Bird Flight and Satish Dhawan: Some Thoughts

K R Y Simha

Great scientists like Newton, Darwin, Einstein, and Raman dreamed freely to unveil the mysterious beauty of natural phenomena. Early engineers built castles, dams, bridges, boats, looms, pyramids and mills by trial and error. Science kept far ahead of engineering until the twentieth century. The first twenty years of the twentieth century witnessed the beautiful minds of Einstein, Planck and engineers like Prandtl, Ford and the Wright brothers. However, World Wars 1 and 2 shattered the utopian spirit of unity, cooperation and trust among scientists. Applications of science and mathematics to engineering and medicine in the aftermath of the wars has created huge business opportunities for universities, laboratories and corporations. Modern scientists seem to be getting increasingly obsessed with seasonal and sensational problems rather than solving philosophically deeper issues. One such issue is bird flight, a subject in which Satish Dhawan evinced a keen interest.

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It is indeed a glaring irony that despite powerful computer and information technologies aiding science, nothing spectacular seems to have emerged after the double helix. This does not mean that all problems have been solved; it only means that non-lucrative esoteric ideas are unviable. Science of degradation of life and environment could solve the mystery of extinction of several species of birds, insects and animals as also human immunity to disease. Similarly, cataclysmic signals from cosmic explosions billions of years ago reaching us now are screaming for explanation. Science too seems to have degenerated into just another profession.

It is at this desperately critical juncture that reviving classics by Darwin, D'arcy Thomson and Feynman could perhaps steer young and pristine talent towards the pure and mysterious beauty of nature.

Keywords
Birdflight, Satish Dhawan

We should encourage students to take interest in studying the grandeur of natural flora and fauna. Nature protects us if we protect nature.

The 1988 CSIR Raman Memorial Lecture on bird flight was delivered by a great orator: Satish Dhawan. For those who missed this lecture, he prepared a 77 page article for *Sadhana* in 1991. Fortunately for some of us, oratory history repeated during the Golden Jubilee Lecture Series of the Department of Mechanical Engineering, Indian Institute of Science, Bangalore in 1995. Dhawan spoke for about an hour on bird flight ending his talk with a high speed movie. Having both heard and read Dhawan's articulate eloquence, it is amazing how little we appreciate the supple structure and subtle flying techniques of birds. Compared to birds, flying machines are monotonous, dull, loud, costly, unstable, and dangerous to our health and environment. It is precisely this terrifying reality that has nearly grounded Concorde – one of the most advanced supersonic jet aircraft in the history of aviation. It is also for this reason that we should encourage students to take interest in studying the grandeur of natural flora and fauna. Nature protects us if we protect nature.

Like crystals, birds may be grouped and the approximate 9000 species of birds are grouped into 27 orders. Dhawan cites an ornithologist James Fisher who established that there are close to a 100 billion birds with South America nurturing over 3000 species, Indian subcontinent 1200 species while North America, Canada and Russia supporting only 700. There is a definite link between birds and environment. Birds avoid congested places devoid of clean air and water. Dhawan's fascination and admiration for bird flight is infectious when he begins the Abstract and Introduction.

"Avian flight has fascinated man from ancient times but it is only in recent years that the efforts of scientists from diverse fields have been able, to some extent, to understand and explain the dynamics of animal flight... Observation show an incredible diversity of flight techniques and maneuvers...

Since time immemorial man has been fascinated and intrigued by the beauty, grace and intricacies of bird flight. There is perfect harmony of

form and function. It is equally exhilarating to attempt to understand how the physiology and performance of birds are related through scientific principles."

With his monograph on bird flight [1], Dhawan joins a special set of people who believe nature as the greatest of all teachers. Nature in all her wild fury of fire, wind, rain and thunder together with other beautiful forms of living nature like flowers and birds has inspired poetry, art, literature, science and technology. In *Monsoon,* Wilbur Smith [2] narrates the kinship of Tom and his younger brother Dorian with an albatross keeping company with their ship. The narrative is scientific in describing the magnificent flying skills of this gentle giant (see *Box* 1).

Henk Tennekes, an aerospace engineering professor at Pennsylvania State University, USA, has a different story to tell in his popular book *The Simple Science of Flight*: From Insects to Jumbo Jets [3]. Introducing the book, the author laments that

Box 1.

