Pilotless Aircraft Research

1953 INSPECTION

PILOTLESS AIRCRAFT RESEARCH DIVISION

PART 1

TITLE CHARTS - (Research Instrumentation and Pilotless Aircraft Research)

ALL LIGHTS ON

The rocket model research technique, which we will discuss here, was first used as a primary source of transonic aerodynamic data, but now the NACA has developed and put into operation transonic wind tunnels which are capable of producing large amounts of this information. Therefore, it has recently become possible to put more emphasis on some of the dynamic problems of flight which can be readily investigated with rocket models at supersonic as well as at transonic speeds. Since they are in free flight it is possible for these models to maneuver just as a full-scale airplane or missile would maneuver, and even though the models are small, most flights are made at low altitudes where speed and the corresponding air flow conditions are identical to those which a full-scale airplane or missile would encounter at high altitudes. In many instances the models represent specific airplane or missile designs, and in some cases actual full-scale missiles are flown.

We will now show you a very short motion picture of a typical model flight.

ALL LIGHTS OFF

MOVIE ON

(Closeup view of delta wing configuration E-17 Deacon drag model mounted on mobile launcher.) Here is a rocket model mounted on a mobile launcher at Wallops Island. (View of launcher from rear.) The after part of the configuration is the booster motor and this forward section is the model proper which houses the internal instrumentation. (Tracking view from down beach showing take-off and flight.) This is a view of the model at take-off. Actual flight speeds are 8 times faster than you see here since this is a slow motion film. When the booster rocket is expended, the booster and model separate, and the model's internal rocket engine ignites as you will soon see. There, the booster separates and the model's internal rocket engine ignites. The model is now free to maneuver. (View of Doppler radar.) During flight this velocity radar and (view of 584 tracking radar) this tracking radar are used in conjunction with telemeter receiving stations (view of model in flight) to record the model's velocity, position in space and all desired telemetered quantities (end of movie).

CHART SPOTLIGHT ON

INSTRUMENT DISPLAY LIGHTS ON

FIRST CHART - (Rocket Models, Type of Investigation)

Listed on this chart are the major headings and their subdivisions under which most of our investigations might be classified. Under Performance we have the ever-present Lift and Drag investigations, Boundary Layer studies, and Inlet characteristics; and under Stability and Control we have Control Effectiveness; control Hinge Moments; aerodynamic Damping in pitch, roll, and yaw; Flying Qualities; Automatic Stabilization; and Dynamic Behavior. Other major studies are Flutter and Buffeting. We would now like to show you some of the models used in these studies.

E-17 and E-25 SPOTLIGHT ON

INSTRUMENT DISPLAY LIGHTS OFF

CHART SPOTLIGHT OFF

Above and to your right we have a large-scale-drag research vehicle (Deacon drag model) and directly behind it a half-scale model of the same type. (E-25)

SLIDE PROJECTOR ON

FIRST SLIDE - (Deacon drag model on launcher)

These models and the ones in the following two slides are part of a program used to investigate the high Mach number drag of various wing plan forms

SECOND SLIDE - (Half-scale Deacon drag model on launcher)

at more realistic flow conditions than those available to the present day transonic or supersonic wind tunnels.

CHART SPOTLIGHT ON

INSTRUMENT DISPLAY LIGHTS ON

SLIDE PROJECTOR OFF

E-17 and E-25 SPOTLIGHT OFF

Using this size (Helium gun model) small-scale model in flight up to low supersonic speeds, it is possible to obtain free flight drag data at flow conditions corresponding to those obtainable in supersonic wind tunnels. Thus, not only can a direct correlation between free flight and wind tunnel tests be obtained, but also the full range of flow conditions can be studied. This specific model is a small-scale model of the NACA RM-10, which may be familiar to some of you.

RM-10 SPOTLIGHT ON

CHART SPOTLIGHT OFF

Here is a full-scale model of the NACA RM-10 which is used for boundary layer and drag studies at high Mach numbers.

SLIDE PROJECTOR ON

RM-10 SPOTLIGHT OFF

THIRD SLIDE - (RM-10 on launching rack)

Here you see an RM-10 model mounted on its launcher. Boundary layer phenomena, besides being important to the study of drag reduction, have a large influence on skin heat transfer characteristics which become important at supersonic speeds where skin temperatures are quite high. In these studies rocket models are particularly useful because they operate in free air.

FOURTH SLIDE - (F-26 nose inlet model on launcher)

Seen here is one of a series of models used in inlet studies. This particular model is a nose inlet model used in the investigation of nose inlet characteristics.

D-32 SPOTLIGHT ON

SLIDE PROJECTOR OFF

Using comparatively simple models such as this one, (D-32 on box) which is disturbed in flight by small pulse rockets, here and here, it is possible to determine the longitudinal or lateral static stability and damping of specific configurations.

E-15 SPOTLIGHT ON

D-32 SPOTLIGHT OFF

Then, by using this more complicated type model (E-15 model on roll free stand) with movable controls, it is also possible to evaluate control effectiveness and hinge moment data. These data are obtained by deflecting this or some other type control periodically throughout the flight of the model and measuring the resultant response or behavior of the model.

SLIDE PROJECTOR ON

E-15 SPOTLIGHT OFF

FIFTH SLIDE - (E-15 on launching rack)

Here is a similar model prior to flight. Since these models are free to fly at the same speed and flow conditions as full-scale aircraft, the dynamic behavior of such models is similar to that which an airplane would experience. Supersonic airplanes are considerably different from present day aircraft, and the design requirements which permit flight at supersonic speeds and high altitudes have resulted in serious problems in dynamic stability, so serious in many cases that pilots are unable to control the airplane; in other cases, serious enough so that the airplane is neither a good gun nor bombing platform.

