PITCH-UP AND DIRECTIONAL INSTABILITY

At this stop we are going to discuss some of the work being done by the NACA in connection with the stability and controlability of modern high speed airplanes. These airplanes must fly and maneuver in the very thin air at high altitudes, and consequently they frequently reach high lift coefficients and high angles of attack even at transonic and supersonic speeds. One of the current problems being studied is that of the high lift stability characteristics of these airplanes.

The first chart illustrates some typical wind tunnel results pertaining to an airplane stability problem known as "pitch-up". Pitching moment is plotted against lift coefficient for an old, low speed World War II type airplane and for a current high speed type configuration.

At this point it might be desirable to give a simple explanation of pitching moment and airplane stability. The pitching moment of an airplane is simply the tendency of the airplane to rotate in this manner.

The stability of an airplane can be considered as its ability to return to an initial flight condition after being disturbed. For example, say an airplane is flying steady and level and a momentary gust or movement of the control increases the airplane angle... If the airplane is stable, a nose down pitching moment will cause the airplane to return to its initial attitude. If the airplane is unstable... the angle will increase till the airplane stalls and rolls out of control.

Most low speed airplanes of the past had stable pitching moment curves of this nature or could be modified to attain these desirable longitudinal characteristics. The high lift behaviour for these airplanes was important primarily at low speed for landing and maneuvering. For this (swept) configuration, as mentioned previously, the high lift behaviour is important also at high speeds at altitude.

One of the problems encountered with some high speed airplanes is illustrated by this curve which shows a marked departure from the more desirable characteristics of the low speed airplane... This loss of stability (point to curve) would cause the airplane to become uncontrollable and to pitch up violently.

The next chart shows what these pitching moment curves mean in terms of the longitudinal motions of these airplanes. Stabilizer angle and airplane angle of attack are plotted against time in seconds. This chart shows a time history of the attitude of the airplane as the pilot makes a gradual pull-up maneuver.

For the low speed airplane with the stable pitching moment curve, as the pilot pulled back on the stick to make the airplane climb, the airplane attitude increased gradually and when the stick movement stopped, the airplane angle of attack remained constant.

For the high speed airplane, the pilot pulls back on the stick and the airplane angle of attack increases gradually up to the angle at which instability is present (point to first chart). Past this point a rapid increase in angle... or pitch-up occurs without further control movement by the pilot. In effect, the unstable pitching moments have taken control of the airplane out of the pilot's hands and the angle continues to increase for some time after the control movement is stopped.

The high attitudes reached in a pitch-up can cause destructive loads on the airplane structure and it is objectionable to the pilot not being able to control the airplane motion during pitch-up especially if he is trying to track a target.

Another stability difficulty that is encountered at high lift is the occurrence of directional instability. The next chart presents some typical wind tunnel results on this problem for the same airplanes being discussed. The variation of directional stability with lift coefficient is shown, values in this region are stable, and indicate the ability of the airplane to return to it's initial heading if displaced. Values in this region are unstable. The old type airplanes had directional stability through the lift range. Although the high speed configurations have high directional stability at low angles of attack, a considerable amount of directional instability has been encountered for some of these high speed airplanes through the higher lift range.

Various modifications have been devised which alleviate the problems of directional instability and pitch-up. For example, relocation of the tail surfaces, or controlling the flow over the wing by use of fences or wing slats has been found beneficial. Experience has shown however, that a modification found beneficial for one arrangement did not always work for others. It has therefore become necessary in many cases to make a detailed study for each configuration.

A coordinated effort is being made by the NACA to attain means for eliminating, or being able to control these high lift stability difficulties. Both the high speed and low speed aspects of these problems are being investigated in analytical studies, static wind tunnel tests, and in flights of high speed research airplanes. These problems are also being studied at low speeds with dynamic models in the Free Flight Tunnel and on a simple catapult which was set up to study entry into spins. A catapult is located above you on top of this structure which launches models into this space... and the models are retrieved in the net. Of course this type of test has to be closely coordinated with full scale results just as has been the case for many years for tests in the Free Flight and Spin Tunnels. Even though models of this small size are tested on the catapult, the motions of the models have been found to correspond closely to the motions of the full size airplane.