One day out of the great wilderness of the water there came an albatross. Circling the ship on wide pinions, dipping and rising on currents of air, gliding and planing, sometimes so close to the crests of waves that it seemed to become a part of the spume, it kept station with the ship for days on end (*Figure* A). Neither of the boys had seen a bird of that size before. At times it sailed close to where they crouched in their barrel-shaped perch, seeming to use the updraught from the *Seraphs* mainsail to hold its position, never flapping its Wings, only gently fingering the air with the black feathers at the tips. Dorian particularly delighted in the creature whose wingspan was three or four times that of his arms.

Mollymawk! He called it by the sailors pet-name meaning Stupid Gull, for its trusting, confiding nature when it settled to earth. Dorian had begged scraps of food from the ships cook and tossed them to the circling bird. Very soon the albatross had learned to trust and accept him, came winging to his whistle and cry. It sailed beside him almost close to touch, hanging almost motionless in the air, daintily snapping up the morsels he threw to it.

On the third day, while Tom hung on to his belt to prevent him falling, Dorian reached out as far as he could with a piece of fat salt pork in his hand Mollymawk regarded him with a wise, ancient eye, banked on his spreading pinions, and took the offering from him with a delicate pinch of his formidable curved beak, which could easily have lopped off one of the boy's fingers.

Box 1. continued...

Over the next few days Mollymawk grew tamer and more confiding towards Dorian. Do you think he loves me, Tom? I shall want to keep him forever as my pet.' But on the eighth morning when they climbed to the masthead the bird had disappeared. Though Dorian whistled for him all that day, he was gone, and at sunset the child wept bitterly...

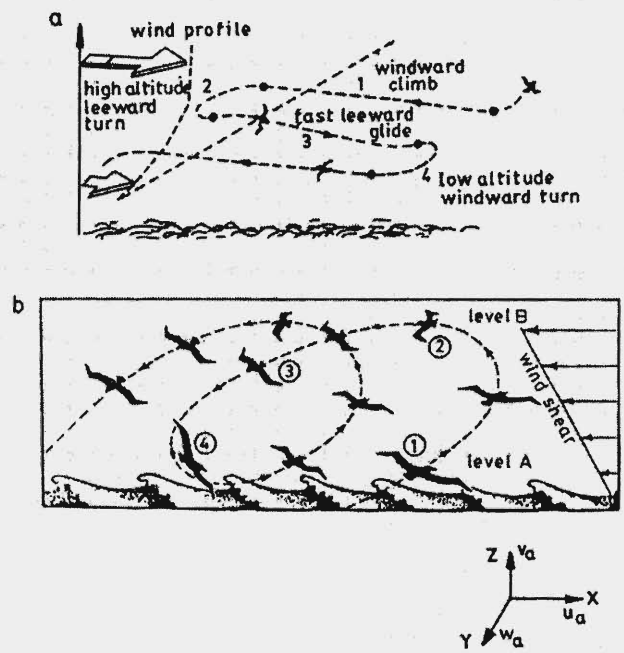


Figure A. Theory of dynamics soaring (Lighthill 1975). (a) Phases in the soaring flight of an albatross. (b) Dynamic soarind: (1) rise into wind, (2) turn at highest point, (3) glide down wind – build up of speed, (4) turn and repeat (1). (From S Dhawan, Bird Flight, IASc)

Frame or ref. moving with bird velocity $V_a(u_a, v_a, w_a)$
Energy equation in moving frame of reference:
Total energy of bird = rate of working of inertia force
– rate of loss by drag

$$(1/2)mV_a^2 + mgz = -[mv_a(dV/dZ)]\dot{u}_a - DV_a$$

K.E. P.E. Inertia force Loss due to drag
Positive if $(u_a v_a)$ is negative

modern education has ignored connecting nature and technology, and exhorts teachers and students to hone their experimental skills (*Box* 2).

Comparing birds with aircraft is a popular pastime for pilots and the public alike, but it is important to emphasize that bird flight is seldom steady. Most birds are either flying up or down or

Box 2.

The book is an act of revenge on the part of an assistant professor of aerospace engineering who dared to use flight calculations of ducks, geese, sparrows, and butterflies to entertain his class on aircraft performance. Two particularly humorless students complained to the head of the department: "We are studying aeronautical engineering because we are interested in aviation. Nowhere in the curriculum does it say that we have to study biology as well. Would you please ask Professor Tennekes to stick to the official syllabus?"...

"Henk, some of your students have complained", said my department head. "In you class you seem to have talked about géese and swans. I cannot condone that. Our profession – mine, and I trust yours, too – is a branch of engineering. Animals that flap their wings are none of our business. Please restrict yourself to airplane theory."