SIXTH SLIDE - (D-4 on launching rack)

In previous NACA Langley inspections you may have seen demonstrations of rocket models such as this one, which is used in the investigations of automatic stabilization devices. The autopilots resulting from these investigations are very important to the design of successful guided missiles and their related guidance or seeker systems.

SEVENTH SLIDE - (D-18 on launching rack)

At today's high speeds and tomorrow's even higher speeds the problems associated with flutter are being greatly magnified. The model shown here is typical of those used in the study of flutter phenomena.

D-28 SPOTLIGHT ON

SLIDE PROJECTOR OFF

Buffeting is again an old problem which has taken on new aspects with the increase in flight speeds. Here you see a body-external-store model,

SLIDE PROJECTOR ON

D-28 SPOTLIGHT OFF

EIGHTH SLIDE - (D-28 model on launching rack)

and here is an airplane configuration model. Both of these models are part of our buffet program.

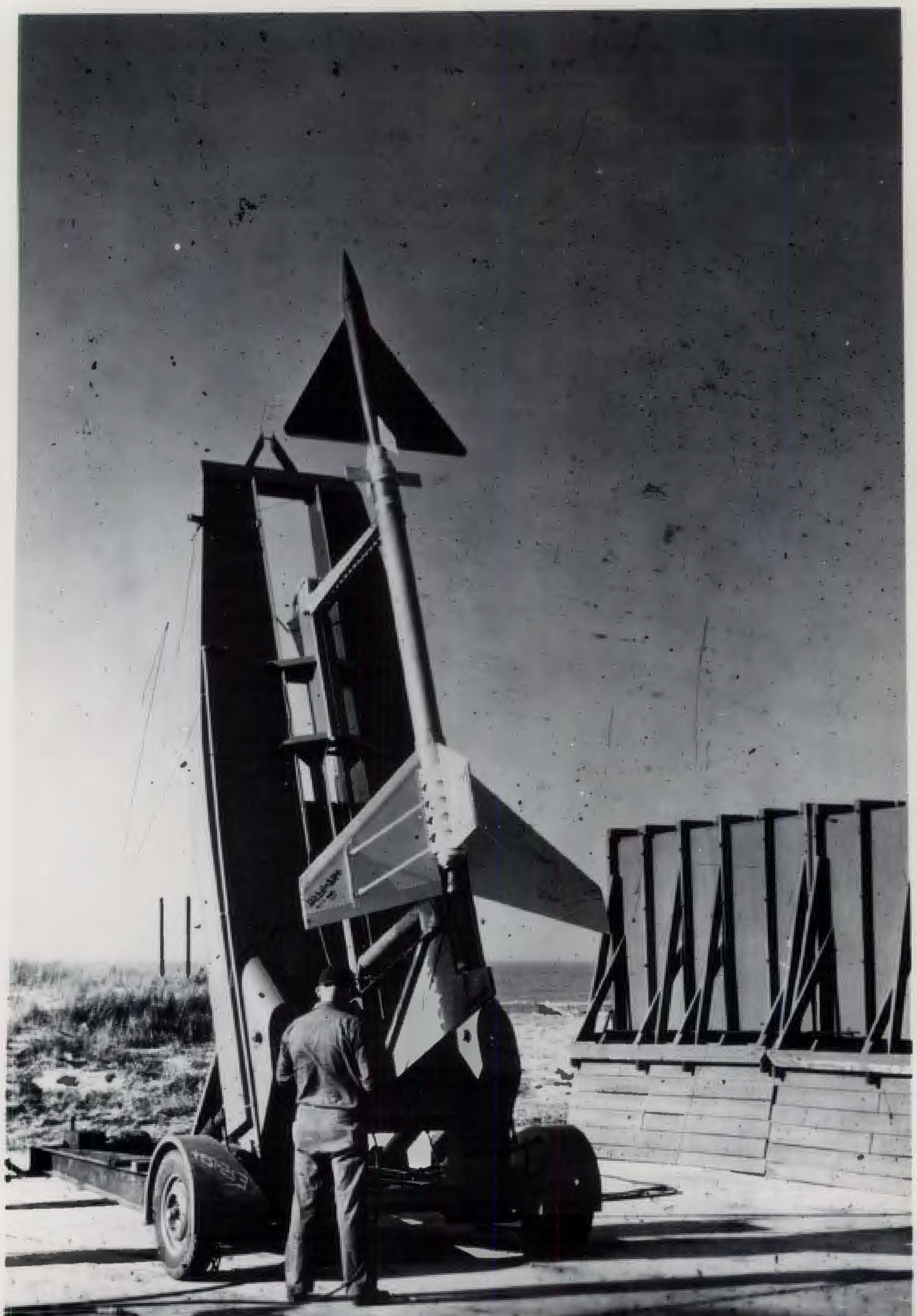
The flutter and buffeting studies mentioned will be discussed in more detail later in the program. For this purpose I will now turn the program over to Mr. Peck (or Mr. Fields) who will discuss some of the results of these rocket model tests.

