AUTOMATIC STABILITY AND CONTROL

presented by

Flight Research Section

As mentioned at previous inspections, airplane dynamic stability and control tends to deteriorate with increasing flight speeds and altitudes. Let us first review this problem by comparing the lateral oscillations of a World War II fighter airplane with those of a hypothetical supersonic airplane, and then let us examine some of the research under way at the NACA which is directed at the solution of this problem.

When an airplane is subjected to a disturbance such as a side gust, a lateral oscillation results-that is, a sideslipping motion combined with a rolling motion. The lateral-oscillation characteristics of a typical World War II fighter are shown on this first chart. Here we have angle of sideslip (that is, the angle between the airplane's center line and the flight path as viewed from above), and angle of bank plotted as functions of time.

The trend in lateral-oscillation characteristics which results from increased airplane performance and the associated changes in airplane shape is indicated by the next chart. This represents an extreme case of undesirable motions which, on the basis of NACA wind-tunnel and flight data, might be exhibited by a supersonic fighter of the future. Once again, angle of sideslip and angle of bank resulting from a disturbance such as a side gust are plotted as functions of time. Let us now compare the lateral oscillations of this hypothetical future fighter with those of the World War II fighter. Among the important characteristics are the period, that is, the time required for the motion to complete one cycle; the damping, or the rate at which the motion subsides; and the ratio of the amplitudes of the banking and sideslipping motions. It is seen that the period of the future fighter is shorter than the period of the World War II fighter; this can be attributed in large part to the increased flight speed from about 0.7 times the speed of sound for the World War II fighter to perhaps 1.5 times the speed of sound for the future fighter. As the period decreases it becomes increasingly difficult for a pilot to time his control movements properly to stop the oscillation. Furthermore, the damping of the oscillations of the future fighter is considerably less than the damping of the World War II fighter. This tendency results in part from the decrease in air density which accompanies increasing flight altitudes from about 30,000 feet for the World War II fighter to perhaps 60,000 feet for the future fighter. To the pilot, this reduction in damping means that he must continually apply precise control motions to stop the oscillations. With regard to the ratio of the amplitudes of the banking and sideslipping motions, these charts show that, for the same amount of sideslip, the angle of bank is much larger for the future fighter than for the World War II fighter.

This tendency can be traced in part to changes in airplane shape, such as increasing sweepback of the wing, and to increases in flight altitude. The pilot is often more annoyed by these banking motions than by the sideslipping motions, and he must move both the rudder and the ailerons in a carefully coordinated manner to stop the oscillations.

The consequence of this undesirable trend in lateral stability may be determined by comparing the ability of the pilot to maneuver accurately with airplanes having these dynamic characteristics. The task of tracking a target airplane with a pursuit airplane will be used as an example flight problem of considerable military importance. The pilot, when tracking, normally attempts to direct his airplane at an aiming point which leads the target. However, to simplify explanations, the example problem today will be that of tracking the target directly without any lead.

The next speaker, Mr. __________, will show some movies which will illustrate this problem. Mr. __________.

The following movie will show first, how these motions of a typical World War II airplane appear to a pilot; and, second, how well he can track a target with such an airplane (Movie I). Here is a picture of the gunsight and the movie camera in the cockpit of the attacker airplane. The camera is mounted here and photographs through a right angle lens the view looking forward. This shows what the pilot sees looking through the windshield. The gunsight reticle is projected here on a glass plate, and here is the camera lens. The next picture was taken with this gunsight camera, in the attacker airplane, during steady straight flight. To simulate the action of a side gust, the pilot abruptly kicks the rudder and returns it to neutral. We see that the airplane returns to straight, level flight in the same manner as was shown in the first chart. Now the pilot is trying to track a target airplane in smooth air. Note that he is able to keep the sighting point on the target. Now, to make the pilot's problem more difficult, his airplane will be disturbed by a device which simulates the action of rough air. Under these simulated rough-air conditions, the motion of the tracking airplane is still small, and the pilot can quickly return the sighting point to the target even when the target makes a turn.