We will now show a movie of some flights made using the catapult. This movie will illustrate the stability problems we have discussed. Since the motions of the model were very rapid, the movie will be shown in slow motion (Nod head for start of movie)

The first view from the rear of the catapult will show a stable flight in which the model does not pitch-up

-----the same flight viewed from the side

-----notice the gradual descent of the model into the net.

-----A repeat of the rear view (as model crosses marker, start the next description.)

The next flights will show both pitch-up and directional instability

----the model pitches up, diverges directionally and spins into the net.

----A side view of the same flight

----notice the high attitudes reached in the pitch-up

----A repeat of the rear view

The next speaker, Mr. (Queijo or Wolhart) will discuss some of our work on damping of lateral oscillations of high speed airplanes.

NACA

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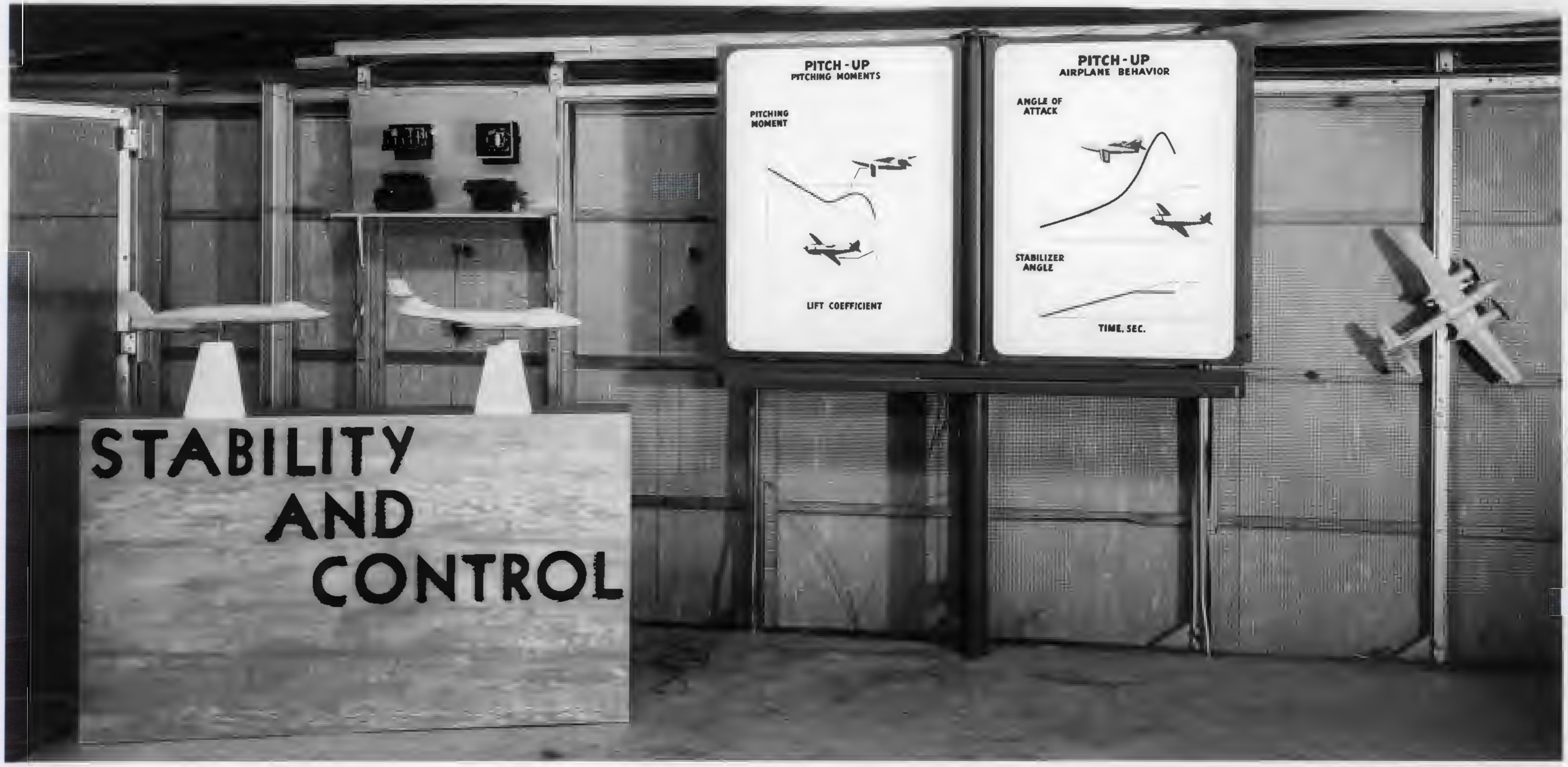