I was flabbergasted. It took me almost a minute before I managed to respond. "But the same theory applies to the performance of birds. Isn't that a nice bonus?"

I have always been fascinated by the similarities between nature and technology. I learn by association, not by disassociation. Weren't a swan and a 747 designed with the same tender loving care? Notwithstanding their differences, they follow the same aerodynamic principles, and it is nor that hard to explain how these principles work...

swinging left or right, enjoying all the degrees of freedom. The hummingbird can hover like a helicopter, and even fly *backwards*! Each wing flap and tail flick is executed artistically and effortlessly to aid birds meander through brush, woods or buildings. In this respect, fighter aircraft designers are studying birds closely to build lighter machines for speed and agility.

Very recently, McNeill Alexander has written a book on principles of animal motion including bird flight [4]. Clearly, the list is growing changing the mindset of students, teachers and scientists. Students, teachers, scientists, general public and mass media are actively promoting field trips and lectures to learn more about our environment through birds [5]. Camping around SHAR and the Nelapattu Sanctuary, Professor Dhawan distilled the essence of bird flight for the expert and the neophyte alike. The sheer biometric diversitv of birds and their complex modes of flight have challenged scientists, evolutionary biologists and mathematicians. Conventional aerodynamic

Kingfishers, sunbirds and hummingbirds are masters at hovering. The mesmerizing sight of these birds suspended in air has inspired over a dozen aerodynamic models.

scaling concepts fail to explain subtle features of bird flight, as debated by over fifty delegates in 1975 at Cambridge [6]. In particular, T J Pedley who edited the proceedings praised the pioneering work on hovering by Torkel Weis-Fogh and James Lighthill. Explaining this unique skill of tiny birds perhaps holds the key for linking birds and insects on the evolutionary totem pole.

Kingfishers, sunbirds and hummingbirds are masters at hovering. The mesmerizing sight of these birds suspended in air has inspired over a dozen aerodynamic models. Insects and birds defy gravity by inducing a steady downward air stream like a ceiling fan by simultaneous flapping and twisting of wings. Hummingbirds are also capable of flying backwards! Dhawan highlights the biomechanics of such magical avian feats including a cinematographic analysis of egret's take-off. This feat is illustrated with a simple plot of the temporal evolution of the flight path (*Figure* 1). It is amazing that this bird is airborne by flapping its wings twice within a matter of few hundred milliseconds. This data can be processed further to obtain power and energy needs.

Hovering and take-off make enormous demands on muscle power impossible to imagine in other animals. The sheer elegance of this extraordinary aerodynamic event is captured on the cover page.

To those who knew him, Professor Dhawan believed in the very best of science and society. This conviction inspired successive generations of students, professors and scientists to excel in their work. The only award or reward was the sheer intellectual excitement of creating new results for self-reliance and eradicating ignorance. With these ideals Dhawan propelled higher education and space research in India to attain the status that it enjoys today. Even after formal retirement, Dhawan took active interest in various activities of Indian Institute of Science. The following anecdote provides a glimpse of this unique personality.