SLIDE PROJECTOR OFF

ORIGINAL LIGHTING

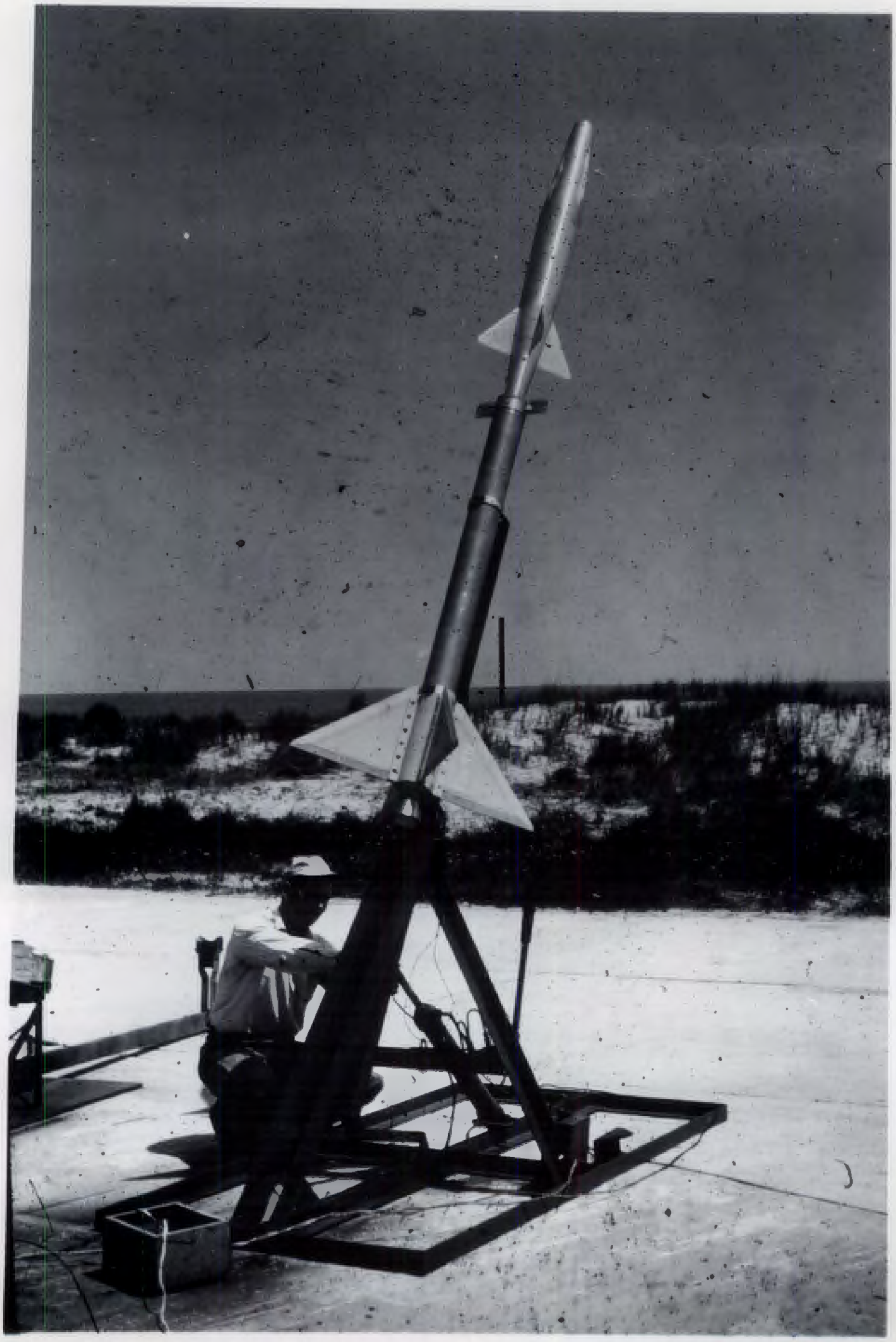
ALL LIGHTS ON

FIRST SLIDE - (Deacon drag model.)



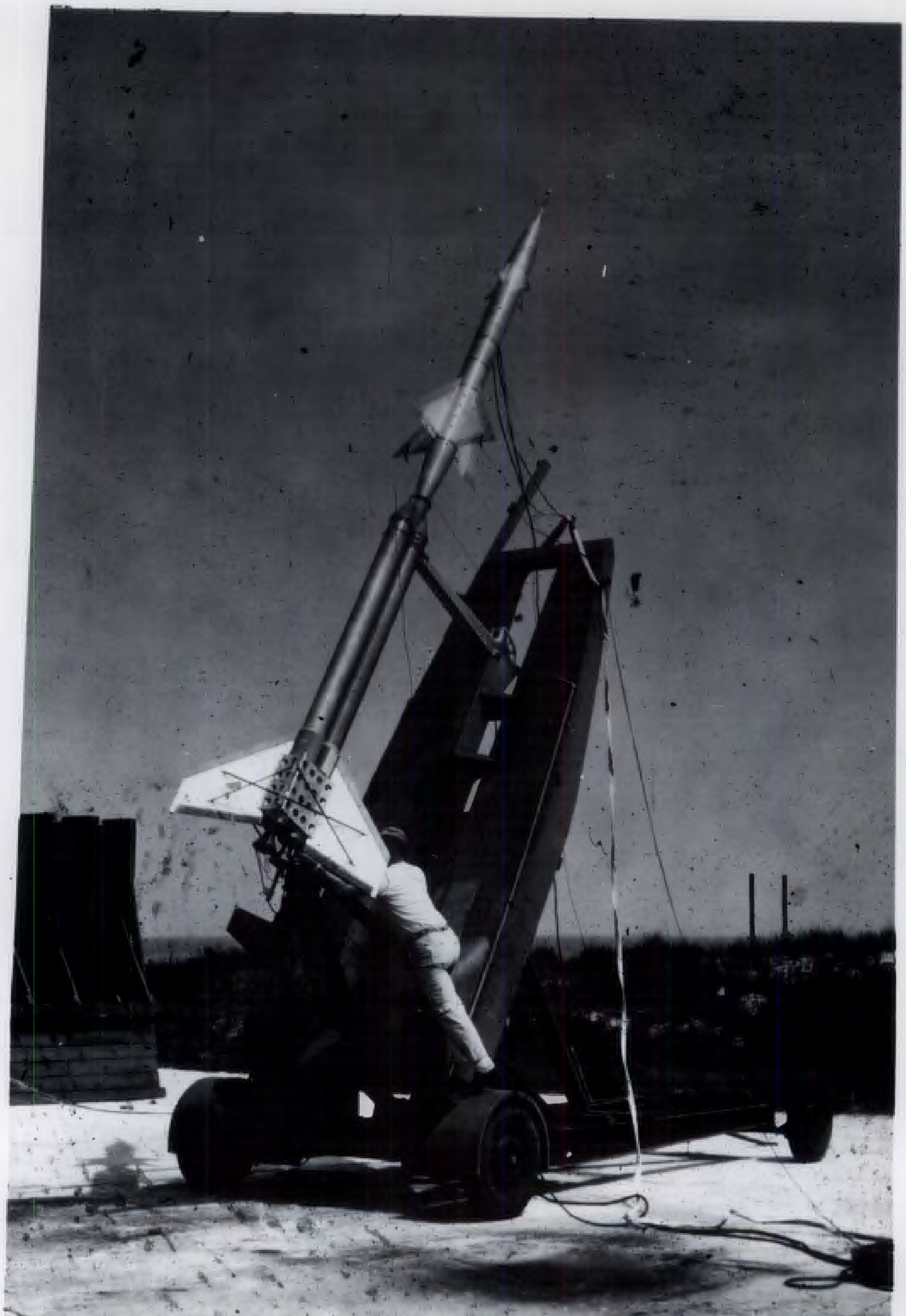
SECOND SLIDE - (Half-scale deacon drag model.)

