RESEARCH ON TAKE-OFF AND LANDING

presented by

Langley Aeronautical Laboratory

You are probably aware that a major part of our research has been directed at increasing the speed of aircraft. This high-speed research, spearheaded by the research airplane program, is one of the more dramatic and urgent aspects of our work, leading already to speeds of 2.5 times the speed of sound for a piloted airplane and to speeds several times that high for rocket-propeller research models.

While all this has been going on, we have not been neglecting the other end of the speed scale. Airplanes must take off and land. As their size and speed has increased, there has been a corresponding tendency for the landing and take-off speeds to increase. The lengths of runways also have had to increase, imposing serious problems for both civil and military airports. In the Navy, carrier sizes have increased until they are the largest ships afloat. To illustrate a high-speed landing, I have a motion picture showing the landing of a research airplane on the very long runway provided by the dry lake at our High-Speed Flight Station at Edwards Air Force Base. In this case the airplane lands at 250 miles per hour.

Comments on movie: This is the approach during which the speed is roughly 330 miles per hour. Here is the touchdown at a speed of 250 miles per hour. A landing such as this requires several miles of runway.

It is evident that anything that can be done to permit aircraft to operate from unprepared surfaces, to decrease take-off and landing speeds, or, ultimately, to permit vertical take-off and landing would be of tremendous value to both military and civil operations.

First I would like to consider the possibility of avoiding the need for long prepared runways by the use of large bodies of water as airfields - that is, operating with aircraft suitable for take-off and landing from water. In the inspection at Langley Field two years ago, we described some of the work done with hydro-skis as a take-off and landing gear for a high-speed water-based airplane. (Show model of D-558 with skis retracted.) We showed this model of the D-558 research airplane that was selected as a typical high-speed configuration on which to work. These are the hydro-skis, which are simple planing surfaces projecting below the hull or fuselage. The lift on the hydro-ski, as it planes on the water, supports the load during all but the low-speed part of a take-off or landing.

Subsequent to this preliminary work on the model of the D-558, a full-size application of hydro-skis to a water-based fighter has been made by

Convair. Here is a motion picture of a landing of this airplane - the Convair F2Y - Sea Dart.

Comments on movie: This is the Sea Dart, with skis retracted, in the clean condition. Here is the Sea Dart with the twin skis extended during approach for a landing. The airplane lands and planes on the rear ends of the hydro-skis. As the speed decreases, the load is transferred from the wings to the hydro-skis and the wetted length on the skis increases. The airplane settles into the water as it comes to rest. The load is now supported by the buoyant forces on the wings and fuselage.

Another interesting application of hydro-skis was developed by All American Engineering Corporation. In this case small wheels were incorporated in hydro-skis which were installed on a light airplane. This permitted the airplane to move about on land or water as shown in this movie.

Comments on movie: Here is the airplane just after landing on the water. The fuselage does not necessarily have to be completely watertight since the aircraft planes on the skis until it reaches the beach. These small wheels permit it to taxi while on the beach. This is the take-off from the beach. The airplane reaches planing speed so that on entry into the water it is supported by the lift on the skis. The aircraft planes on the skis as it accelerates to getaway. Note the relatively short distance required for the taxi run while on the beach.

By use of dynamic models, the NACA recently has been investigating the application of hydro-skis to a fighter operating from a ramp. This model (display - model with skis) shows the arrangement of the skis. For convenience, these skis were simply added to the original gear of a land plane. For an actual application they would be retractable for normal flight. I will now show you motion pictures taken during this investigation.

Comments on movie: Here is a landing of a swept-wing fighter on hydro-skis. The aircraft planes on the hydro-skis until it reaches the ramp. The landing run is completed as the airplane taxies up the ramp. You can see the wheel combined with the ski. This is a front view of the same landing runout. This is the beginning of a take-off from the ramp. As the model reaches planing speed, it enters the water. This is a rear view of the same run.

In addition to the work on hydro-skis, recent research on hull-type seaplanes has also led to some interesting results. From about 1937 until quite recently, flying boats were known to be relatively slow aircraft, as represented by this model. These designs were characterized by their relatively wide hulls and short hull lengths. As a result of continued research, high-speed seaplane configurations, as represented by this model, are coming into the picture and offer promise as top-performance aircraft which may be water based. These configurations have long, narrow hulls and are consistent with shape requirements for low aerodynamic drag and improved aerodynamic performance. The results of our research have shown that with the fine aerodynamic shape, together with the sharp-vee hull, acceptable hydrodynamic characteristics can be obtained with these configurations even at the high landing and take-off speeds that are now required.

