AMES 1950 INSPECTION

July 11 Session in Auditorium

John F. Victory

Good morning, gentlemen. The voice you are hearing is that of John F. Victory, Executive Secretary, National Advisory Committee for Aeronautics. It was my honor and privilege in the name of the Committee to extend the invitations pursuant to the acceptance of which you are gathered here this morning. Perhaps I should take just a moment to say a word about the NACA. It is an independent agency of the Government organized very much like a typical American business corporation. The stockholders are the people of the United States; their President appoints the Directors - 17 in number - including representatives of the Air Force, the Navy, various governmental agencies, industry, and scientists from private life. The main Committee meets monthly. It determines policies and programs, elects its own officers annually, and appoints the head executive officials: the Director, Dr. Dryden; the Executive Secretary, yours truly; and the Associate Director for Research, Mr. Crowley. The NACA has three major research stations: the senior laboratory, the Langley Aeronautical Laboratory, located on the Langley Air Force Base in Virginia; the Ames Aeronautical Laboratory, located here at Moffett Field, California, a Naval Station; and the Lewis Flight Propulsion Laboratory, located on the Cleveland Municipal Airport. It has about 7000 employees, all under civil service.

It is also my great privilege and pleasure this morning at this time to present to you Dr. Jerome C. Hunsaker, Chairman of the National Advisory Committee for Aeronautics.

Dr. Hunsaker--

<u>Dr Hunsaker</u>

Gentlemen - The Chairman's function is largely perfunctory, but it is a pleasure to welcome you here on behalf of my colleagues of the Committee to see something of the activities of this laboratory and some subsidiaries and to give you a sampling of what is being done in the way of scientific research on those problems that appear to be of great current importance and in a somewhat abbreviated way some idea of the results or potential results of that research. I think you are the best judges as to whether those potential results are of significance to the quality of our future aircraft. The research program that is undertaken by the Committee, and on which public funds are expended, contains many research authorizations - many, many projects. You would have to spend a long time in any one of these laboratories to get an over-all impression of what these projects amount to. To save you time, the staff here have worked up, and I think with commendable intelligence and good sense, a sampling procedure. There is a statistical theory of sampling. If the samples are properly chosen, you do get a correct impression of the whole. I trust these samples will not only be intelligible to you but entertaining.

I will now call upon Dr. Dryden, who is the leader of these 7000 devoted people working on the scientific problems of flight. Dr. Dryden- -

Dr. Dryden

Dr. Hunsaker and friends, both old and new - I am very curious to know how many of you are attending an inspection here for the first time. Will those of you for whom this is the first inspection hold up your hands so that we can get a rough division. Why this is almost 100 percent, a very high percentage. I want to tell you in a general way just a little about the work of the Committee - what it is we are trying to accomplish. As we see it, our job falls down into three general areas. First, we do serve the military services and the industry in connection with immediate problems associated with airplanes that are now in operation and those coming into operation - in other words, the familiar trouble shooting- attempting to give such assistance as goes out of our own background of knowledge and experience and such assistance as can come from tests or experiments which can be carried out in a very short time. Our principal function, however, as we see it is to lay the ground work of scientific knowledge which will enable the designers in industry to design airplanes for particular uses. Most of you are sufficiently familiar with aircraft design to know that the designer is confronted with many compromises. You can't design to be the best in every possible respect. It's necessary to make choices. There is a very simple illustration, in the question of how to get the air into a jet engine. The aerodynamicist will tell you that the most efficient and easiest way is to take it in through a hole in the nose, but the designer of aircraft has other uses for the nose besides putting an air duct there. He might like to put armament or radar or something else, and so he has to make the compromise in the particular design. What he would like to know and what we would like to be able to furnish him is the full story on what penalties would be paid if the air inlet is put somewhere else - what the external drag amounts to, what the loss in ram pressure may be. If there is sufficient broad knowledge available, he can then make his design in an intelligent manner. This laying of the foundation for scientific advances in design we consider our primary function, and it occupies by far the greatest part of our effort. Finally, we feel the responsibility to try to outguess the designers a little bit as to the future to be prepared in time for his new demands, and so we are occupied on some much longer-range things. We have to devise the tools of research. We have to anticipate what kinds of wind tunnels we may need and see that the money is obtained and that they're built in time so that the research results will come out when the designer wants them, and so you will find us doing experiments at very high speeds some of you may think rather impractical at the moment and of less interest; but the research man must look ahead to the future, and we have long-range work of this kind.