THIRD SLIDE - (RM-10)



FOURTH SLIDE - (F26 nose inlet model.)

FIFTH SLIDE - (E15 pulse control model.)



SIXTH SLIDE - (D4 autopilot model.)

SEVENTH SLIDE - (D18 flutter model.)

EIGHTH SLIDE - (D28 buffet model.)

PART 2

One of the problems of airplanes that can be investigated with rocket models is the dynamics of flight; that is, the resultant behavior or response of the airplane to applied forces and moments. Although the model inertias are not in most cases actually scaled to the full-size airplanes, they do approximate full-scale conditions closely enough so that we believe the motions measured on the models would be obtained on airplanes. Occasionally during these flight tests, flight time histories of an unexpected character are obtained, sometimes leading to distruction of the model. Such flights are usually not failures, however, and yield information of an extremely valuable nature, although it may be different from that contemplated when the test was planned.

SECOND CHART - (Coupled Yaw and Pitch)

This chart illustrates one of the types of motion which has been measured on an airplane configuration model - coupled yaw and pitch. In modern high speed airplanes the weight distribution is such that most of the weight is concentrated within the long fuselage and very little in the short wings. Consequently, the pitch and yaw inertias are very much greater than the roll inertia. The model in the flight described here was initially disturbed in yaw. Because of low damping in yaw or sideslip the model maintained a yaw oscillation as shown here. This yawing motion produced a rolling motion through which a coupled pitch oscillation was generated as shown here. This type motion is uncontrollable by the pilot and has actually occurred during flight of a full-scale airplane at high Mach number. Such a type of motion may be pretty hard to visualize, so we have set up this model (D-32 on box) to simulate the motion. We simply disturb it in yaw, and then you see the coupled pitch and roll motion develop. The desirable type of response to a yaw disturbance would, of course, be as shown on the lower part of the chart where the yaw oscillation damps out very quickly and there is no coupled pitch motion.

THIRD CHART - (Pitch Up)

The next chart illustrates some interesting longitudinal motions that were obtained from the flight of another rocket model which was typical of supersonic airplane designs. Here again the design has a high ratio of pitch or yaw inertia to roll inertia. In this case, the model was disturbed in pitch by deflecting the elevator in such a manner as to make the model pitch up to an angle of attack as shown here. But at this angle of attack the model entered into an unstable range and pitched up to the high angles of attack shown here. The angle of attack here was of the order of 50 to 60 degrees. When the elevator was again pulsed to bring the model back to zero angle of attack the model did not respond to the control. At this point the model then began a sort of pendulum type roll and yaw oscillation which ended up as a very fast constant roll about the airplane longitudinal axis. The small airplane drawings here illustrate the motions of the model. This type motion is again completely uncontrollable by the pilot. This model has been set up to illustrate the type of roll motion in the latter part of this flight where the model was rolling continuously about the body axis. (B-15 model on roll free stand.) If you will immagine this model flying along parallel to the floor at this angle of attack, you can see that as the model rolls through 90 degrees the angle of attack of the wings becomes zero while the angle of attack of the vertical tail is now equal to the original angle of attack of the wings. Then at 180 degrees roll the wing has a negative angle of attack equal to the original positive angle of attack. This is shown here on the chart where you see the large negative angles of attack. Most modern airplanes are not designed to withstand these high negative angles and the large tail angles of attack. Thus is illustrated the grave necessity to eliminate pitch up which was the basic cause of this whole thing.

Flutter testing using rocket-powered models has consisted of flying test wings through the desired speed range and observing the flutter frequency and speed. In an attempt to obtain more information from a single model, a device has been developed which disturbs the model wing in bending during flight. By measuring the frequency and damping of the free vibration following each disturbance a better idea of the flutter characteristics of various wing planforms may be obtained. This idea is not new; wings have been disturbed in wind tunnels by using some device to strike the wing while the air is flowing over it and recording the free vibration. The problem here was to develop a means to disturb the wings during a free-flight test. (Wing with exciter block.) This device is essentially a .32 calibre triple barrel pistol with a barrel about a quarter inch long. It is fired with miniature electric squibs and a fast burning powder contained in the small cylinders you see here. The recoil from the lead slug excites a free vibration of the wing.