Now let us look at a similar movie in which the character of the motion of the attacking airplane has been changed to represent the motion of the future fighter. (Movie II). The airplane is flying straight and level; the pilot kicks and returns the rudder to simulate a gust. The resulting motion has a short period, is lightly damped, and there is a large amount of bank. Again the pilot is trying to track a target airplane while flying under simulated rough-air conditions. You can see that the pilot has great difficulty keeping the sighting point on the target and that the average error is large.

Now, consider the problem of a designer who is trying to develop an airplane to have, for example, good tracking performance. He should first know how those airplane stability characteristics over which he has some control affect its tracking ability. Poor tracking performance can be expected when an airplane has such bad characteristics as the one in the last movie -- that is, poorly damped motion of so short a period and with such a large amount of roll. However, since we cannot yet predict the effect on tracking of all the other possible combinations of laterial-oscillation characteristics, we are engaged in flight research to obtain information which will let us make these predictions. Both the Ames and Langley laboratories are collecting and analyzing tracking data for a number of airplanes with different dynamic properties.

We are also gathering such information through use of variable-stability airplanes, such as the F6F on display just outside this door. It is fitted with electrically operated servo devices by which its dynamic stability and handling qualities can be varied over wide ranges. The motion pictures you just saw were taken from the variable-stability F6F airplane with the servo equipment adjusted to produce the characteristics that have been discussed. Similar equipment is being installed in an F-86 airplane which will enable it to simulate the lateral oscillations typical of an even wider range of high-speed airplane designs.

Assume now that the designer knows the range of oscillation characteristics which will result in satisfactory behavior in tracking runs or other required tactical maneuvers. The next problem, then, is that of designing the airplane to have the desired characteristics without seriously compromising other requirements, such as performance.