Now, I think that's enough for a general idea. Our product of course is information, which we try to convey in various ways. Perhaps the poorest way is the printed report. There are other ways which are used: the technical conferences, the small groups sitting around the table discussing the problems of a particular design group, and finally, this type of inspection where we attempt to give you a general impression of what's going on and what you might hope to find if you came around when there wasn't such a big crowd and could sit around the table and go into greater detail.

And now we will get down to a little more detail rather quickly and I will introduce to you Mr. DeFrance, the Director of the Ames Laboratory and your host for today.

<u>Mr. DeFrance</u>

Dr. Dryden - We are always glad to have our friends of the armed services, the industry, and other government agencies visit the laboratory. Many of you have visited the laboratory from time to time with specific problems, but at that time you did not have the opportunity of inspecting the entire laboratory. Today we hope to give you that opportunity and give you an opportunity to see some of the work that has been done here at the laboratory and also at the Langley Laboratory. I hope that the inspection will be interesting and pleasant to you, and we want to make your visit very pleasant.

Here at Moffett Field we have a very good neighbor, the Navy, without whose assistance it would be almost impossible for us to carry on our work. It is my pleasure at this time to introduce to you Capt. John Harris, Commanding Officer of Moffett Field. Naval Air Station. Capt. Harris - -

Capt. John Harris

Gentlemen - We consider it a rare privilege to be associated with the Ames Laboratory. We think very highly of Smith DeFrance and his crew, and we do everything we can to help them out and Smith does everything he can to help us on any of our little problems that come up. As the Commanding Officer of the Station, I want to extend to you the welcome of the Station and if there is anything that we can do to make your visit here a little more pleasant, we are at your command. Welcome to Moffett Field.

Mr. DeFrance

Thank you Capt. Harris. We thought that it would be of interest to you to have a summary of the type of work that is conducted at the laboratory and give you a better idea of some of the things that you will see during your tour today. In other words, by giving you the summary we hope that you will be able to coordinate what you see today and a complete research picture. At this time I would like to introduce Mr. Russell Robinson, Assistant Director of Ames Laboratory, who will present a summary of our research work. Mr. Robinson - -

(Reference Mr. Robinson's speech as previously presented on July 10)

Mr. DeFrance

Mr. Robinson in his summary has given you the theme of the inspection tour that you are to take today. I hope that this has clarified some of the terms and some of the things that you will see during your tour. Before we start on the tour, I would like to introduce our Associate Director of Research, Mr. John W. Crowley - - - - and our Executive Officer, Mr. Chamberlin.

You will notice that you have been given cards with a definite color. From here we will proceed in one body, but at the next stop we will divide into those colors; so therefore do not try to break up at this time. The busses are on either side of the auditorium, and I would like to ask you to proceed as rapidly as possible and board the busses and you will be taken to the first stop. Thank you.

AMES 1950 INSPECTION

July 12 Session in Auditorium

John F. Victory

Good morning, gentlemen. The voice you are listening to is that of John F. Victory, Executive Secretary, National Advisory Committee for Aeronautics. It was my honor and privilege in the name of the Committee to extend the invitations pursuant to the acceptance of which you are assembled here this morning. In the name of the Committee I bid you welcome to this biennial inspection of the Ames Aeronautical Laboratory. This is the third and concluding session of the biennial inspection. The first was for the industry and Government, universities; the second for the military services; and the third for military schools. Perhaps a word would be in order as to what is the National Advisory Committee and what is its status and mission. It is an independent agency of the Federal Government organized very much like a typical American business corporation. The stockholders in the corporation are the people of the United States, the taxpayers. Their representative is the President and in their name he appoints the directors instead of the stockholders electing the directors. The directors, the members of the main Committee, are 17 in number. They include the Air Force chief of staff and one other, Navy, Civil Aeronautics Administration, four scientific agencies of the Federal Government, four representatives of science from private life, and a representative each of the airframe, the air engine and the air transport industries. The purpose of the Committee as provided in the law is to supervise and direct the scientific study of the problems of flight with a view to their practical solution and to direct and conduct research and experiment in aeronautics. Under the main Committee there are 4 major and 22 subordinate technical committees. In that way the NACA has striven to mobilize in America the scientific talent in aeronautics with a view to laying down research programs calculated to anticipate and to meet the needs of the military services so that America will always have the fundamental basic information and design data to enable the military and the industry working together as a team to produce in our beloved country aircraft unexcelled by those of any other nation. The main committee functions, as I said, as a typical board of directors. They meet monthly - that's the difference - ordinarily boards of directors meet annually or semiannually. They determine policies and programs; they elect annually their officers - a chairman and vice-chairman, and they appoint their chief officials, a director, yours truly the executive secretary, and an associate director.