FOURTH CHART - (Damping Record)

This chart is an enlargement of a portion of a telemeter record obtained from a flutter model. An exciter was fired here. A damping coefficient may be obtained from the rate of decay of this oscillation.

A typical Mach number-time plot for a flutter rocket is shown on this chart.

FIFTH CHART - (Flight Flutter Study)

The model is boosted up to here and the booster separates. The sustainer rocket ignites here, and the model is pushed through the test range with a relatively low forward acceleration. Exciters are fired at predetermined times throughout the test range here, here, here, etc. The records obtained are reduced to damping data and plotted as a function of Mach number to give damping curves as shown here. This is a typical curve where flutter would occur as the damping passes through zero. Many wings have a damping curve of this shape where the damping falls off to a low value and then increases again. In a flutter test without vibration exciters, we would only know that this type wing was flutter free as tested. With vibration exciters it is possible to determine this actual damping and the flutter safety margin of the wing over the entire speed range. These damping data then can be applied in predicting the flutter safety of similar wings under different conditions and are particularly useful in generalized flutter studies.

This buffet research model which was pointed out to you previously contains instrumentation designed to tell us the buffet magnitude and model response. This model represents one of a series of body external store combinations. Shock induced buffeting not only occurs on a wing but may also occur on a body or tail or may be induced by flow interference effects of adjacent components.

SIXTH CHART - (Buffeting - External Stores)

This chart illustrates some arrangements of a particular store and body combination that have been flight tested. Of primary interest in this series is the proximity of the store to the body. Illustrated on the right of the chart is the type of data obtained from each model. In this case the lateral acceleration of the store. The semi-store or submerged store arrangement had no more tendency to buffet than the body without a store, but the tangent mounted store buffeted severely. Putting the store out on a pylon reduced this buffeting somewhat but did not eliminate it. These data then indicate that of course it is better not to have an external store, but, if you must have one, it should either be submerged in the body or placed as far away from the body as practical.

This concludes the program to be presented here, and we now return you to your group leader.

ROCKET MODELS

TYPE OF INVESTIGATION

PERFORMANCE

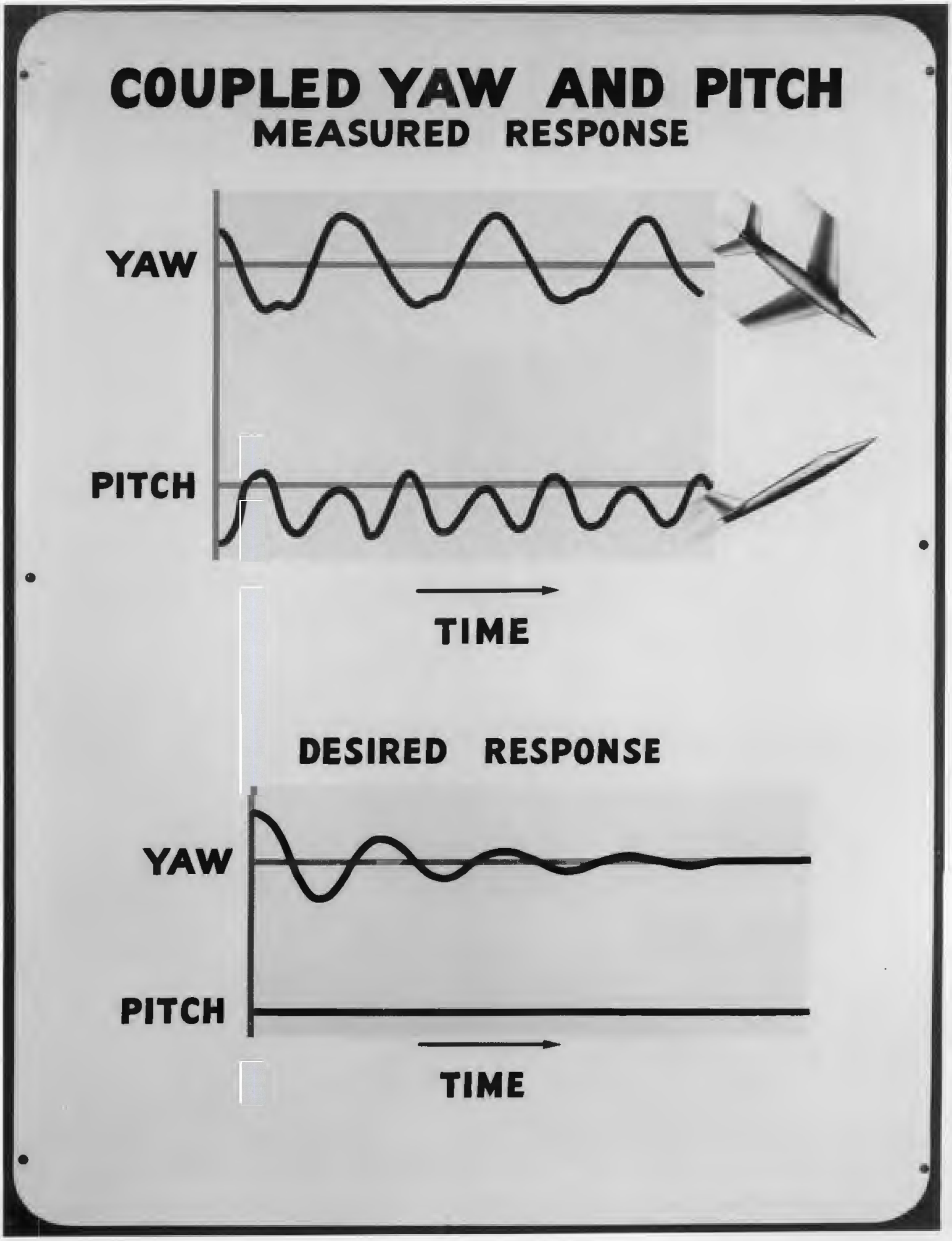
- LIFT AND DRAG
- BOUNDARY LAYER
- INLETS