We may conclude from this that one possible solution to the problem of long runways required for high-speed aircraft would be that of operating from water.

The tendency toward higher landing and take-off speeds can be countered to some extent by the use of high-lift devices. Such devices have been the subject of extensive research for many years. Without attempting a complete review of this subject, we would like to make some remarks about boundary-layer control in this connection. Certain fundamentals regarding the use of boundary-layer control for high lift by blowing or sucking have been known for a long time. Recently, however, the use of the jet engine has given rise to great interest in applications of boundary-layer control to high-speed aircraft. The jet engine provides a convenient pump or air supply that can be adapted to the boundary-layer control system and at the same time the lack of a slipstream over the wings with the jet-driven aircraft gives rise to an increased need for lift augmentation. Thus, a great deal of effort has been directed recently at the problem of obtaining detailed information for design applications of boundary-layer control to modern jet-driven aircraft. Much of the NACA's effort in this direction has been carried out in this tunnel and the full-scale tunnel at Langley.

Illustrative of this research are full-scale experimental applications made to an F-86 airplane at this Laboratory. At the top of this chart (chart #1) we have a photograph of the airplane with an experimental application of area suction to this porous leading edge of the flap for boundary-layer control. At the bottom of the chart is a photograph of a portion of the wing and flap of the same airplane with an experimental application of blowing for boundary-layer control. Through a slot, just forward of this second row of rivets, air is blown over the top surface of the flap.

In either case, boundary-layer control by blowing or sucking has been effective in delaying separation of air flow over the flap and thereby increasing the lift. This model of the flap shows the general type of construction used when area suction is applied for boundary-layer control. Low-energy air from over the flap is drawn through this porous material into this duct in the leading edge.

The cutaway of the wing and flap shown on the next chart (chart #2) shows how blowing for boundary-layer control is applied. High-pressure air from the engine enters this duct in the flap and is exhausted through this slot or nozzle, which extends over the span, and high-energy air is added to that blowing over the top of the flap.

The relative merits of the various boundary-layer control systems will not be discussed because, in any particular design, the usual design compromises which take into account all of the conflicting requirements will have to be made.

A further solution to the take-off and landing problem is that of vertical take-off and landing. Although the helicopter does this very well, I believe that you are familiar with this work and we will therefore limit the discussion to a statement that we have been conducting and are continuing research on the problems related to helicopters. What we would like to stress, however, are the other possible methods for achieving vertical take-off and landing. This research will be described by Mr.________ of the Langley Laboratory.

If we carry the idea of reducing the take-off and landing speed to the extreme we come to the vertical take-off or VTO airplane. Two years ago at the inspection of the Langley Laboratory we discussed this type of airplane briefly as we demonstrated a free-flying research model (sometimes called the "Venetian blind" model) which achieved hovering flight by deflecting the propeller slipstream downward with four large wings or turning vanes. During the past two years we have continued our work on this type of airplane along two lines. First, we have conducted force-tests investigations to develop a simple wing-flap system which has a reasonable turning efficiency and can be readily retracted to form a clean monoplane wing. Some of the results of this work are illustrated on this chart (chart #3) which shows three wing-flap systems which have been tested.

In order to achieve hovering flight the slipstream has to be directed straight downward. The plain-flap configuration shown at the top of the chart (chart #4) can only turn the slipstream about 45° so the fuselage has to be at a very high angle for hovering flight. For the second configuration in which boundary-layer control (consisting of blowing over the leading edge of the flap) was utilized, the fuselage angle was reduced to about 25° for hovering flight. Similar results were obtained with a large double-slotted flap without boundary-layer control. The addition of a leading-edge slat as shown in the lower configuration reduced the fuselage angle to about 15° which is considered an acceptable value. With the slat installed, approximately the same results were obtained with or without boundary-layer control. Research is continuing along this line in an effort to find even simpler configurations which will turn the slipstream satisfactorily.

Work on the redirected slipstream type of VTO airplane has also been continued by constructing and flight testing the flying model shown in the bottom photograph. In this model the slipstream is turned by a large plain flap and a cascade of auxiliary turning vanes which can be retracted for normal forward flight. We are also flight testing a VTO transport model in which the slipstream is turned downward for hovering flight by rotating the wing and propellers 90° relative to the fuselage (upper photo). We will now show you a short movie of the flight tests of this model.