We have three major research stations. The senior station is the Langley Aeronautical Laboratory located on the Langley Air Force Base in Virginia. The second station is the Ames Aeronautical Laboratory located here at Moffett Field, California, a Naval Station, and the third is the Lewis Flight Propulsion Laboratory located on the Cleveland Municipal Airport. In addition we have two subordinate activities, one at Wallops Island, Virginia. We have the whole of that little island south of

Chincoteague. There we are conducting some basic research on the stability and control of guided missiles. We also have a high-speed research activity located at Muroc. I believe your tour will include Muroc, and you will have a chance to see it. I don't believe you get into Wallops Island on your tour. We would like to have you go there some time. Our laboratories comprise a paid civil service staff of about 7000 employees. The total plant value as of today is between $140,000,000 and $150,000,000. Congress has just appropriated an additional $75,000,000 to implement the Unitary Wind-Tunnel Plan Act of 1949 to enable America to have some really modern first-class supersonic research facilities to be at the disposal of the military services and industry. That briefly, gentlemen, is a bird's eye view of what is the NACA. We are very happy to have you here on these occasions. We greet you as friends. Some of you may have been with us before, although I imagine this group is probably making its first visit here. We are glad to show you a little sampling of what we've been trying to do here at the Ames Laboratory and also at the Langley Laboratory during the past year.

It is now my pleasure to present to you the Director of the Ames Aeronautical Laboratory, Smith J. DeFrance.

Mr. DeFrance - -

Smith J. DeFrance

On behalf of the staff of Ames Laboratory, it is a pleasure to welcome the members of the military schools and our friends from the bay area and the San Francisco Chamber of Commerce Aviation Groups. These inspections, as Mr. Victory has said, are held biennially at this laboratory and the alternate year biennially at Langley Laboratory. It is the purpose of the inspection to make a report to the industry and the armed services of the work that we have been doing both at this laboratory and at the Langley Laboratory. I am just curious to know how many of you have ever attended an NACA inspection at either this laboratory or at the Langley Laboratory. Will you raise your hands. Not many of you have attended an inspection previously. Well, I want to assure you that this is not going to be too technical. We have tried to present the material so that you will understand the work that has been done without going into the technical side too deeply.

At this time I would like to present Mr. Carlton Bioletti, the Assistant Director of Ames Laboratory, who will present to you a summary of what you will see on your tour today and tie up the theme of the inspection with the research that has been completed. Mr. Bioletti — -

(Reference Mr. Robinson's speech as presented on July 10 and 11, which is the same as that given by Mr. Bioletti.)

Mr. DeFrance

Thank you, Mr. Bioletti. With this summary, I believe you will be able to coordinate the material that will be presented at the various stops on your tour today. I hope that you will enjoy the tour, and I hope that it will be instructive to all of you.

You will notice that you have been given tags - identification cards - with colors on them. At this time we will leave the auditorium. I would like to ask all of you to divide according to the color on your badge, and you will be conducted throughout the day by busses with the same color on the busses. All of you will see the same exhibits and get the same tour. I would like to introduce your group leaders at this time. The Red group, Mr. Charles Harper. Will you hold up your banner there, Mr. Harper. You will follow with him, and the bus with the Red group will be on the east side of the auditorium. The White group, Mr. Wallace Davis. Will you hold up your banner. The White group bus will be on the west side of the auditorium. The Blue group, Mr. Arthur Freeman. Will you hold up the banner please, and the bus for the Blue group will be on the east side of the auditorium. And the Green group, Mr. Albert Erickson, and the bus will be on the west side of the auditorium. You will now please proceed to the busses. We will start the tour. Thank you.

AMES 1950 INSPECTION

High-Speed Research on High-Speed Wings

by

Flight Engineering

In the course of your visit here today you will be shown many of the test facilities of the Ames Laboratory and data from a large number of facilities both here and at Langley will be presented. These facilities test models of greatly different size and over widely different ranges of speed. The question that naturally occurs to the visitor viewing this is "Why are so many different types of facilities required" At this stop we are going to try to answer that question. Our answer will follow essentially these steps.

First, we will take stock of what facilities the NACA actually does have.

In the process of taking stock we will also try to indicate some of the reasons why the various facilities have different operating ranges.