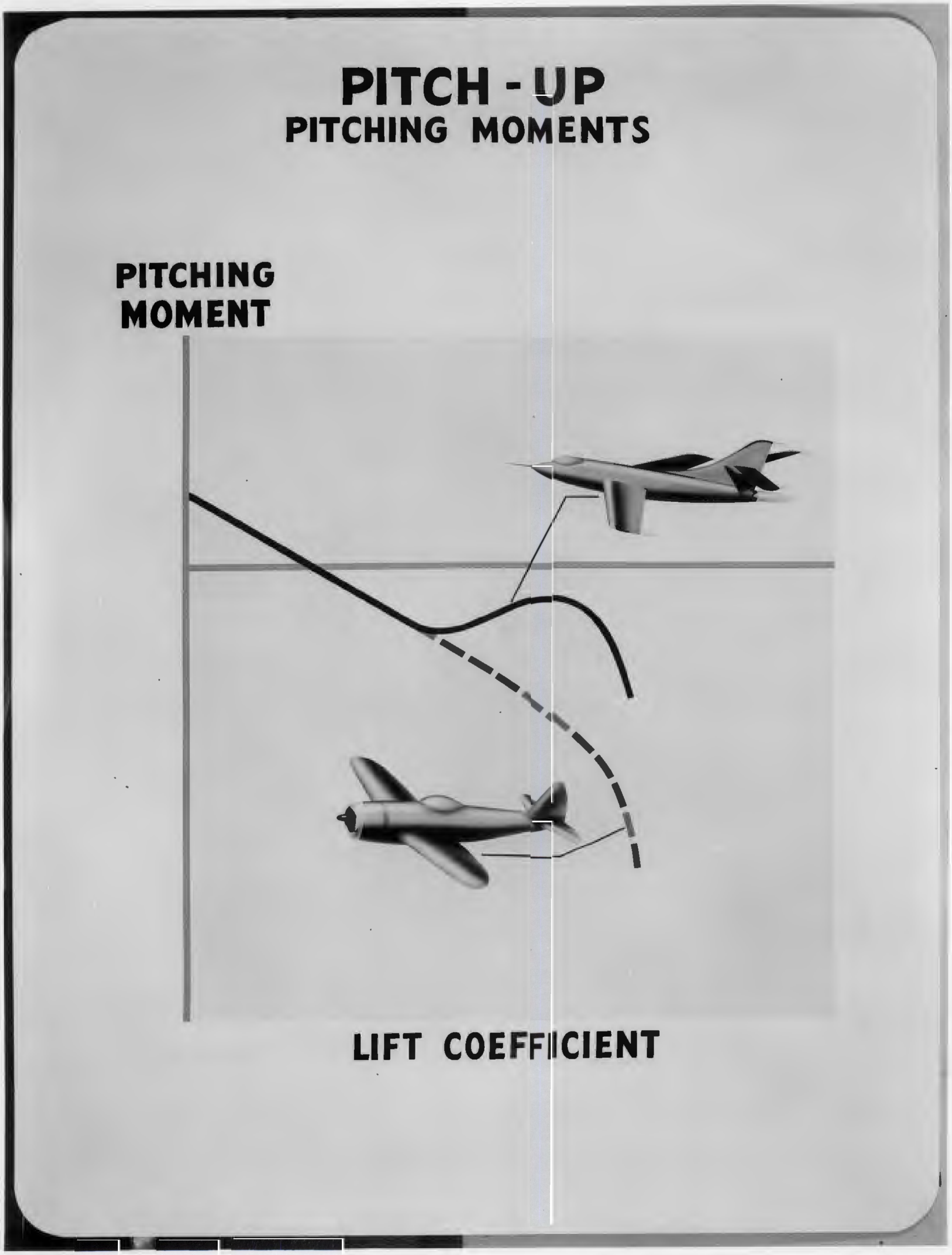
PITCH - UP
PITCHING MOMENTS
PITCHING