STABILITY AND CONTROL

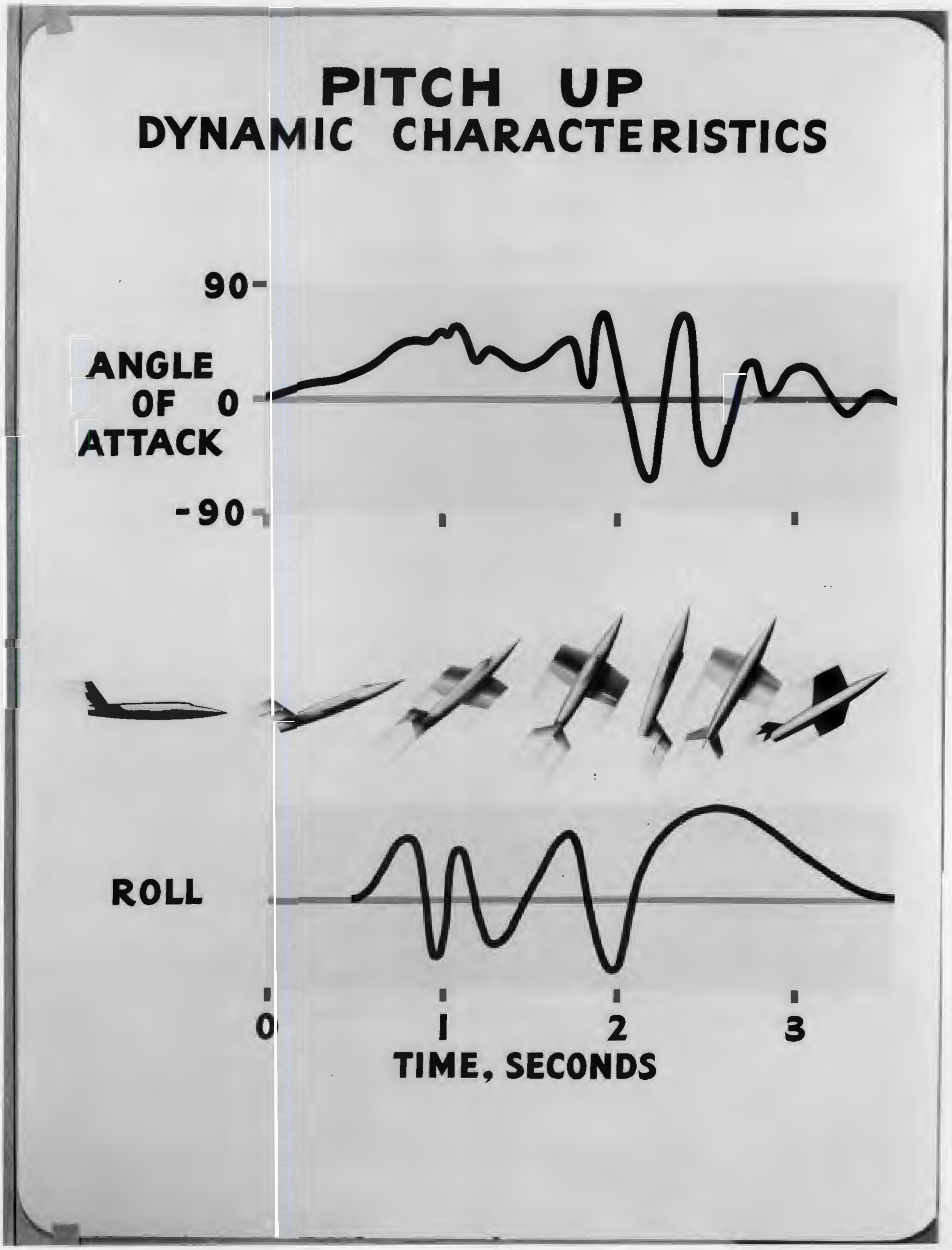
- CONTROL EFFECTIVENESS
- HINGE MOMENTS
- DAMPING
- FLYING QUALITIES
- AUTOMATIC STABILIZATION
- DYNAMIC BEHAVIOR