Then, having listed the facilities that the NACA now has, we will consider why it is necessary to cover as broad a range as is indicated. To do that, we will present and discuss some recent results of high-speed research on high-speed wings.

As a starting point in taking stock of NACA facilities let us assume that a number of them are to join in coordinated research on a wing design. The range of operations of the various facilities would be different. First, because these facilities are of different size, they would test models of different scale which would result in different Reynolds numbers. Now, this factor Reynolds number can be quite important in changing test results. In general, we can say that the closer the model Reynolds number to the airplane Reynolds number the closer the test results will represent those for the actual airplane.

And second, different facilities are designed to cover different ranges of speeds or Mach numbers. It is most important that the Mach numbers of the model tests match those of the actual airplane - far more important, in fact, than in the case of Reynolds number.

So with this background let us see how the Reynolds number would vary with Mach number for a group of typical NACA facilities. We have selected for the comparison, this wing, swept 45°. To provide a standard for comparison, and to give you a physical feeling for the dimensions of this Reynolds number scale, we have also included in this chart the curve labelled "Flight" which represents the Reynolds number variation for an airplane of this wing spread as it flies through a representative design range. The drop-off in this curve with increasing Mach number is due to the increasing altitude that goes with the flight plan that was used. This flight plan, incidentally, is a typical one for airplanes flying over this Mach number range. The lines on the chart indicate the highest values of Reynolds number possible for each facility in testing this wing over the Mach number range.

As you can see, at low subsonic speeds, full scale Reynolds numbers of our hypothetical airplane are reasonably matched by testing models like this in such wind tunnels as the 40- by 80-foot tunnel. At supersonic speeds, it would require fantastic amounts of wind-tunnel power to test full-size airplanes. The 40- by 80-foot wind tunnel, for example, requires 36,000 horsepower; to run a tunnel of the same size at these speeds would require several million horsepower, or just about the total power output of the Grand Coulee dam. Therefore, at higher speeds, we resort to the device of running the tunnels under pressure, which effectively increases the scale of the model. By this device, wind tunnels like the Ames 12-foot pressure tunnel, the Ames 6- by 6-foot supersonic tunnel, the Langley 4- by 4-foot supersonic tunnel, and the Ames 1- by 3-foot supersonic tunnels obtain Reynolds numbers approaching flight values, even though the models are quite small. The models shown here are actual test models. This 6- by 6-foot wind tunnel requires only 50,000 horsepower - little more than that of the 40- by 80-foot wind tunnel.

At transonic speeds it is difficult to obtain data in wind tunnels. This is indicated by the gap in this area here. Early attempts to obtain data at these Mach numbers involved the use of the wing-flow and tunnel-bump techniques, in which the model is tested by supporting it in an air stream that is accelerated in moving over a wing, or over a bump in the tunnel. An airplane fitted for wing flow tests can be seen here, and a tunnel bump model of the 45° wing is seen here. The Reynolds numbers for these facilities are low. However, despite the low Reynolds numbers these facilities have served a very useful purpose in indicating trends of results in the transonic region when no other test technique was available. Also, for some types of data that are not greatly affected by Reynolds number, these facilities, as well as the 1- by 3-1/2-foot high-speed wind tunnel are still of value for obtaining results economically and quickly.

Meanwhile, much of the data for the transonic region are being obtained by free-flight methods. One of these methods developed at Langley uses rocket-propelled models similar to this which are fired from a ground station. The Reynolds number - Mach number variation for that technique is shown here. In another free-flight technique models are released from an airplane at high altitudes and allowed to fall freely to obtain the required speeds. The Reynolds number - Mach number range covered by this technique is shown here. In one version of this technique the models are recovered by using a brake and parachute to ease them back to earth. A model of this type, prepared for tests of the 45° swept wing, is shown here. These free-flight methods are generally somewhat less economical than wind tunnels and are slower to produce data. Therefore, efforts are being continued to extend the range of operation of the wind tunnels into the transonic region.

In the Langley 8-foot wind tunnel, for example, modifications are being made which would give these Mach numbers. By modernizing some of our larger wind-tunnels, like the 16-foot wind-tunnel, with these modifications, we should be able to obtain these Mach numbers which will close still more the gap between flight and wind-tunnel Reynolds numbers in this transonic region.

We should point out before leaving this chart, that it is intended to convey a typical, rather than a complete listing of the facilities that operate in this region. Also, we should point out that other supersonic tunnels, and the hypersonic tunnel which are being demonstrated today extend the limits beyond this chart.

