

# ***The Simple Science of Flight***

*From Insects to Jumbo Jets*

*revised and expanded edition*

*Henk Tennekes*

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## ***Preface***

I wrote a preliminary draft for this book in 1990. Much has happened since. For one, the book generated a lot of response, both from professionals in a variety of disciplines and from interested outsiders. Professional criticism concentrated on my decision not to delve into the details of aerodynamics. I am a turbulence specialist; I could easily fill an entire book with the curious tricks airflows can play. But that would lead me astray and confuse my readers. In the first edition I stuck to flight performance; in this revision I maintain that choice, except for a novel treatment of the aerodynamics of induced drag and trailing vortices in chapter 4.

I much enjoyed using parts of my book in college-level courses for senior citizens. The always lively interaction with my audience forced me to ponder how I should avoid pitfalls, where I should explain things in more detail, where I should tighten the argumentation, and what I should leave out. Similar feedback on the lecture circuit also gave me plenty food for thought. One frequent source of misunderstanding was my rather casual use of numbers. In this book I am not interested in great accuracy. I much prefer representative approximate numbers above three-digit precision. I want my book to be accessible to a wide audience; the nitpicking typical of much work in the so-called exact sciences would make it harder to achieve this objective.

I remember vividly how I was corrected in one of my senior citizens' courses. I was talking about bicycle racers and pilots of human-powered aircraft, and I explained that their hearts grow bigger from continuous exercise, just like their leg muscles. At one point, a gentleman in the last row raised his hand and said "Henk, it isn't just heart size that counts; the entire circulatory system is adjusted to long-distance performance." He turned out to be a

retired professor of cardiology, and he proceeded with a twenty-minute lecture on hearts, the elasticity of arteries, and what have you. The class loved it, and so did I. But the incident was also a reminder that I shouldn't get stuck in matters outside my field of competence. *The Simple Science of Flight* is meant for a general audience; it is neither a vehicle for scientific debates on animal physiology nor a manual for airplane design.

Still, I admit I am fascinated by the similarities between nature and technology. I learn by association, not by dissociation. Swans and airliners follow the same aerodynamic principles. Biological evolution and its technological counterpart differ in many ways, but I find the parallels between them far more exciting. Just what is it that makes some airplanes successful, but others misfits? And can such matters be explained without sophisticated advanced mathematics? Would high school algebra suffice?

Many popular science books make quite a fuss of the marvelous progress of science and engineering. All too often the hidden message is "Dear reader, you are but a layperson. You should have deep respect for the sophistication revealed to you by specialists, who are the ones who really understand the secrets of the universe, the building blocks of life, the fantastic blessings of computer technology, or the great achievements of aerospace engineering." I have never been a fan of such grandiose perspectives. They tend to elevate science to a level where ordinary people have no choice but to kneel. I prefer to make science accessible, and I don't mind that it takes a lot of effort to struggle with the arcane texts presented in scientific journals. Also, I do not agree that one's respect for miracles is lessened by an attempt to understand them. On the contrary, one's sense of wonder can only grow as one's insight increases. After one has computed how large a swallow's wings should be, one's respect for the magnitude of the mystery that keeps the bird in the air can only be greater. The intimate knowledge of meteorology that migrating monarch butterflies apparently possess helps me to keep my feet on the ground.

There is a lot of news from the research front. Systematic observation by several groups of ornithologists during the last twenty

years has made it clear that the migration speeds of many birds are substantially higher than the speed calculated from the simple algorithms I had condensed from the professional literature. I used to think that only homing pigeons fly at top speed regardless of the consequences. (They race at more than 40 miles per hour, though taking it easy at 25 mph would minimize their fuel consumption.) Now it appears that all migratory birds fly as fast as their muscles allow when they are in a hurry. Not all species are in a hurry, though; the migratory habits of gulls and terns, for example, seem rather relaxed.

The study of bird migration has made giant strides since 1990, thanks primarily to the continuing accumulation of radar data but also thanks to the use of lightweight transmitters and fieldwork on the Arctic tundra. The current migration champion is the bar-tailed godwit (*Limosa lapponica*), a fairly large wading bird that weighs 500 grams at takeoff. It has been confirmed by several parties that the godwit flies nonstop across the Pacific Ocean, from Alaska to New Zealand—a distance of 11,000 kilometers (7,000 miles). That feat, comparable to the performance of a long-distance airliner, proves that the godwit has much better aerodynamics and much better muscle efficiency than was previously thought, and that it undergoes rather severe physiological adaptations before and during its seven-day flight. New evidence on the migration of other wader species points in the same direction. Professionals have severely underestimated birds' flight performance. Impressed by the new evidence, I had to make many changes throughout the book. New wind-tunnel studies also have generated excitement. The champion of those studies is a young female jackdaw (*Corvus monedula*) that apparently was quite at ease in the wind tunnel of the Flyttnings Ekologi (Flight Ecology) department of the Ekologiska Institutionen at Lund University in Sweden. It exhibited superb gliding performance notwithstanding its rather ordinary wings. It would glide more than 12 feet forward for each foot of height loss, twice as far as most researchers had thought. In retrospect, many of the early wind-tunnel experiments with birds and even some recent ones failed to produce reliable results.

In the first edition I dealt with flapping flight in a rather offhand way, partly because there were very few wind-tunnel data available. This time I can be a lot more specific. The Swedish jackdaw receives considerable attention, because its best gliding speed is much lower than its reported migration speed.

I was a fan of the Boeing 747 when I conceived the first edition of this book, and I remain a dedicated fan of the Big Bird that, in the 1969 phrasing of *Newsweek*, introduced A New Air Age. But much has happened since. Airbus, the European conglomerate, now markets the A380, which is meant to drive the 747 into oblivion. And Boeing has responded. Its 777 offers transportation capacity equivalent to that of the 747, but with improved aerodynamics and superior engine efficiency. In the first edition, I wrote that the Boeing 747 had been the dominant mode of intercontinental transportation for 25 years, and that it would remain in service for at least another 25. Yes, it will. However, like an old warrior, it will fade away 30 years from now. Other airplanes, such as the Boeing 777 and 787 and the Airbus A350, will promote the idea that we don't have to change planes as we fly from Hamburg to Pittsburgh. The hub-and-spoke system of airports will no longer dominate intercontinental traffic.

The Concorde went out with a bang. A fiery crash near Paris on July 25, 2000, signaled the end of its career. It didn't quite make the centennial of the Wright brothers' first powered flight. In chapter 6, I reflect on the fate of supersonic transportation. In retrospect, the Concorde was a fluke, more so than anyone could have anticipated. From an evolutionary perspective it was a mutant. It was a very elegant mutant, but it was only marginally functional. The fate of the Concorde inspired me to draw parallels between biological evolution and its technological counterpart wherever appropriate.

*The Simple Science of Flight* has been my sweetheart ever since I started dreaming of it, back in 1978. It has become a favorite of many readers all over the world. Its revitalization and rejuvenation will surely endear it to the next generation of people who are, like me, enthralled by everything that flies.