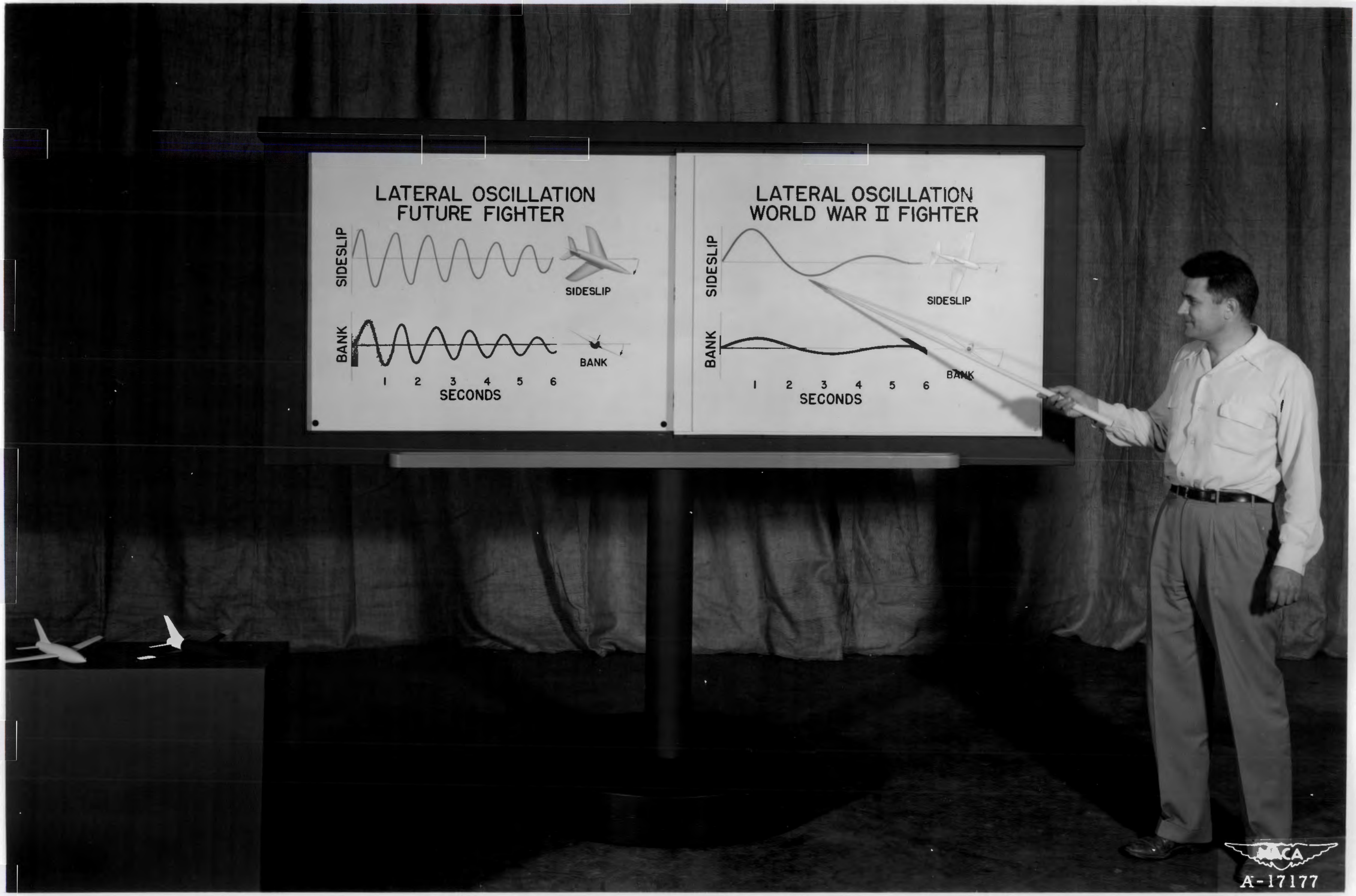
The NACA has continuing research studies directed toward obtaining desirable dynamic behavior of high-performance aircraft by aerodynamic means, and, results show that such behavior is obtainable to some extent. However, over the widening range of flight speeds and altitudes, it is becoming increasingly difficult to obtain satisfactory dynamic behavior by aerodynamic means alone. Another powerful and increasingly popular method of obtaining desirable dynamic characteristics is the use of artificial stability systems. In these systems, control surfaces are actuated automatically in such a fashion that dynamic qualities are improved while the pilot remains in direct control of the airplane. Our next speaker, Mr. __________, will discuss some of the NACA research on these artificial stability systems and other types of automatic control. Mr. __________.

An artificial-stability device with which you may be familiar is the yaw damper. A simple yaw damper measures the airplane's directional motion, and, with the servo motor, drives the rudder in such a fashion as to damp the motion quickly. In more complicated artificial-stability systems, additional signals may be fed to servos which actuate both the ailerons and rudder. Although this equipment is undesirable from the standpoint of weight and complexity, its effectiveness is indicated in the following movie. First, we will again illustrate undesirable lateral oscillations exhibiting short period, poor damping, and a large amount of roll. (Movie III). The pilot is now switching on his artificial-stability equipment. With this equipment in operation, a rudder kick is followed by a quick, smooth return to the initial flight path. The pilot is again tracking the target airplane in rough air. You can see that with the stabilization equipment in operation, he is able to keep the sighting point on the target with little error. These movies were also taken from the variable-stability F6F airplane which was described earlier. The experience gained and reported by the NACA in designing and operating such equipment can be applied to the design of artificial-stability systems for operational use.

