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NASA RESEARCH OBJECTIVES AND ROLES

1

Alfred Gessow
NASA Headquarters

I think that it is very fitting that this conference on advanced technology airfoils be held here at Langley, for this Center is the origin of the well-known and widely-used NASA series airfoils. It was those airfoils, more than any other single factor, I believe, that gave NACA its well-deserved international reputation. I also want to express my pleasure in being a cochairman of a conference which has as its honorary cochairmen Ira Abbott, who spearheaded much of that early effort, and Dick Whitcomb, who is responsible for getting much of the current NASA effort started.

I've put together (fig. 1) an abbreviated chronology of airfoil development in order to put the present NASA airfoil program in perspective. As you can see, the bulk of the NACA airfoil effort occurred in the 1930's and the early 1940's. Although there was some additional effort in the 1940's and early 1950's such as the "H" series for rotorcraft, NASA didn't get back into the airfoil business in a meaningful way until the late 1960's when Whitcomb began his supercritical airfoil work. The success of that effort and the extension of the technology it represented to other applications led to the present expanded airfoil program which was started in the early 1970's.

In structuring our present program, it is instructive to consider the reasons why the NACA series airfoils had the impact they had. The first and obvious one is that they were good airfoils, better in a number of respects than the ones which they eventually replaced. The second is that they were the result of a systematic development program of families of airfoils which were derived from a particular design philosophy and carefully documented. In this way, airplane designers could choose an airfoil that seemed optimum for their use and could assess what performance penalties would occur if they had to deviate from the ideal section because of practical constraints. The key to success, then, was a systematic program which resulted in families of airfoils for different applications with documented characteristics.

This view was brought home to us by the industry representatives who attended a NASA/Industry Airfoil Workshop which we held in Washington in January 1975. The purpose of that workshop was to review and discuss our airfoil program to determine its responsiveness to industry's needs. We received a number of good suggestions from that meeting and adjusted and refocused our program accordingly. The specifics can best be brought out by considering the objectives and elements of our present program (fig. 2).

As you can see, the thrust of the objectives is twofold. One is to research and provide advanced analytical and experimental methods for the design and for the determination of the characteristics of not only single element airfoils, but of multielement airfoil combinations used in aerodynamic controls and high-lift systems (fig. 3). The increased emphasis we are now giving to such airfoil systems is a result of the needs for such information which was expressed at the 1975 workshop. The analysis and design methods which we research are made available to industry for their use in developing airfoils for their specific use and are also used by us in the second half of our program to develop and document the behavior of generic families of airfoils for a range of aircraft types as shown in figure 4.

The analysis methods which have been and are being developed draw heavily upon and benefit from the remarkable advances made in computational aerodynamics during the past few years. The use of computational codes, coupled with mathematical optimization techniques, constitute a powerful tool for turning out new airfoil designs to satisfy specific requirements. In spite of limitations, these computational methods have proven to be singularly successful for design purposes and can be used to document airfoil characteristics as well, at least at conditions involving no or small amounts of separation. Simplistically, the state of the art can be characterized by the theory-data comparison shown in figure 5. Viscous theory is fine, whether we are talking about low speed calculations or more sophisticated transonic codes, but only until separation occurs. Thus, the problem of handling viscous-dominant flows is receiving wide attention by researchers, and one approach which is starting to show promise is shown in figure 6, which gives results of Prof. Carlson's free-streamline modeling theory applied to a low speed airfoil. Another approach - the use of Navier-Stokes codes - may work for the very low Reynolds number situation wherein laminar separation occurs (fig. 7), as we can see by comparing Mehta's code with a flow visualization experiment and even for unsteady transonic flow at small angles of attack. Unfortunately, such codes do not work as yet for situations involving large regions of turbulent flow and we are placing a great deal of emphasis at our Centers in providing better turbulence models for handling such cases with Navier-Stokes codes.

We have spent and are spending a good deal of effort in the third element of the methods part of our airfoil program in improving existing facilities and developing new ones and in developing test and instrumentation techniques to extend the range and validity of 2-D data. You will be hearing talks on this aspect of our program, and I will only mention here that our stable of facilities, which includes Langley's low-turbulence pressure tunnel, 6- by 28-inch transonic tunnel, and 0.3-meter transonic cryogenic tunnel, and Ames's 2' x 2' transonic tunnel and 11' transonic tunnel, cover the complete Mach number and Reynolds number map for all classes of aircraft combinations.