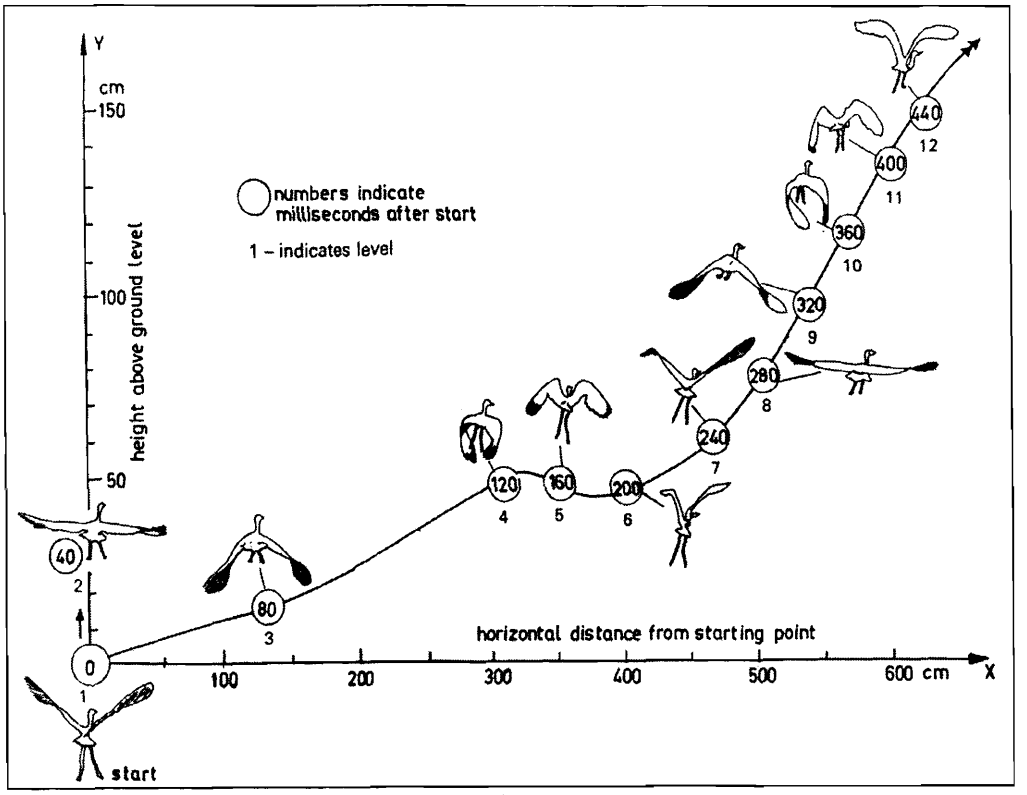
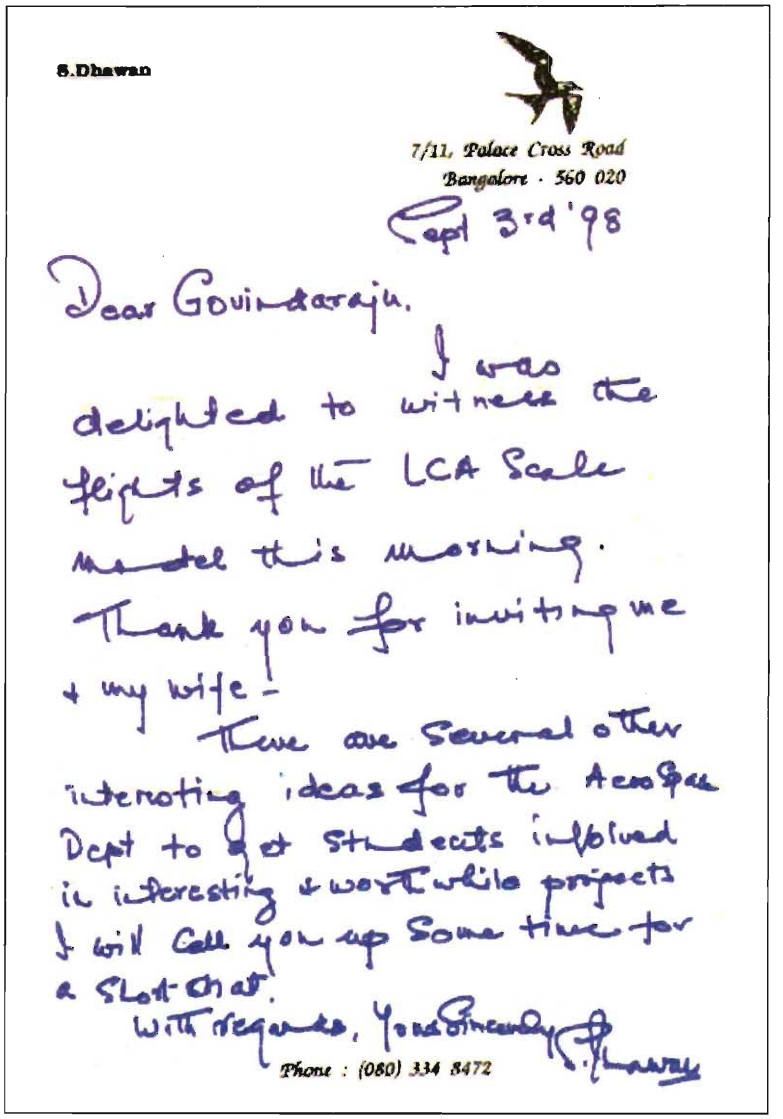


Figure 1. A study of the egret take-off. The horizontal distance from the starting point (in cm) is plotted against the height above ground level. The number within the circle indicates milliseconds after start. The number below the circle indicates the level. Note that between levels 4 and 6 the bird drops about 10cm as its flight has not fully stabilised. At level 12 the bird's speed is approximately 10m/s and its climbing rate is about 0.33 m/s. (From S Dhawan, Bird Flight, IASc)