Comments on movie: This is the rotating wing and propeller model. Roll control in hovering flight is provided by varying the pitch of the outboard propellers differentially. Yaw control is provided by differential deflection of the wing flap, and pitch control is provided by simultaneous deflection of the wing flap. These flashing lights are control indicator lights which aid in studying the film. Here is the same model hovering in the test section of the full-scale wind tunnel. As the tunnel air speed builds up you will notice that the wing tilts slowly forward. The wind in this scene moves from right to left. The only special feature other than wing tilting for making a transition with this model was a provision for taking account of the fact that the yaw and roll controls changed function during the transition. For example, deflecting the wing flaps differentially which provides yaw control in hovering flight gives roll control in high-speed forward flight. The wing has now rotated to about 45° incidence. The equipment which you see here has nothing to do with these flight tests. It is part of a full-scale tunnel force test setup. Here the wing is at 0° incidence but the model is flying at a pretty high angle of attack because it is flying at a low air speed. As the tunnel air speed was increased further we eventually got down to an angle of attack of about 15°. (Appropriate remarks will be made during the film about the stability and control characteristics, test technique, model size, etc.; and the control systems of the models will be explained.)

Tail-sitter type VTO airplanes, such as the well-publicized Convair and Lockheed designs, are related to the tilting-wing type in that the wing and propellers rotate through 90° angle of attack during the transition between hovering and normal level flight. Our work on the tail-sitter type started in 1949 with simplified research models. Later, when the Navy contracted for the Convair and Lockheed airplanes, we tested models of these designs at the request of the Navy. This research model in its present configuration resembles the Lockheed XV-1. These are other wing and tail configurations which were used on this model. Incidentally, one VTO investigation was conducted here at the Ames Laboratory by flying a larger model of the XFV-1 here in this tunnel. At Langley we have recently extended our work on the tail-sitter type to cover jet VTO designs. We will now show you a short film covering flight tests of tail-sitter VTO models and some flight scenes of the actual Convair airplane.

Comments on movie: This is our model of the Convair XFY-1. You can see the propeller guard which prevents the flight cable from fouling the propellers. Here the model is hovering in the test section of the Langley full-scale tunnel. As the air speed is slowly increased, the model is tilted into the wind to perform the transition. The transition is progressing and now the model has completed the transition and is flying like a normal airplane. Here is the XFY-1 airplane, ready for take-off.

Notice that the transition is started immediately after the take-off. Now the transition is complete and the airplane is flying like a conventional airplane. This is the landing approach - the pilot pulls up into a steep but slow climb into the hovering attitude. Here the plane has backed down and is preparing to land. (122 jet model) The model has a 60° delta wing and a large triangular vertical tail. It has normal elevon and rudder control surfaces for forward flight and jet reaction controls for hovering flight. It is powered by counter-rotating propellers in a duct to simulate a jet. Each propeller is driven by a 5 HP electric motor. Pitch control is obtained by deflecting the main jet with this eyelid. This eyelid gives yaw control. Roll control is provided by these nozzles which are supplied by air bled from the main jet. This scene shows the jet-powered model making a take-off, a short hovering flight, and a landing. These maneuvers were easy to perform and the model flew smoothly in hovering flight without any automatic stabilization. In this scene the model is performing a transition in the tunnel similar to that shown previously for the Convair model. Transition flights could be made easily and this model flew more smoothly through the transition than any other models we have tested. (Appropriate remarks will be made during the film about the stability and control of the models and the control system of the jet model will be explained.)

By now, most of you have heard of the new flying-platform type of vertical-rising machine, such as Hiller's new platform aircraft, sponsored by the Navy, and of DeLackner Helicopter's new aircraft called the Helivector. A man stands on these machines to fly them and balance and control are attained by the natural reflexes of the flyer as he stands on the aircraft, much as one balances when standing on the ground. Technically, this mode of flight can be described in principle as standing on a column of air or a thrust vector.

The groundwork for this mode of flight was laid by an invention by Charles Zimmerman in 1947. In 1950 the NACA verified by actual experiments Zimmerman's contention that a man could fly a machine of this type using his natural balancing reflexes for control. Since we did not want to become involved with the propulsion problems associated with a practical machine and were only interested in proving the balancing principle, we used this simple air-jet supported platform in the first experiments. Two air hoses attach at these connections and the air jet issues from this supersonic nozzle. This research device was successful, having excellent balance and controllability. The principle of balancing on a thrusting device was therefore proven.