This concludes our description of what the NACA has in the way of facilities to cover the research field. The next speaker will discuss some results that indicate why it is necessary to obtain such broad coverage.

The aerodynamic measurement which we have chosen to discuss is the ratio of the lift to the drag of the airplane. This ratio is a simple measure of aerodynamic efficiency – that is – the higher the lift-drag ratio the more miles per gallon the airplane will fly or the greater the load it can carry.

On this next chart we see a typical test curve of lift-drag ratio versus lift coefficient for an airplane. The general shape of this curve is characteristic for all airplanes.

Depending on the particular operating condition, different portions of this curve will be of prime interest to the designer. To improve the efficiency in high-speed flight, high lift-drag ratios are necessary in the low-lift coefficient range. To improve the cruising performance higher lift-drag ratios in this range are needed. Likewise, faster climbing and better maneuvering will result from higher lift-drag ratios in the higher lift-coefficient range. Since, in general, different expedients may be used by designers to improve the lift-drag ratio in these different regions, we will in later portions of this talk, focus our attention on these different regions, one at a time.

The curve we have just examined is typical for one test speed. However, airplanes have to be designed to fly at various lift coefficients over a wide range of speeds ranging from landing speeds of the order of 100 mph to high speeds of perhaps 1000 to 1500 mph.

Actually, as was pointed out earlier, no one test facility is capable of obtaining data over this wide a range of Mach numbers efficiently. Therefore, in order to get a picture like the next chart, on which is plotted lift-drag ratio versus lift-coefficient for a flight range of Mach numbers, we must use many facilities.

Perhaps the best way to demonstrate this point would be to review the test program from which we derived the data for this chart.

The preliminary tests of this supersonic design were made on this model in the Ames 1- by 3-foot and 1- by 3-1/2-foot tunnels and by means of the wing- flow technique from Mach numbers of .5 to 1.5. To determine characteristics at landing speeds this model was tested in the 40- by 80-foot tunnel. To determine the effects of Reynolds number a model of this size was tested in the 12-foot pressure tunnel from a Mach number of .2 to .9 and in the 6- by 6-foot tunnel from 1.2 to 1.7. It is easily seen that much cooperative effort from many facilities is necessary to obtain complete research data over the entire flight range.

The significant trend shown by this chart is the reduction in the lift-drag ratio as the Mach number increases. This reduction would be much greater at transonic speeds for wings of upswept plan form.

We will next examine in more detail the effects of changing the wing shape on the lift-drag curve. Changes in wing shape can be subdivided into changes in airfoil section which is the cross-section shape in the direction of flight, and changes in plan form or the shape of the wing as viewed from above. The variation of lift-drag ratio as wing shape is changed will be discussed first for the high-speed condition and later for flight at higher lift coefficients.

In order to obtain high lift-drag ratios in the high-speed conditions, we must concentrate our interest on the most important influencing factor - the minimum drag coefficient.

Perhaps the most important section variable is the airfoil thickness.

The importance of change in thickness is shown on the next chart which presents tests of straight wings in the Langley 4- by 19-inch tunnel on models similar to these over this Mach number range and by means of the rocket technique over this Mach number range. The adverse effects of large thicknesses are easily seen. At low speeds the drags of all the sections are about equal, but at supersonic speeds the drag of the 12-percent-thick section is about five times that of the 3-percent-thick section.

The second shape variable to be considered in improving lift-drag ratios in the high-speed condition is plan form. On the next chart is shown the minimum drag coefficient plotted against Mach number for a group of plan forms. In order to rationalize the comparison, the thickness of these wings have been selected so that the strengths of all are about equal.

The data shown are results from the Ames 12-foot, 6- by 6-foot, and 1- by 3-1/2-foot tunnels and the Langley 9-inch supersonic wind tunnel. The drag rise for the conventional subsonic bomber-type configuration, which is included for comparison, is very steep and occurs at quite low transonic Mach numbers. Sweeping a wing to 45° and 63° reduces the drag. From the limited data shown, the wings having short span wide panels appear to be superior in that the general level of the drag over a wide range of Mach numbers is less.

The benefits of thin wings and wings with swept plan forms have been shown for flight in the high-speed condition. If this condition were the only one of interest to the designer, the selection of wing shape could be made from this chart. Usually, performance at higher lift coefficients will be of equal importance. The next speaker will discuss the effects of wing design on performance at higher lift coefficients.