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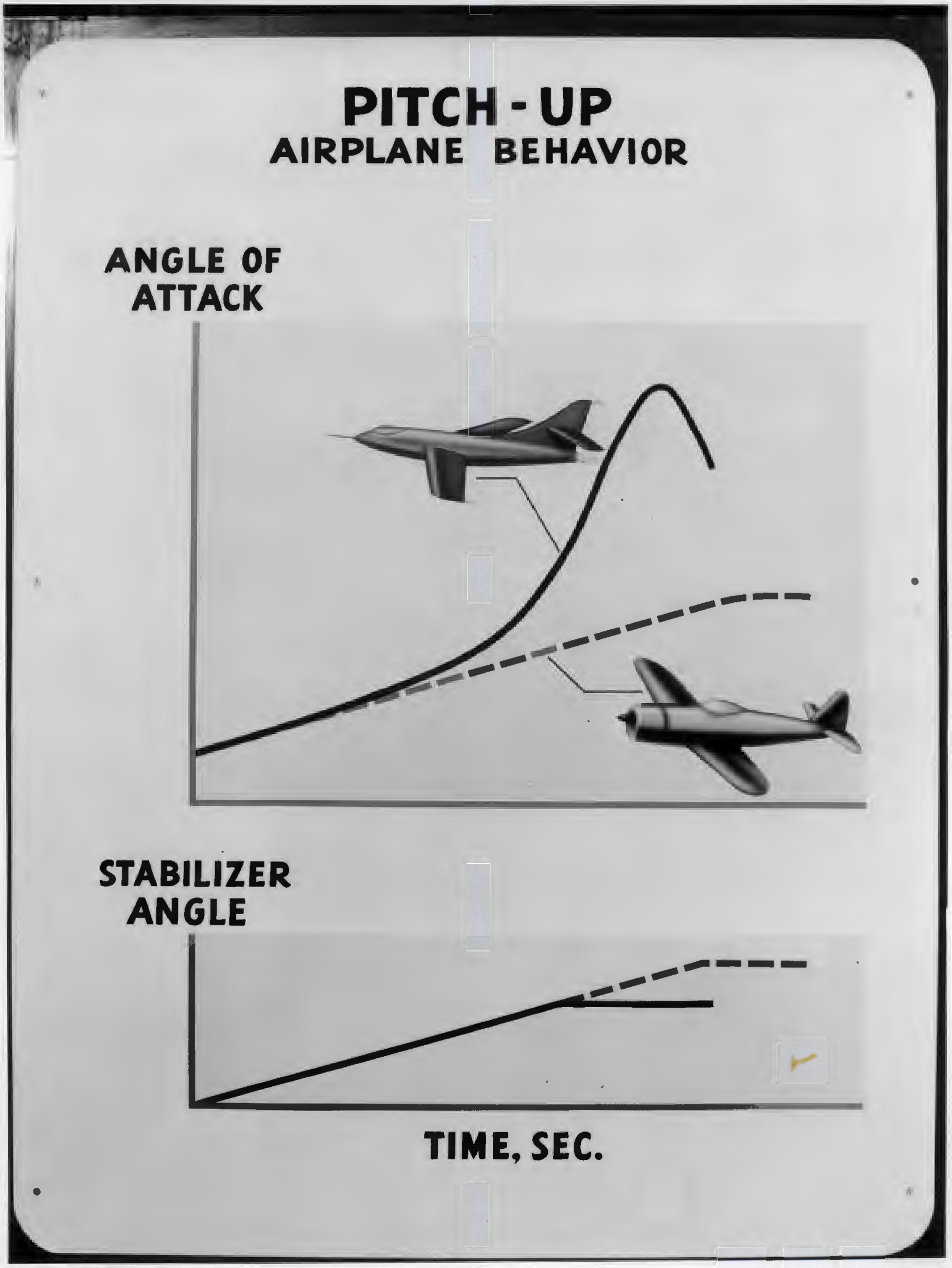
LIFT COEFFICIENT