FLUTTER

BUFFETING


COUPLED YAW AND PITCH
MEASURED RESPONSE
YAW
PITCH
TIME
DESIRED RESPONSE
YAW
PITCH
TIME

LAL 80155


PITCH UP
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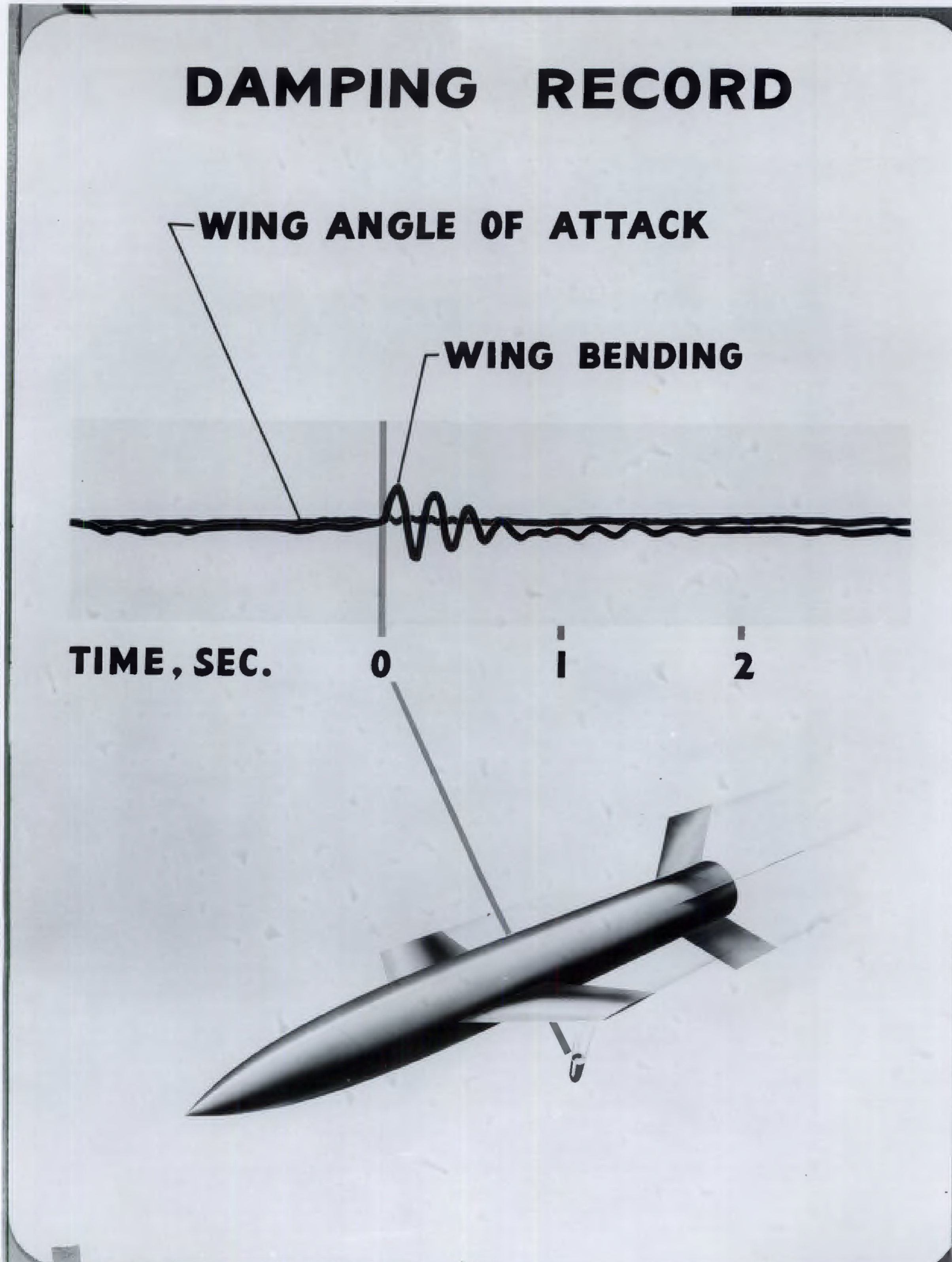
ANGLE OF ATTACK
0
-90
ROLL
0
1
2
3