Insofar as the applications part of our program is concerned, you'll be getting some detailed information regarding our efforts from the following two speakers. I will only mention a few things that we have done to be responsive to the needs and recommendations of the industry as surfaced at the January 1975 workshop: We have expanded our experimental program to document the characteristics of our new supercritical and low speed airfoil designs covering a large range of thickness and design lift coefficients, and in particular, we have included data on high-lift systems; we have initiated and now have in operation an airfoil design and analysis service at Ohio State University; and after a slow start, we have tested a large number of rotorcraft airfoils to get baseline data for new designs which are underway. Our applications program also includes the design and testing of very thick airfoils for large cargo aircraft, very thin airfoils for turboprop application, and special purpose airfoils for wind generators, RPV's (remotely piloted vehicles), and rotating machinery.

As to where and how the program is carried out, it is clear that the bulk of the design and testing is in-house although we have gotten some excellent university help in obtaining low speed airfoil data. We also look to universities and industry for help in advancing our analytical capability. Langley is our lead Center in this program with an across-the-board capability, with Ames making particular contributions in Navier-Stokes analysis, design optimization procedures, and in acquiring high-lift system and unsteady aerodynamic data. The contributions from the various in-house and outside sources will become apparent as the papers are presented in this conference.

Before turning over the podium to the next speaker, I'd like to say that I think that we have made some solid contributions in airfoil development and hope to make a lot more in the next few years. Much of the success of the Langley program can be attributed to Bob Bower's interest and support in marshalling the resources of the Center behind the program. The other individual who has worked hard and effectively on a day-to-day basis to make the program and this conference go, who has acted as a principal spokesman for the program to the outside community, and who feeds me information as I need it with great patience and humor, Ken Pierpont. I take this opportunity to acknowledge their efforts.

DATE	TYPE	APPLICATION
EARLY 1900's	JOUKOWSKI, GOTTINGEN, NPL, ETC.	MOST AIRCRAFT
1920's	CLARK Y	PROPELLERS
1930's	NACA 4 & 5 DIGIT SERIES	MOST AIRCRAFT
	NACA 1 & 2 SERIES	PROPELLERS
1940's	NACA 6 SERIES	1ST GENERATION JET AIRCRAFT
1950's	NPL "PEAKY"	2ND GENERATION JET AIRCRAFT
1960's	NLR SHOCKLESS, WORTMANN	ROTORCRAFT
1970's	NASA SUPERCRITICAL, GA(W)-1, AND OTHER ADVANCED TECHNOLOGY PROFILES	ALL SUBSONIC AND TRANSONIC AIRCRAFT

Figure 1.- Chronology.