PITCH - UP
AIRPLANE BEHAVIOR
ANGLE OF ATTACK
STABILIZER ANGLE
TIME, SEC.

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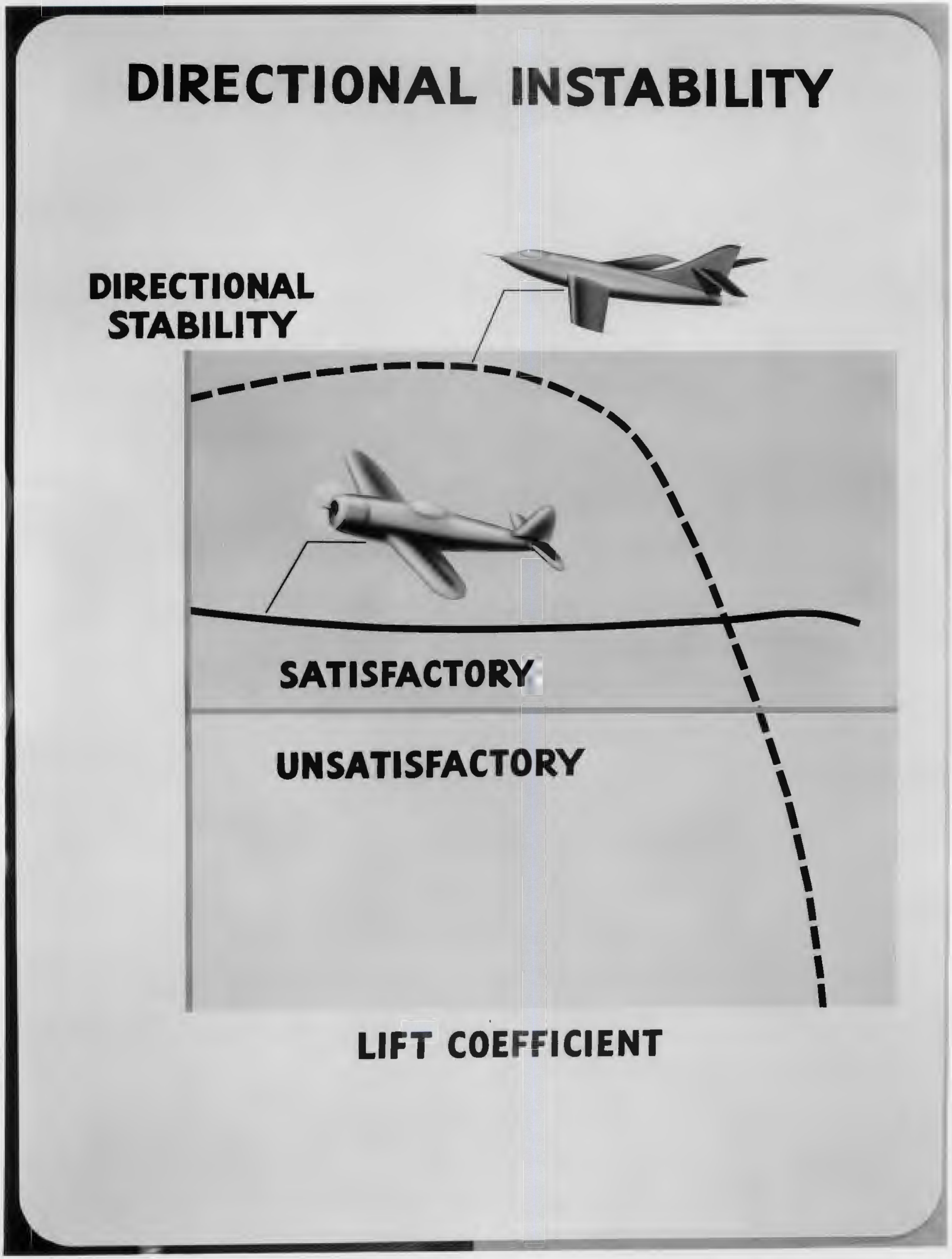