Even these powerful artificial-stability devices will not insure accomplishment of many missions involving precision flight at very high speeds. The next short film, which was taken with a gun camera in a modern jet-propelled fighter, illustrates the situation which may confront a pilot as he attempts a firing pass on a target airplane. Note the high closing rate, and the short time during which the sighting point is near the target. (Movie IV). As flight speeds increase, the time required for the pilot to perceive and react to the tactical situation severely hinders the airplane's combat effectiveness. Because of these human limitations, it becomes necessary to use automatic-control equipment--equipment which, instead of merely assisting the pilot, assumes complete control of the airplane during critical maneuvers. Such equipment offers several inherent advantages. For example, it can permit operation in all kinds of weather; and can compute and apply corrective control movements more rapidly and accurately than a human pilot. Investigations of automatic-control systems have been initiated by the NACA to gain fundamental information, particularly with regard to the fitting of these complex systems with the airframe and its aerodynamic properties. In addition to analytical studies which employ electronic simulators, one flight project currently under way at the Ames Laboratory involves the use of an SB2C airplane originally furnished with automatic control equipment by the Navy. This airplane has been further modified by the NACA and can now be considered a simulator which permits the study, in low-speed flight, of many of the automatic-control problems of future high-speed airplanes.

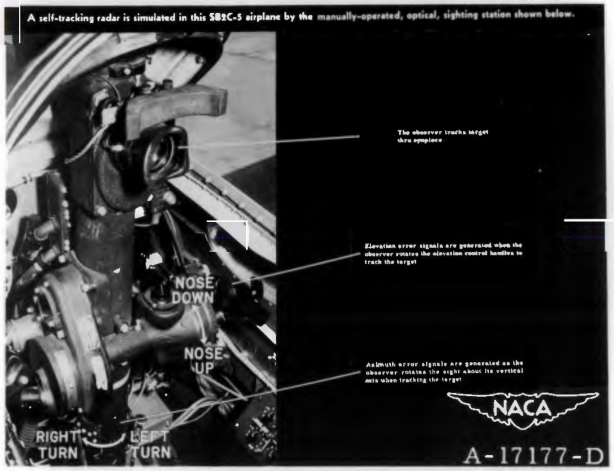
The following movie shows this airplane in automatically controlled flight. (Movie V) An observer in the rear cockpit tracks the target airplane with a movable sight, which generates signals similar to those furnished by a tracking radar system. These signals control the airplane. The next scenes were taken by various cameras during a tracking run made under automatic control. The SB2C enters its run on the target airplane. Here is a pilot's view of the control stick during this maneuver. The movements of the stick reflect the control-surface motions which were applied automatically during the turn entry. Now we are looking over the pilot's shoulder; his hands are resting on the instrument panel. Note the smooth steady flight.

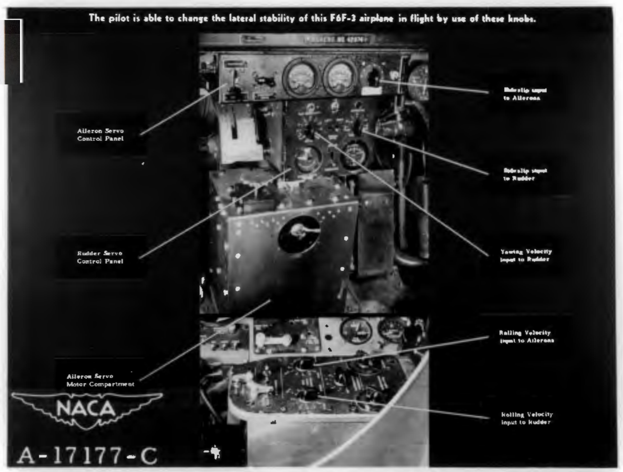
Today's discussion has shown that as airplanes are designed for higher speeds and altitudes, problems in stability and control are introduced which require use of automatic control equipment. Extensive research is required to furnish information as to the best methods of employing such equipment. We have described only a few phases of NACA research which is directed toward solution of these problems of automatic control in high-speed flight.



(a) Main display

Display for presentation of "Automatic Stability and Control"





(b) Auxiliary display