Next the NACA tested a rotor-supported test vehicle which was a configuration of more immediate practical interest but like the first machine avoided the propulsion problem by using compressed air. We have this research vehicle here. It has a 7-foot-diameter teetering rotor, a foot platform and guard rail. The rotor is driven by air which comes in through air hoses, goes out through hollow blades and out at the blade tips. This research machine had satisfactory flight characteristics both in indoor and outdoor flights. Movies of both research vehicles during test flights will now be shown, and will be followed by movies of the Hiller and DeLackner machine.

Comments on movie: This is the jet-supported platform. Here are the air hoses. This is the machine before the landing gear was added. It was found that a man could control this machine better if he did not concentrate on controlling it. Here the flyer is disturbing the machine, then stopping it. He can stop it very quickly. Here the rotor platform is being flown outdoors in gusty and variable winds. The gusts were up to 30 mph. The machine could be controlled satisfactorily even under these adverse conditions. Of course, the machine flew more smoothly than this in still air. This is the Hiller aircraft flown this year. It is powered by two motors turning counter-rotating propellers in a duct. The machine has taken off, will make a short hovering flight, then land. This is the DeLackner Helivector. It has counter-rotating 15-foot-diameter rotors powered by a single water-cooled outboard motor. To translate, the pilot merely shifts his weight in the desired direction - as in the case of the jet board, the rotor platform, and the Hiller machine.

THIS CONCLUDES THE PROGRAM AT THIS STOP.

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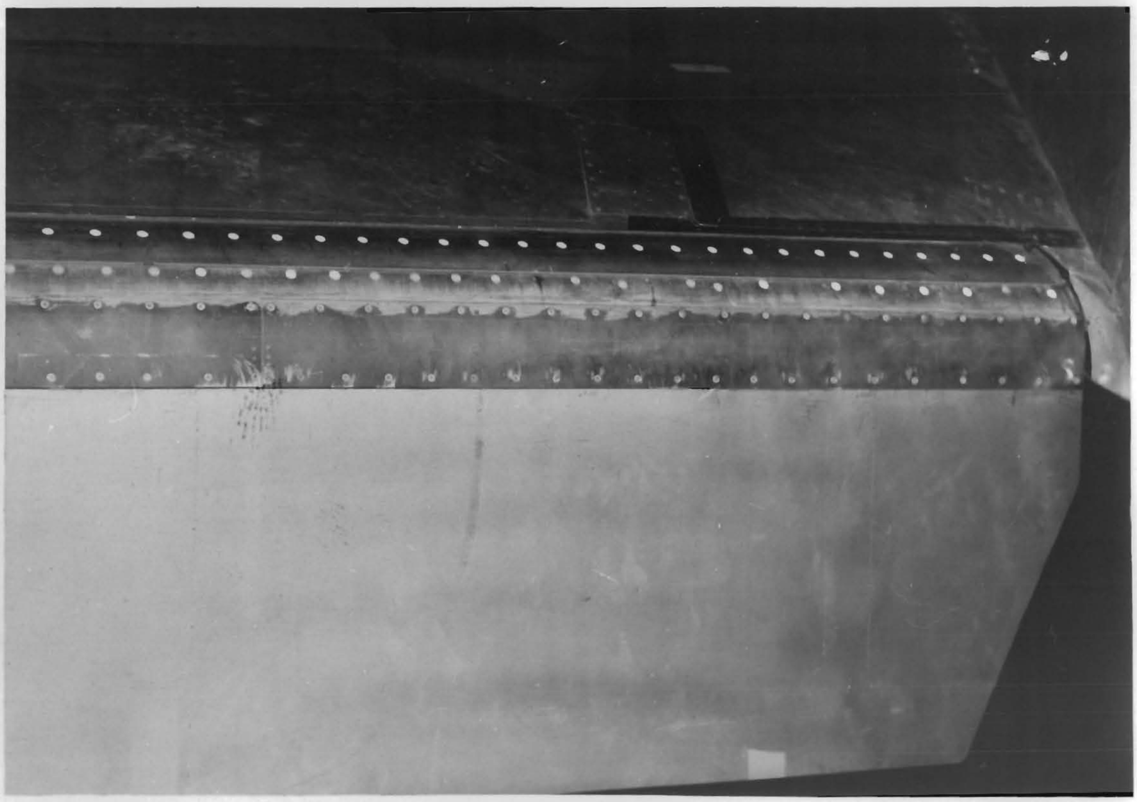