DIRECTIONAL INSTABILITY
DIRECTIONAL
STABILITY
SATISFACTORY
UNSATISFACTORY
LIFT COEFFICIENT

One of the changes in stability which has occured in the transition from World War II type airplanes to present-day jet airplanes is the aggravation of a tendency to perform persistent lateral oscillations like this. Many modern jet fighters have this tendency, which of course is undesirable from the standpoint of ease in flying and accuracy in gunnery.

The theoretical requirements for elimination of this tendency have been known and efforts have been directed toward making practical use of this knowledge for some time. As a result of these efforts it has been possible to design equipment which provides rudder movements such that the resulting air forces cause the oscillation to die out quickly. Typical equipment used for this purpose is shown here, and consists of a power supply, a sensing gyro, a mixing amplifier, and a servo motor. These units are, of course, the basic elements of an autopilot system. This equipment is quite complicated and is expensive in first cost and in maintenance. There is another, mechanically simpler, means of actuating the rudder in such a manner as to cause the oscillation to die out quickly. This method depends for its action on certain aerodynamic characteristics of the rudder which can be obtained by proper rudder configuration and the use of a linked tab. The only special equipment required is a small hydraulic cylinder (show) which acts on the rudder something like a shock absorber. The simplicity of this device, in comparison with this other equipment is obvious. A system employing a cylinder of this type has been tested by the NACA on a modern fighter airplane. Without this device the airplane oscillated in this fashion. With the cylinder installed the oscillation died out rapidly like this.

Although these automatic mechanisms are effective, it would of course be advantageous to minimize or eliminate the necessity for them. In order to assess the possibility of accomplishing this, the NACA has been making a study of possible means of employing the known theoretical requirements to arrive at airplane configurations which would inherently have good oscillatory characteristics. The results of these studies have shown that one of the most important factors in determining the oscillatory characteristics of an airplane is how the weight is distributed. Airplanes having weight high at the rear, as in this model, tend to have poor characteristics, whereas airplanes with weight low at the rear generally have better characteristics.

Here we have an example of how an airplane might look if it were designed to take advantage of this influence of weight distribution on the oscillatory characteristics. The engine and horizontal tail are located low at the rear, and underslung inlets are used. We would expect the oscillatory characteristics of such an airplane to be considerably better than those of this design. The design of any aircraft is of course a compromise between the various requirements for stability, structures, economy, payload, and so on; therefore such a configuration might not be entirely satisfactory when all factors are taken into consideration.

Because of the importance of obtaining satisfactory oscillatory characteristics the work of the NACA in this catagory, which has been briefly reviewed here, is being continued with a view to obtaining other solutions to this problem.

The next speaker is going to discuss some of the stability and control problems of high speed airplanes which are especially designed to be capable of flying at very low speeds and of hovering. Mr.____________

TALK ON VERTICALLY RISING AIRPLANES

FOR 1953 BIENNIAL INSPECTION

Speakers:
Robert H. Kirby
Robert E. Shanks

Model Demonstrators:
Edwin E. Davenport
Louis P. Tosti

During the past few years helicopters have clearly shown the value of aircraft that can take off and land vertically. Helicopters, however, are inherently limited in top speed, so considerable attention is now being given to aircraft that can achieve high top speed as well as hover. With the recent development of very light-weight high-powered engines it has become possible to put enough power in a conventional airplane so that it can develop enough thrust to support its weight in hovering flight. There is more to the problem, however, than simply providing enough thrust to support your own weight. For this reason, vertically rising airplanes will look quite different from conventional airplanes such as this although one type will hang on its propellers like this for vertical take-offs and landings and rotate to a horizontal attitude as it picks up speed for normal level flight. This type is not suited for transport work because of the attitude of the fuselage in hovering and transition. Two types that keep the fuselage in a more or less horizontal attitude are illustrated on this chart on which the tinted plastic represents the propeller slipstream.