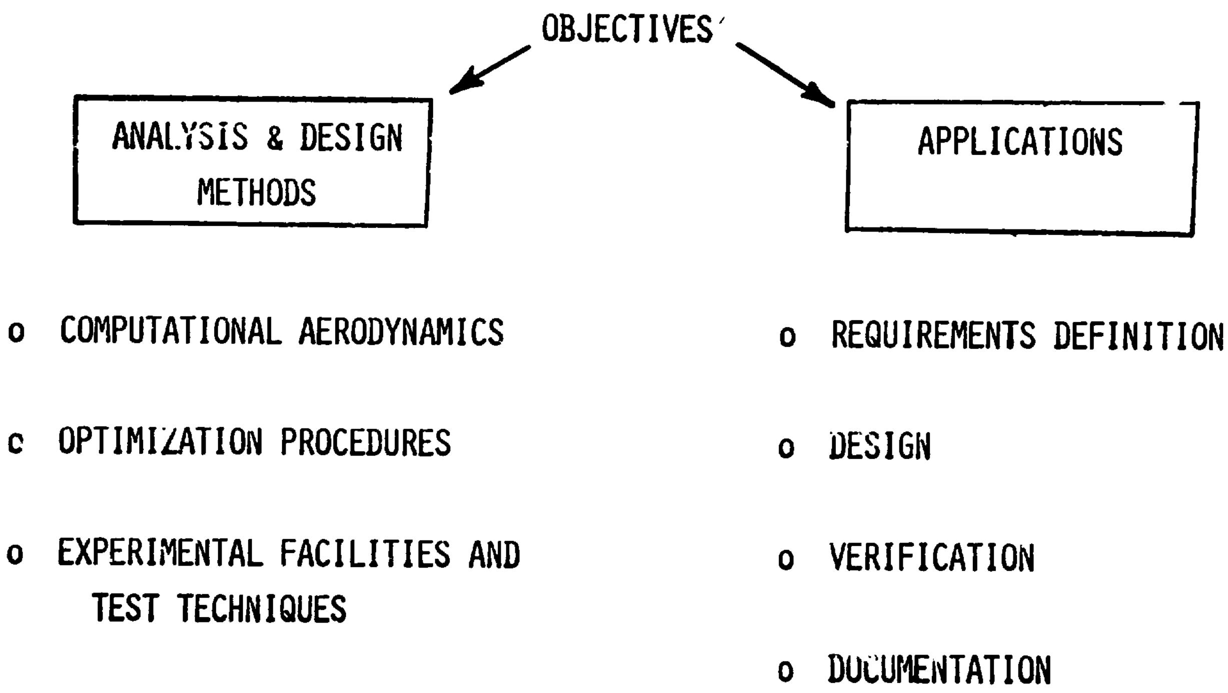


Figure 2.- NASA airfoil development program.

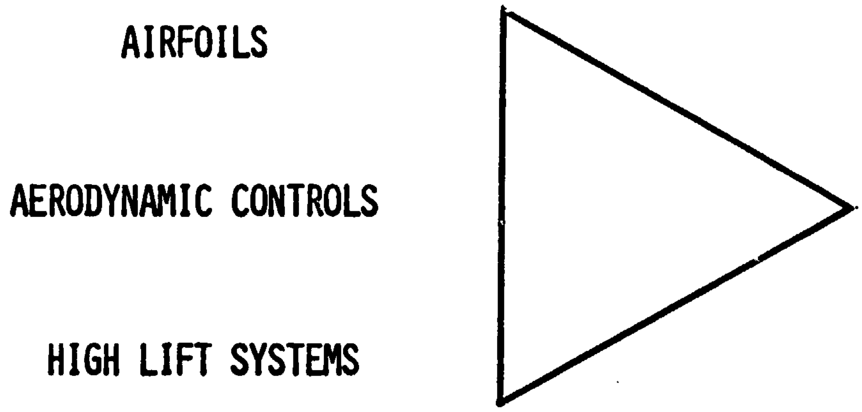


Figure 3.- Single element airfoil thrust.

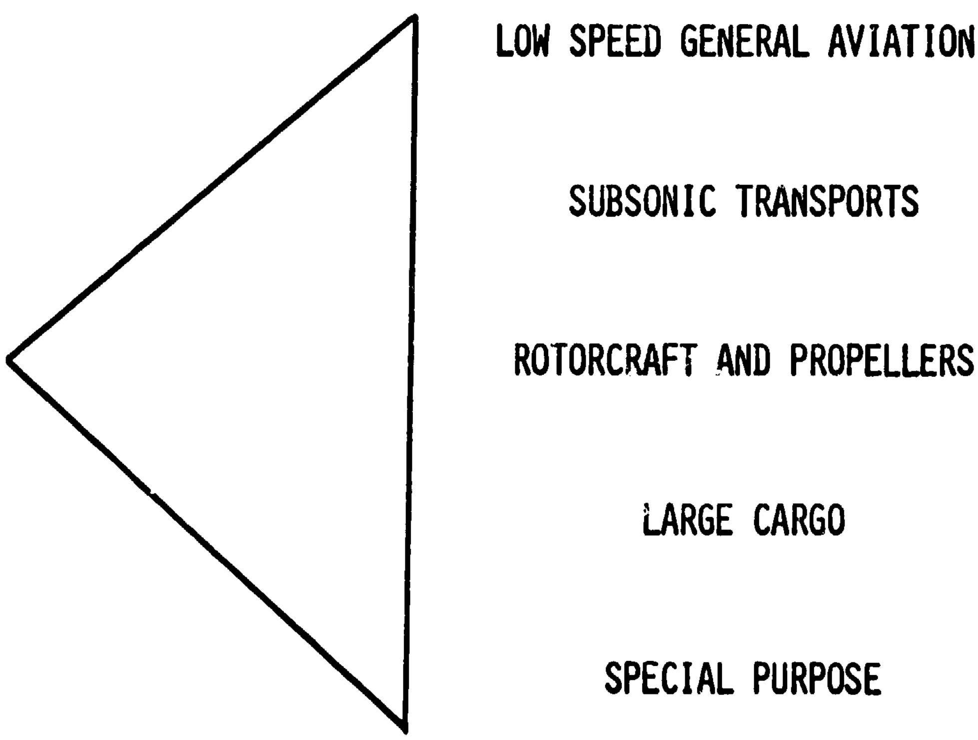


Figure 4.- Airfoil applications.