We will now discuss some of the results that show how the maximum lift-drag ratio can be increased. Previously it was pointed out that cruising flight is normally in the region of maximum lift-drag ratio; however, since any changes made in an airfoil to improve the maximum lift-drag ratio will usually improve the lift-drag ratio at higher lift coefficients as well, we should consider these results as applying to climbing and maneuvering flight as well as to cruising flight.

Here again, as with the case of minimum drag, the two physical properties of the wing that can be adjusted to give the optimum design are the airfoil section and plan form. The airfoil section shape that affects the maximum lift-drag ratio is the camber or curvature of the mean line. These data were obtained from tests on these models in the Ames 1- by 3-1/2-foot wind tunnel. Here we have the variation of lift-drag ratio with section lift coefficient for various amounts of camber. The increase in the maximum lift-drag ratio with increasing camber is obvious. Camber also increases the lift coefficient at which the maximum lift-drag ratio occurs. This increase in lift coefficient at which the maximum lift-drag ratio is obtained is also important, because the trend toward heavier planes, swept wings, and flight at higher altitudes all increase the lift coefficient at which the airfoil section must operate.

These section data have been used with simple sweep theory to estimate the increase in maximum lift-drag ratio that might be expected from the use of camber on this wing with 63 degrees of sweepback. The results of this study are shown on this chart. Here we have the variation with Mach number of the maximum lift-drag ratio of the plain wing swept 63 degrees, the experimental maximum lift-drag ratio of the cambered wing, and the estimated values for the cambered wing.

The increase obtained by the use of camber is sufficient to increase the range of an airplane by about 20 percent. This difference between the experimental and estimated gains is possibly due to Reynolds number effects or to the inadequacy of the theory used to account for the three dimensional effects. Further research to bring the curves into closer agreement is in progress.

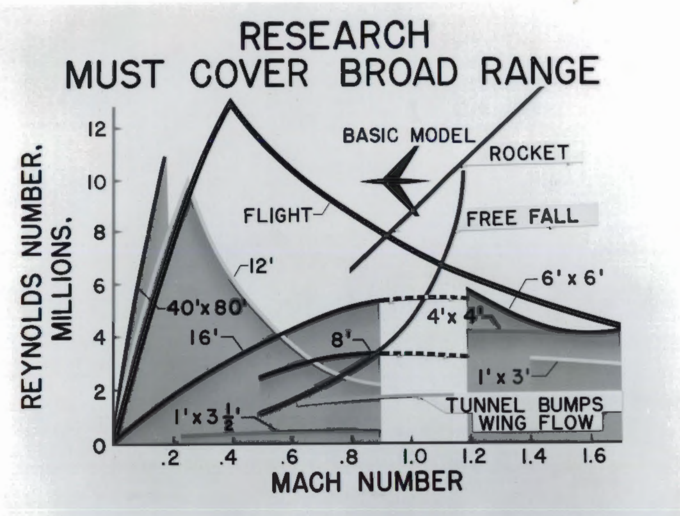
Now let's look at the effects of plan form variation. This chart shows how the maximum lift-drag ratio varies over a wide range of Mach numbers for the series of structurally equivalent wings that were discussed earlier. Here, too, we have included for comparison the curve for a straight wing that is representative of current bombers and transports. These results demonstrate that the designer must consider the particular Mach number range in which he desires high efficiency. At subsonic speeds the straight wings with long slender panels are the most efficient. As the transonic region is approached this type of wing becomes less efficient and the wings with swept leading edges become better. Finally, at supersonic speeds all the swept plan forms shown have roughly the same values. It should be apparent then, that in order to make a thorough design study of a prospective airplane, data must be available over a wide range of Mach numbers.

In our discussion we have considered results bearing only on the lift-drag ratio of an airplane. The designer, of course, before making his final wing choice must consider not only the performance of the airplane as indicated by this parameter, but also the stability and control characteristics. These would be indicated by other measurements made on these same models in the same test facilities.

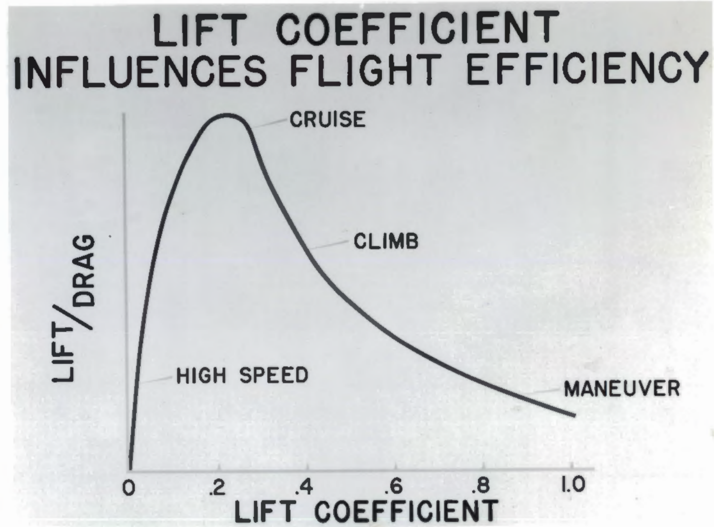
From what we have said here it is hoped that you will have a better physical grasp of the scope of the problem and of the wide variety of facilities that the NACA is devoting to its solution.