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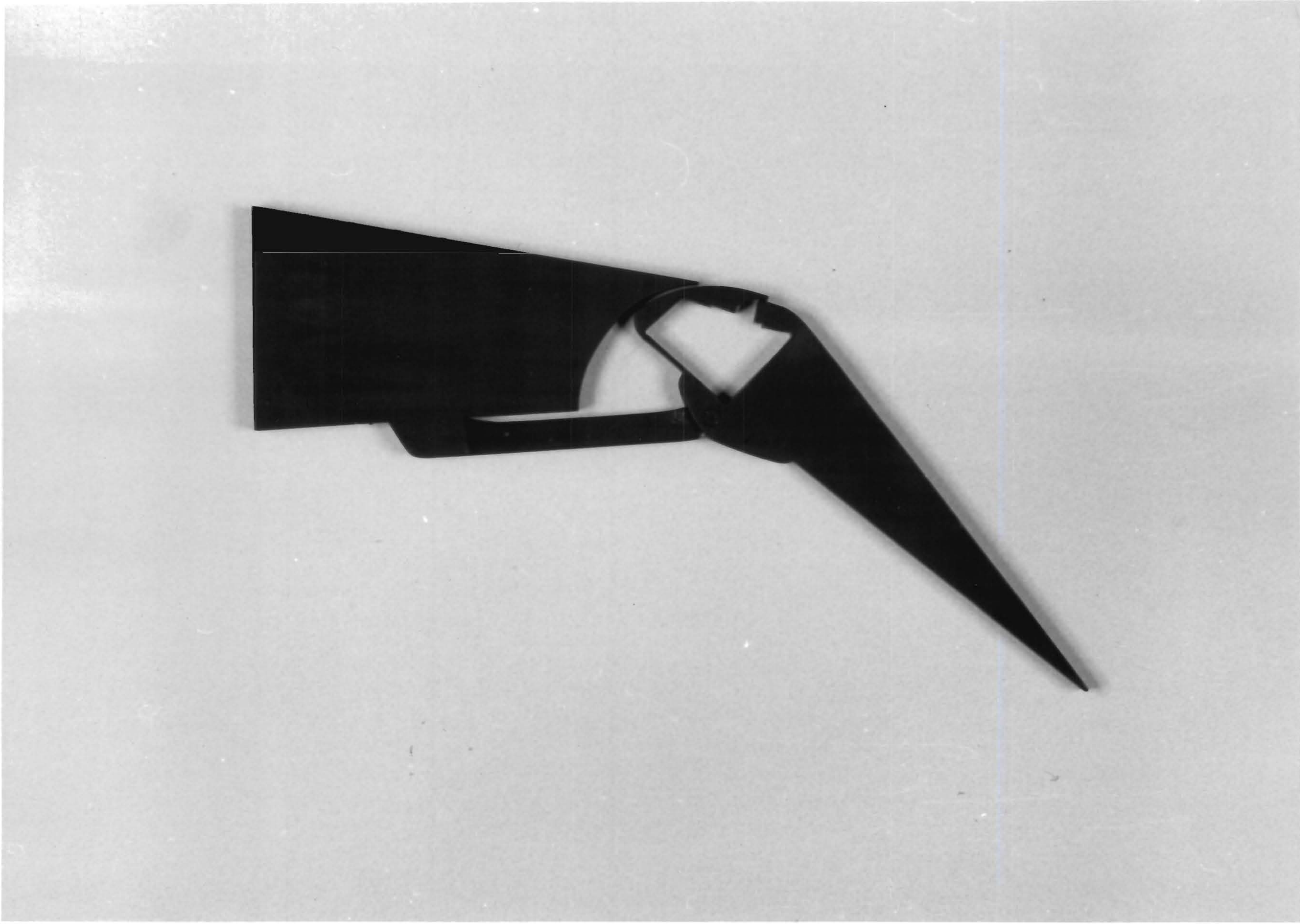