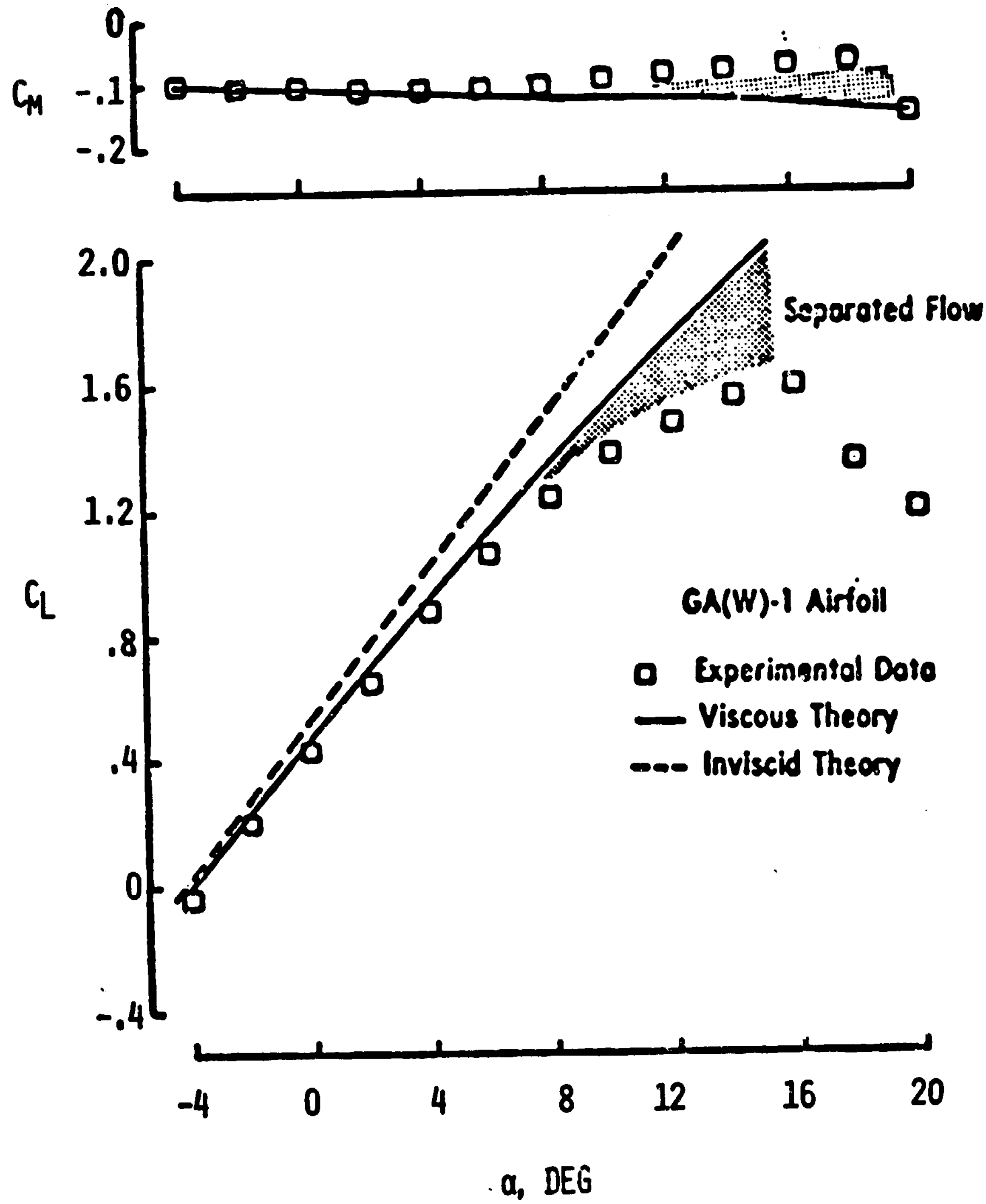


Figure 5.- Airfoil with separated flow.

