fighting.