Display for Presentation of "High-Speed Research on High-Speed Wings"
by Flight Engineering

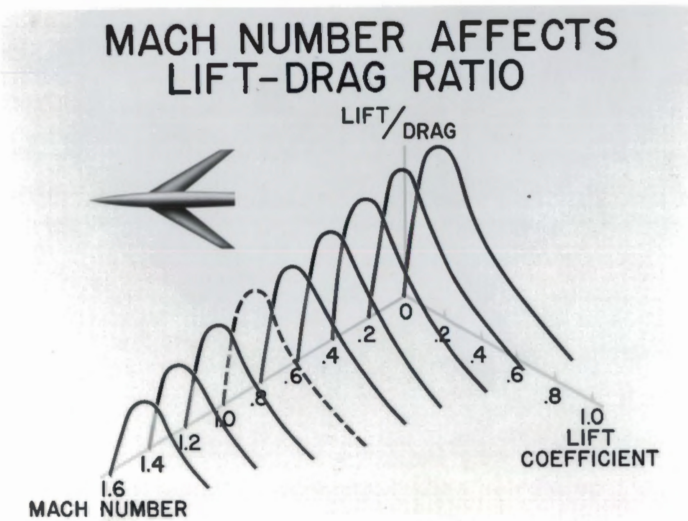
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
AMES AERONAUTICAL LABORATORY, MOFFETT FIELD, CALIF.