TIME, SECONDS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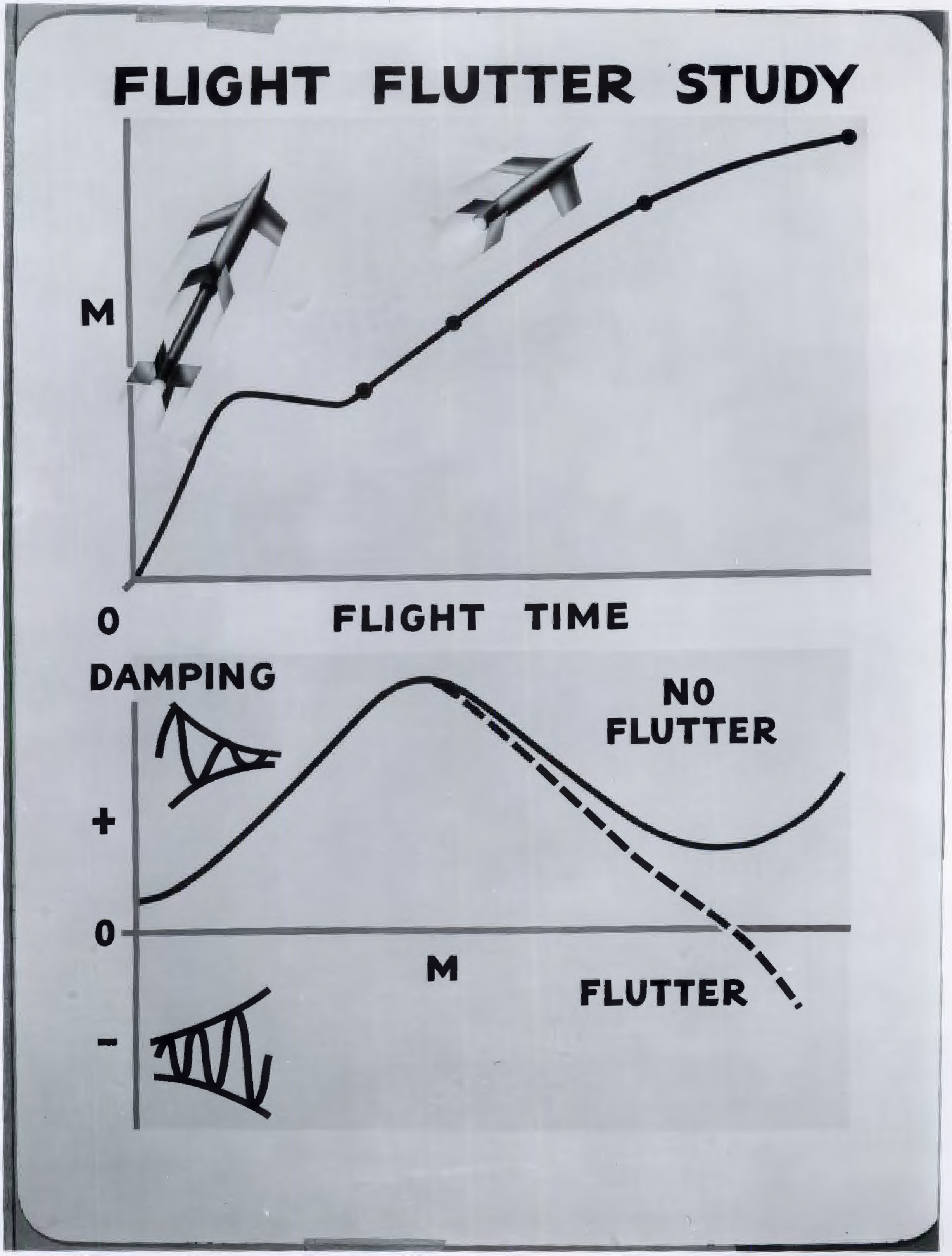
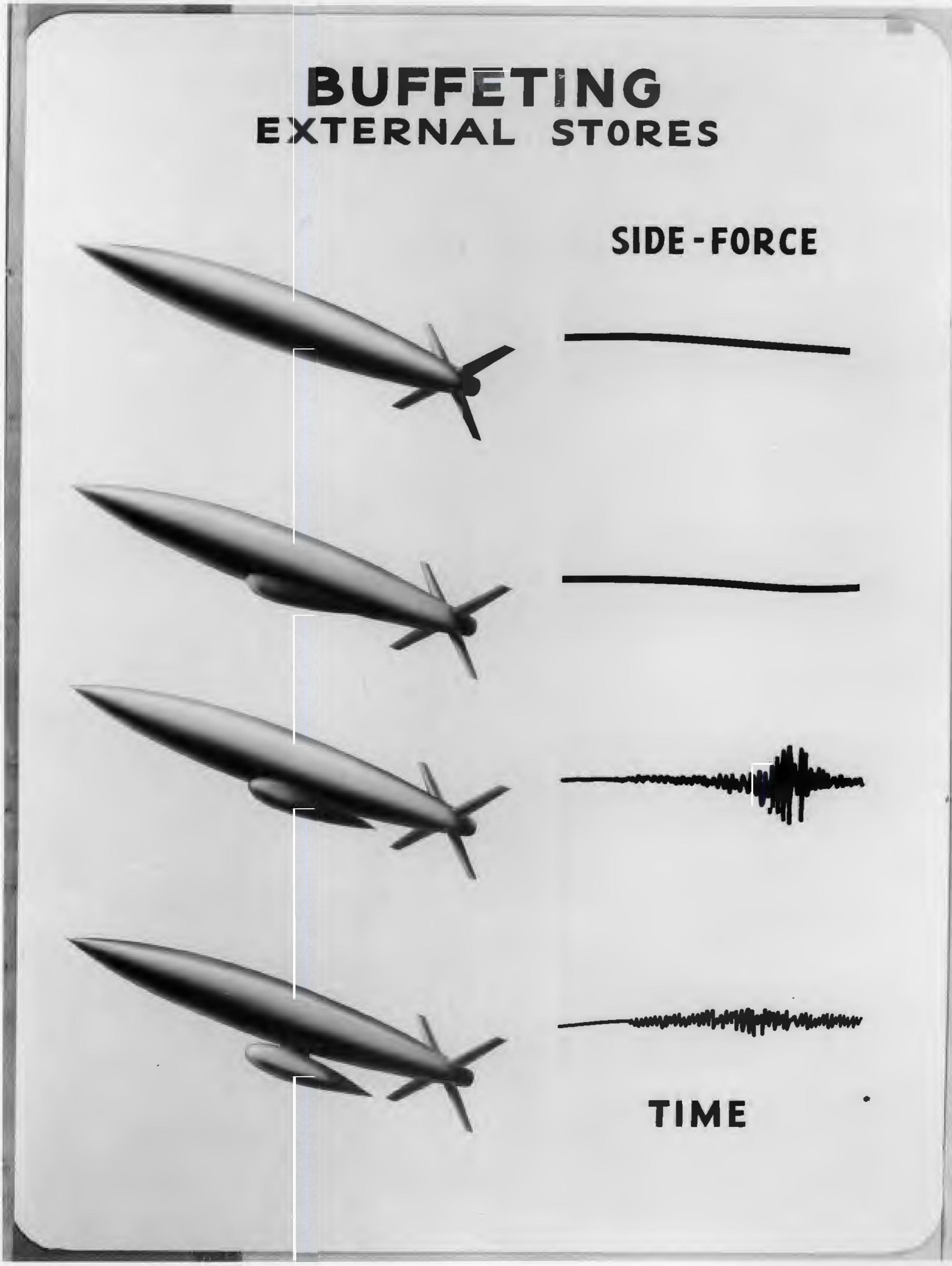
WING ANGLE OF ATTACK
WING BENDING
TIME, SEC.
0
1
2


FLIGHT FLUTTER STUDY
M
0
FLIGHT TIME
DAMPING
+
0
-
M
NO FLUTTER
FLUTTER


BUFFETING
EXTERNAL STORES
SIDE-FORCE
TIME