THE THEORY OF SOARING FLIGHT IN VORTEX SHELLS-1

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INTRODUCTION

In order to insure the continued progress and growth of any technical endeavor, it is necessary to provide a carefully planned supporting program of fundamental research. This is especially true of the art and sport of soaring flight, where progress depends entirely upon the acquisition and exploitation of new knowledge. The direction which this research should take must be carefully considered since it will be governed by the modest budgets of voluntary contributors.

For those of us interested in the technical aspects of soaring flight, and hence in the planning and execution of such research, a primary step is the formulation of realistic goals towards which to work. Obviously, if we today possessed a quantitative knowledge of atmospheric structure and phenomena, we could immediately design sailplanes capable of the maximum possible performance in any specified task. We could answer with certainty the many important questions which face us today such as: What further increases may we reasonably expect in distance, goal, and duration flights by conventional sailplanes? Does the present trend in sailplane design offer the maximum efficiency in utilization of the most common atmospheric energy sources? Is it possible that some undiscovered atmospheric or aerodynamic phenomenon exists whose utilization will open new horizons for soaring? Is there any way of significantly extending the present range of geographical areas in which soaring may be commonly practiced in this country? And most important of all, is it possible to significantly increase the certainty and reliability with which soaring flights can be performed, especially as regards goal and return flights? Unfortunately, we do not possess the necessary knowledge; it will be quite some time before we do. Despite the great progress of meteorological science, that part which has been reduced to a sufficiently quantitative form to be useful to soaring technology is quite small.

It thus appears that until we have gained a much more detailed quantitative knowledge of the form, magnitude, and availability of the various geophysical - meteorological energy sources which actually exist in nature, we cannot expect soaring technology to show significant progress. Fortunately, however, there exists a promising alternative which can effectively guide our current research efforts. We can follow the birds.

The value to soaring of the information to be gained from a scientific study of soaring birdflight cannot be overestimated. I have previously called attention to this fact.* In natural soaring we find use being made of almost every soaring energy source, with an efficiency and reliability that seems impossible. Just to achieve such efficiencies and reliabilities with man-made craft would be an enormous accomplishment in itself, quite aside from the possibility of improving upon them. All that is required is that we critically examine the facts of natural soaring and attempt to deduce the principles. In this way we can cull from the large number of theoretically possible soaring mechanisms those relative few that the birds show us do exist in nature in sufficient magnitude to make soaring a practical, daily routine. It may well be that some valuable soaring possibilities exist which the birds have not seen fit to utilize; this knowledge will come to us only after great strides in meteorology have been made, and we are presently seeking promising means for immediate soaring progress. Let us, therefore, consider briefly the known forms of natural flight and see what profitable avenues of soaring research are indicated.

Forms of natural soaring.—On the basis of the two fundamental conditions first stated by Rayleigh in 1883,* all soaring, be it by bird or man, must come under the classification of dynamic or static. In dynamic soaring the air currents have no average vertical velocity relative to the earth and the flight depends upon the nonuniformities of the wind with regard to time and location in space. In static soaring there is a net local upward vertical velocity relative to the earth. Based on our present knowledge of the atmosphere, dynamic soaring of several forms is possible and under certain conditions is most profitably used by birds. Under the constant conditions of surface wind shear existing over the oceans, such superb soaring birds as the albatross practice dynamic soaring almost exclusively. Over land areas, however, the evidence that birds practice dynamic soaring, except under stormy or turbulent weather conditions, is scarce. This is certainly not to say that land birds cannot soar dynamically or that the air is not sufficiently nonuniform to power dynamic flight, but simply that observations indicate that the generally used forms of natural soaring are not of dynamic origin. It appears that even though dynamic possibilities may exist over land, they are overshadowed except in rare cases by a much more certain and usable form of soaring energy. For land birds the soaring flight appears to be almost exclusively of static origin. This conclusion is verified by the fact that man in his sailplanes has been able to imitate, to a more or less successful degree, all of the common soaring modes of land birds; man has not yet accomplished successful dynamic flight.

The static soaring of birds is classified according to the manner in which the vertical air currents are produced, and hence the classification depends upon the energy source. The geometry of the bird and his flight regime have evolved to most efficiently satisfy the aerodynamic requirements for using these various forms. There are three principal sources of vertical motion in the atmosphere: (1) declivity currents caused by air being diverted upward over a surface obstruction, (2) so-called thermal currents caused by the convection of buoyant fluid masses, and (3) a combination of declivity - thermal sources wherein unstable stratified air is set into buoyant convection by the declivity motion initiated as the air passes over an obstacle. It should be noted that very strong declivity currents can be produced even without apparent surface obstructions. For example, when wind blowing over a large body of water encounters a

* C. D. Cone, Jr.: "An Apprenticeship to the Birds," *Soaring*. May-June, 1957, p. 19-23.

** Lord Rayleigh: Letter to *Nature*, XXIII, 1883, p. 10.