In 1962 just before he became Director of IISc, Dhawan enrolled a young student for a laboratory course on aerodynamics. This student completed his doctorate in aeronautics and became his colleague. Many decades later, long after Professor Dhawan had retired, this younger colleague invited his teacher to attend a flight demonstration of LCA scale models at Jakkur. The event was scheduled for 1000 hrs on the morning of September 3, 1998. Due to heavy traffic, the host turned up ten minutes late! Professor Dhawan chided his host for being late: "You should allow for traffic delay in your planning!" Once the trials commenced and enthralled everyone, Dhawan remarked: "Now, I believe the LCA will fly." Delighted, the same day he wrote a letter of appreciation thanking his host for inviting him. The host – S P Govindaraju, who narrated this incident provided a scanned reproduction of this treasured letter showing a flying bird (*Box* 3), and also wrote a specialist review of Dhawan's book on bird flight which appears in this issue. This human quality of



S.Dhawan

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Sept 3rd '98

Dear Govindaraju.

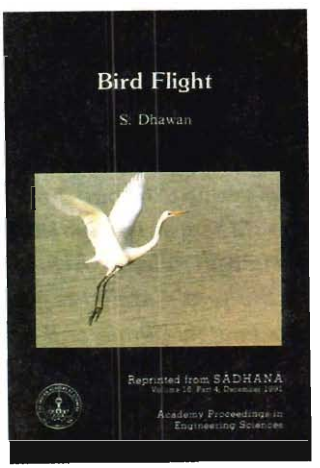
I was delighted to witness the flights of the LCA Scale model this morning. Thank you for inviting me & my wife -

There are several other interesting ideas for the Aero Sp. Dept to get students involved in interesting & worthwhile projects I will call you up some time for a Slot then.

With regards, Yours Sincerely

Phone : (080) 334 8472

Bird Flight, Academy Proceedings in Engineering Sciences, Reprinted from Sadhana, Vol.16, Part 4, December 1991.



spontaneous and sincere praise Professor Dhawan lavished on his students and colleagues endeared him to the people.

It is remarkable that Raman and Dhawan studied nature to enrich their respective professions to help launch Bangalore to a premier position in world science and technology. Bangalore is rapidly losing a lot of her charming gardens, lakes and birds except for some dashing green barbets and some sparkling sunbirds. But the charming spirit of Dhawan will continue

inspiring students, teachers, naturalists and environmentalists besides aerospace scientists and engineers. Reviving nature classics in science journals could perhaps revive the philosophical spirit of science among young students and scientists.

Suggested Reading

[1] Satish Dhawan, Bird Flight, *Sadhana*, 16(64), pp. 275-352, Dec 1991

[2] Wilbur Smith, *Monsoon*, Pan Books, 1999

[3] Henk Tennekes, *The Simple Science of Flight: From Insects to Jumbo Jets*, The MIT Press, 1997.

[4] R McNeill Alexander, *Principles of Animal Motion*, Princeton University Press, 2003.

[5] Madhav Gadgil, Project Landscape-9, Crows, *Resonance*, Vol. 6, No. 2, February 2001.

[6] *Scale Effects in Animal Motion*, Ed. T J Pedley, Academic Press, 1977.

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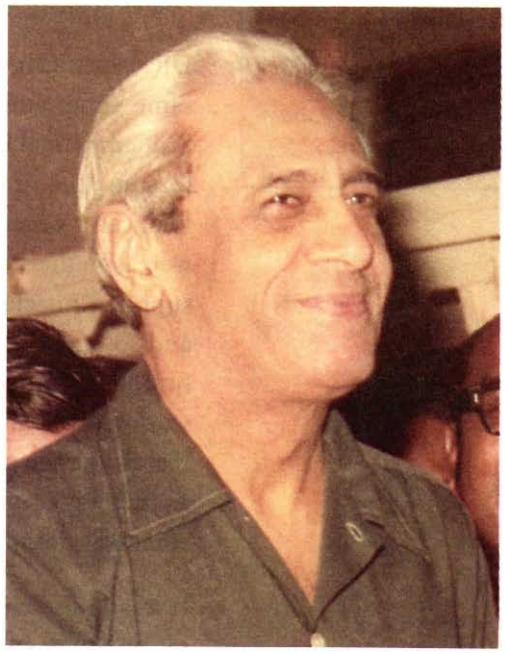
Satish Dhawan – with his wife, Nalini



... in a lighter moment