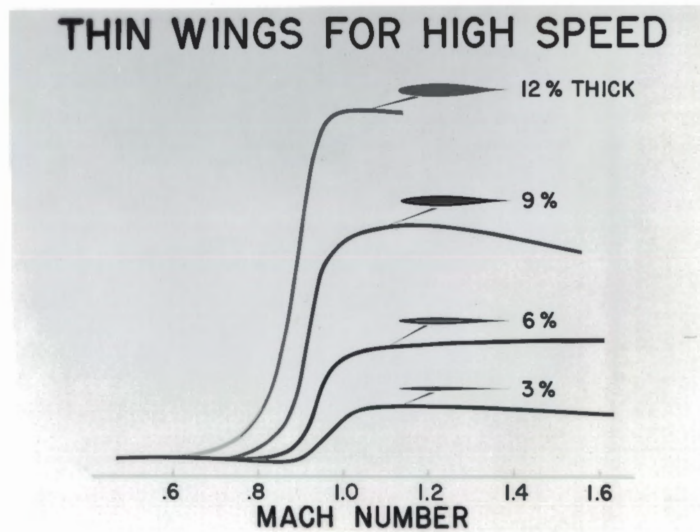
A-15203-A



A-15203-B

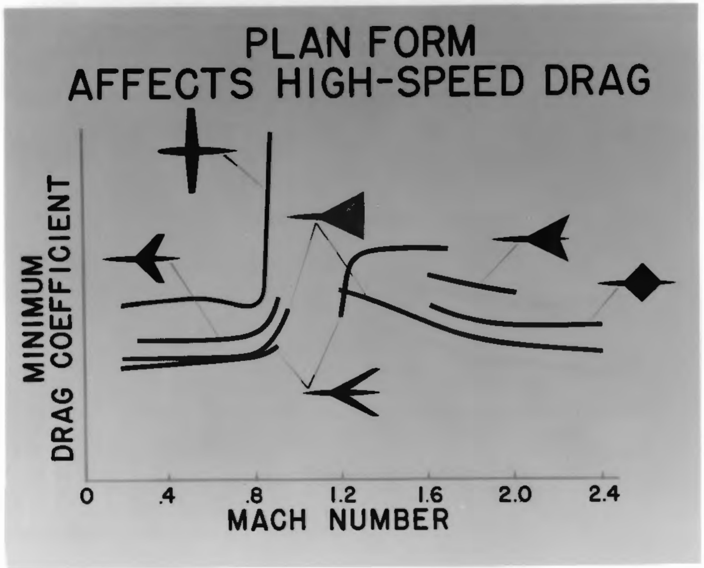


A-15203-C

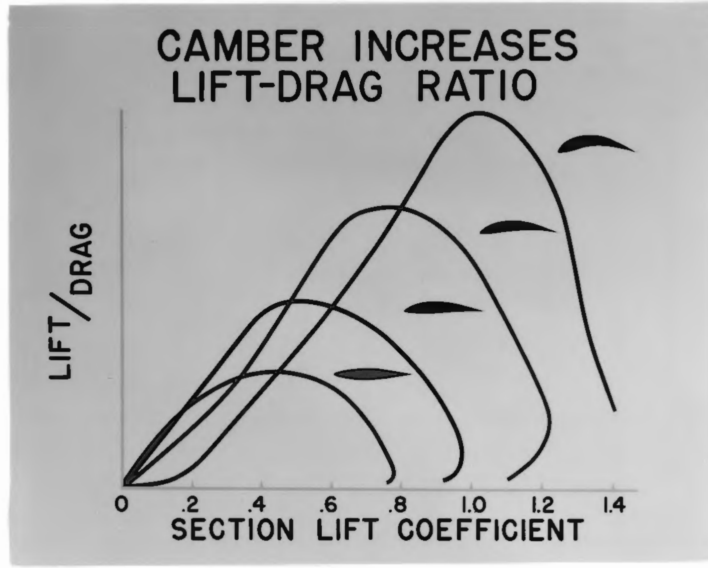


A-15203-D

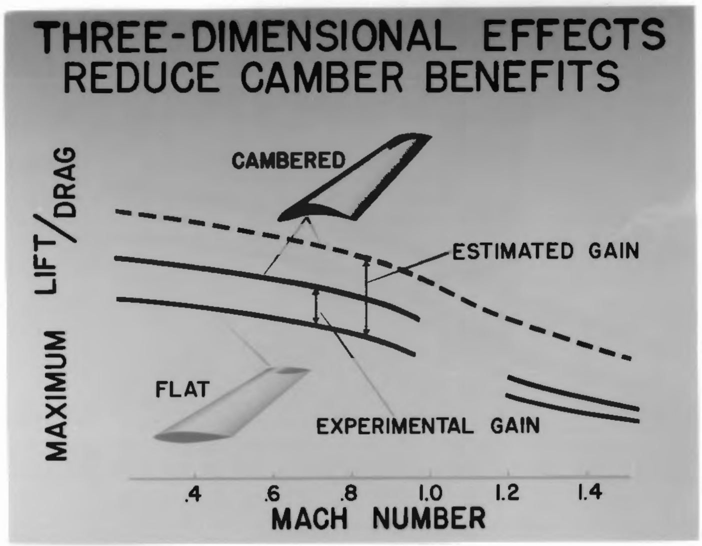
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
AMES AERONAUTICAL LABORATORY, MOFFETT FIELD, CALIF.



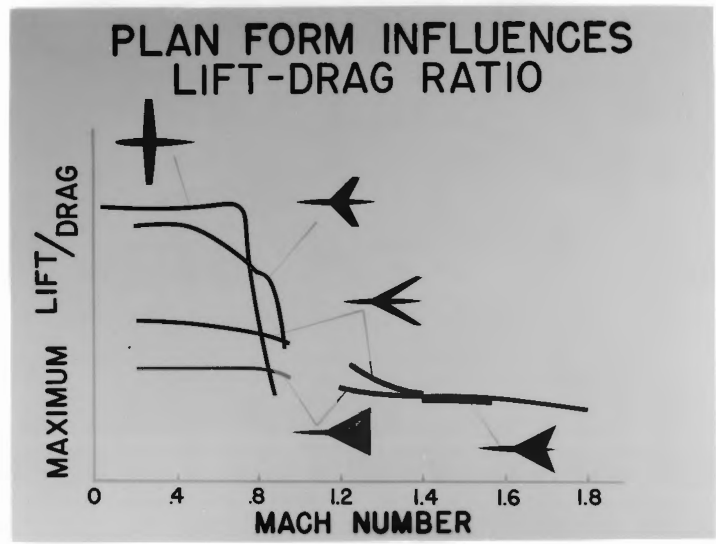
NACA
A-15203-E



NACA
A-15203-F



NACA
A-15203-G



NACA
A-15203-H

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
AMES AERONAUTICAL LABORATORY, MOFFETT FIELD, CALIF.