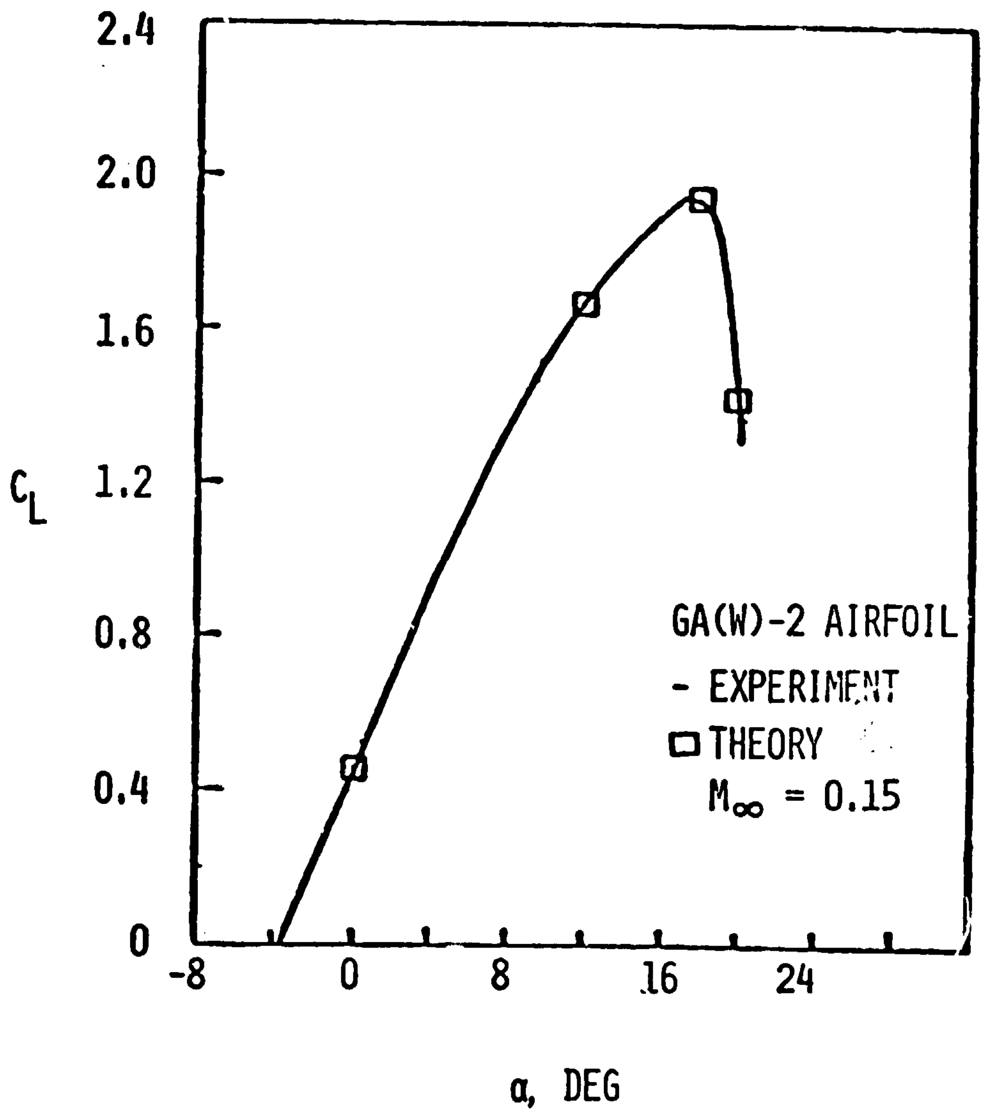
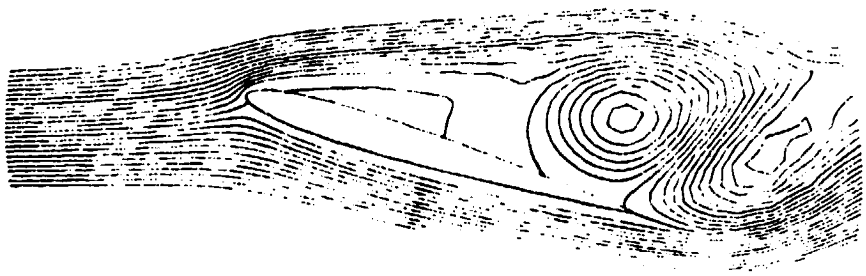


Figure 6.- Massive separation flow model.



(a) Angle of attack, 15°; Reynolds number, 10^3; 9% thick symmetrical airfoil.

(b) From Prandtl, L. 1952 Essentials of Fluid Dynamics, p. 200, figure 3.83.

Figure 7.- A qualitative comparison of leading-edge stall.