To produce direct lift for hovering flight it is necessary to accelerate air straight downward. For the upper airplane this is accomplished by rotating the propellers through 90° as it goes from normal level flight to hovering. For the lower airplane, this is accomplished by deflecting the wings and flaps so that the slipstream is turned straight downward while the propellers remain in their normal attitude. The transition from hovering to normal forward flight is accomplished by slowly raising the flaps so that the slipstream is deflected backward to produce some forward thrust so that the airplane picks up speed until it is in normal forward flight.

As you can see from this chart the tail surfaces are not in the slipstream during transition and hovering flight. For this reason we can expect new stability and control problems in these flight conditions. Our work on these problems for the hovering flight condition is being done in this building using the type of equipment and test technique that you will see in a few minutes. We are going to show you a movie and a demonstration flight to illustrate some of our work for a model of this type in which the wings are used to direct the slipstream downward. This model is not intended to be a practical configuration. It is simply a test vehicle for studying stability and control in hovering flight. Before we present the movie and demonstration flight, we will show you how the controls on this model work.

The red flap is used as an elevator for pitch control. The green flaps are used as rudders. Roll control is obtained by varying the pitch of the outboard propellers differentially. This flexible cable carries power to the model motor and controls, and also serves as a safety cable for catching the model to prevent crashes in case of control failure or in case the motions become very unstable. The cable is normally slack during a flight so that it has practically no effect on the motions of the model. We will now show you a short movie illustrating some of the results obtained with this model while we prepare the model for a demonstration flight.

The first scene shows the model in controlled flight. It has an unstable pitching oscillation but the pilot is able to fly the model by careful use of the controls. (Notice that the cable which supplies power to the controls is slack.) The second scene will show how unstable the pitching oscillation actually is.

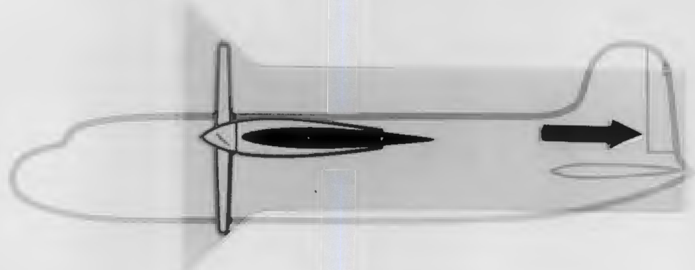
Here we have the uncontrolled pitching oscillation.

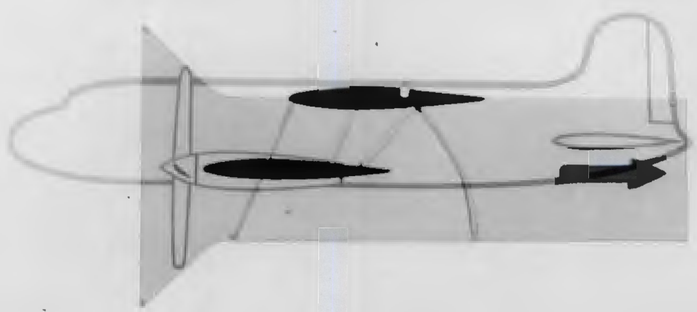
This last scene shows the model with a rate-sensitive artificial stabilizing device providing additional damping in pitch. The model is flying hands-off in pitch.