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SLIPSTREAM REDIRECTION

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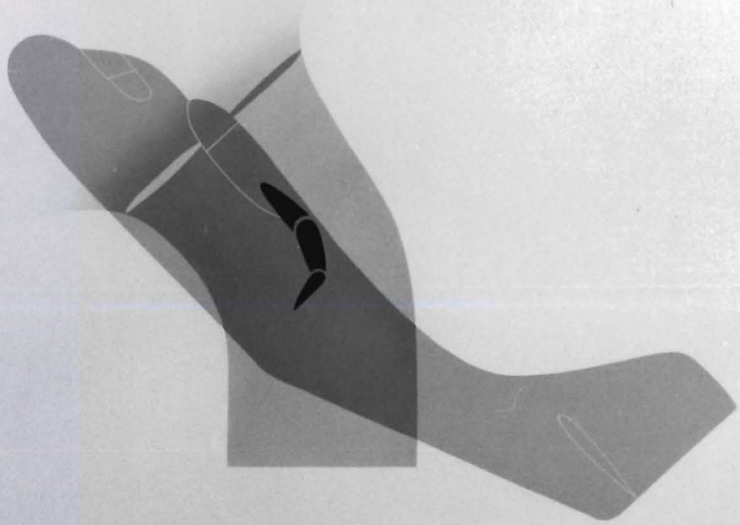
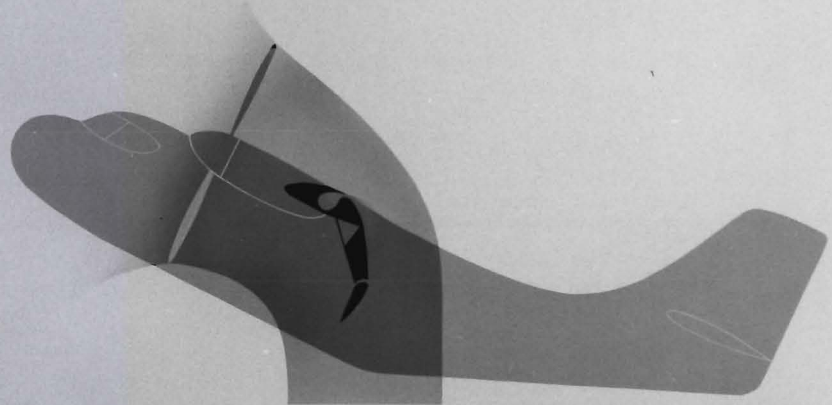


PLAIN FLAPS



BOUNDARY-LAYER CONTROL

BOUNDARY-LAYER CONTROL
WITH SLAT

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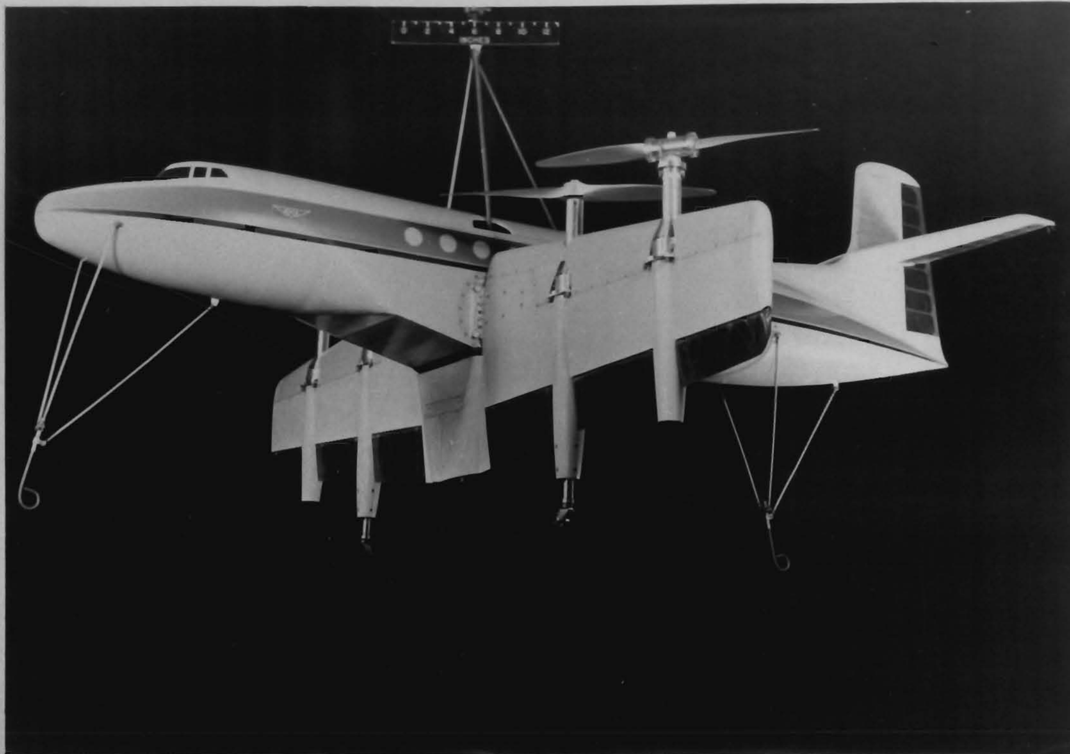

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