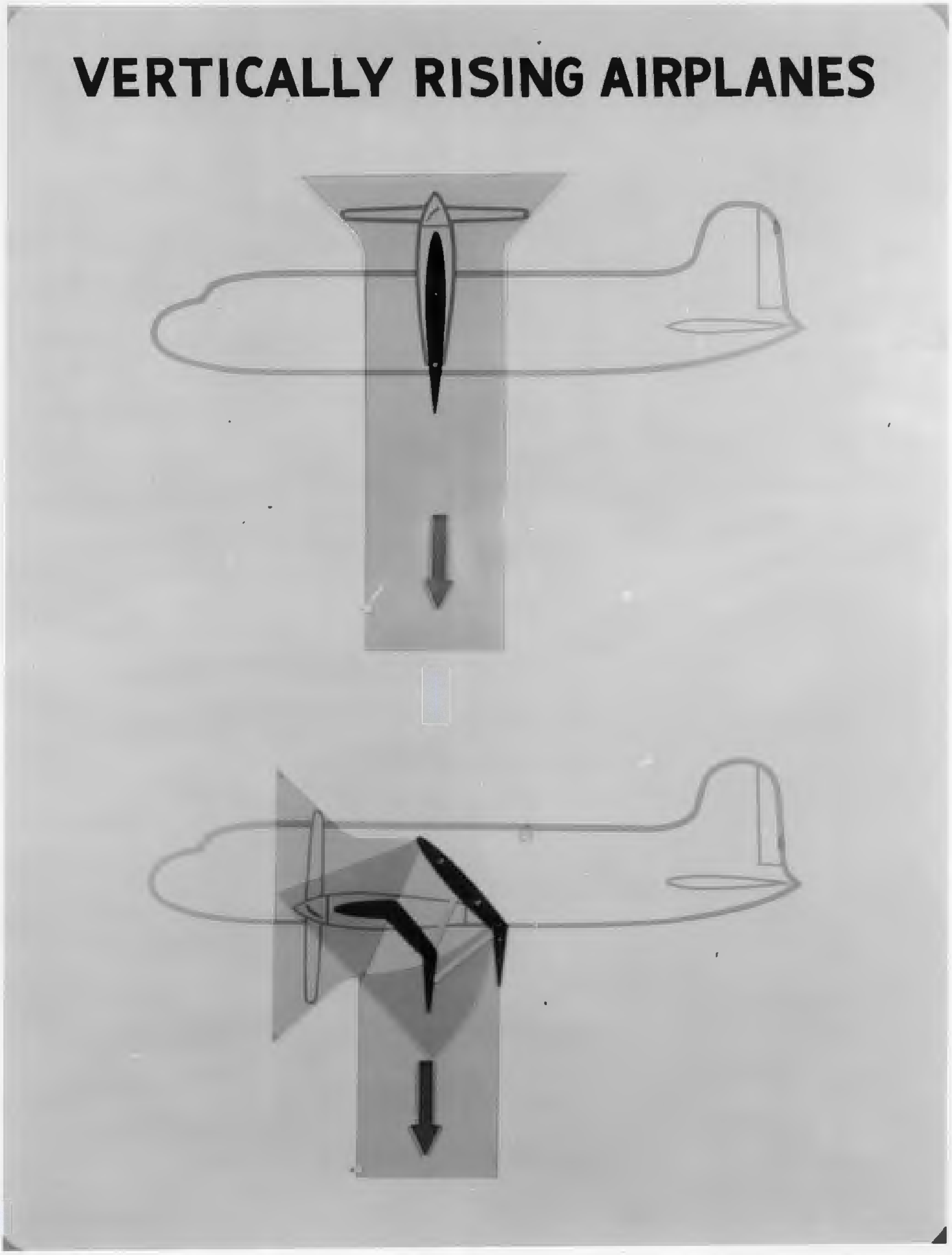
Now we will show you a short demonstration flight in which we will take off, hover a while, and then land. One operator, who will control the model in pitch, is up here to your right. The rest of the operators are located back to your left.

This concludes our program.

VERTICALLY RISING AIRPLANES






VERTICALLY RISING AIRPLANES