

LOW-SPEED AERONAUTICS

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Spacecraft and hypersonic aircraft are very much in the news these days, and you will hear more about them again today. This emphasis on high performance, however, has not lessened the requirement for low-speed research. Indeed, the problems we face today in this area are greater than in the past for two reasons. For one thing, as long as we put people in these aircraft or spacecraft, they have to come back and land. The shapes of these vehicles, however, are being dictated by their high-speed or reentry characteristics, not by their low-speed characteristics. We're having to learn how to live with these shapes and how to modify them the little bit we can, within the limits of the high-speed requirements, to make them safe to land.

The other main reason that we are interested in low-speed aeronautics is that in the past few years we've been working on a class of aircraft that is capable of flying at very low speeds - much lower than conventional aircraft. These are the helicopters and the other V/STOL aircraft which have introduced brand new problems because they are flying so slowly.

Although the problems are new, we are fortunate in being able to use many of the facilities and techniques that have been built up over the years - here at Langley, at Ames Research Center and at Flight Research Center at Edwards, California. Some of these facilities and techniques are indicated by these photographs across the top of the display.

Under flight tests is shown the X-14, a deflected-jet VTOL aircraft. We have large-scale and small-scale wind-tunnel force tests which give you, mainly, performance data. This shows a fan-in-wing VTOL model in our 40- by 80-foot tunnel at Ames Research Center and this is our 17-foot test section here at Langley. We have several different flying model test techniques with which we can study the dynamic motions of aircraft, free-flight model tests in this 30- by 60-foot tunnel, free-flight model tests in which you drop radio-controlled models from a helicopter to study motions that are too big to study in a wind tunnel, then the traditional spin-tunnel tests. And, finally, the large area covered by this last picture, the analytical technique or theoretical analysis.

Now, our work in low-speed aeronautics covers a broad range of concepts from helicopters to supersonic transports and spacecraft, so I'd like to use just two examples, one in the V/STOL area and the other spacecraft landing, to illustrate how we use these facilities and how the different techniques are blended to support a configuration from the first conceptual idea on through specific support for operational hardware.

In the vertical or short take-off and landing area, we start out showing you the case of the development of the tilt-wing V/STOL aircraft. Ever since the helicopter demonstrated the desirability of vertical flight an effort has been underway to combine this vertical flight capability with the good cruise efficiency of the airplane. One way of doing this is the tilt-wing concept where the wings and propellers of the aircraft are tilted up 90° in this manner for vertical take-off and landing and then would be returned to their normal

position for cruising flight. This chart shows the first conceptual model that was built here about 10 years ago. This was a flying model which was part of an exploratory investigation of a number of different VTOL types. There was also some parallel small-scale work going on in the 17-foot low-speed wind tunnel. This work was encouraging in that it demonstrated the feasibility of the concept, at least partially in that such an aircraft could hover and make the transition between hovering and forward flight. As a result the work was continued along three lines - small-scale investigations were continued with improved configurations, large-scale aerodynamic research was started with big wind-tunnel models such as the one shown here in the Ames 40- by 80-foot tunnel, and flight investigations were started with the VZ-2 tilt-wing research airplane, over here to your left, which was built for the Army. For the past 2 or 3 years (after the initial flights by the manufacturer and the Army) the NASA has been conducting flight investigations with this airplane to document the hovering and low-speed handling qualities and to investigate approach procedures. This movie shows a flight of this aircraft taking off from the apron in front of our flight hangar. In forward flight this aircraft flies as a normal airplane so the novel part is its low-speed flight which is shown here.

This particular flight was one of a series to investigate the aircraft's low-speed maneuverability by making a fairly tight turn around the flagpole, here in front of the hangar, with the wing tilted over part way.

Well, after all of these intermediate steps with tilt wings, and as a result of the work on other V/STOL types since the early 1950's, the armed services decided the technology had developed to the point that a large V/STOL aircraft could be built for operational evaluation. The resulting configuration is shown in this artist's sketch - the XC-142A V/STOL assault transport. This aircraft will be capable of carrying a 4-ton payload at a 250 - 300 knot speed. The NASA has supported this aircraft program using practically all of the facilities and techniques shown above.

The XC-142A is still under development and will not fly until later in the year but I have some motion pictures I would like to show you of some flights of a 1/9-scale flying model which is sitting here on the floor. On the airplane each propeller is driven by a turboprop engine and they are interconnected by cross-shafting. The wing and propellers are up like this for hovering and a large flap is programed to extend and deflect as the wing is tilted to go into forward flight. This sketch illustrates the flying model technique used in testing this model. It shows the model flying by remote control in the 30- by 60-foot open-throat test section of this tunnel. The trailing cable, which is kept slack during the flights, acts as a safety cable to catch the model in case of control failure and to supply the model with power and control signals from pilots and operators on the side and rear of the tunnel.

In hovering flight, the normal aerodynamic control surfaces are not effective so some auxiliary means must be found. This film clip shows the hovering controls used on this configuration. Changing propeller pitch or thrust differentially from one side to the other gives roll control. Differential ailerons acting in the propeller slipstream give yaw control and a tail rotor is used for pitch trim and control.

This scene shows a transition from hovering to forward flight. The model is hovering now, the tunnel has not been started. The auxiliary controls are being used. As the tunnel is started and the airspeed is increased, the pilots and operators use their controls to tilt the wing to perform the transition into forward flight. As the wing tilts on over, most of the lift is obtained from the wings and the normal aerodynamic controls, the ailerons, rudder, and elevator, become effective and the model is now flying as a conventional airplane.

In addition to these tilt-wing investigations which were used as an illustration of our work in this field, our effort in the V/STOL area is continuing with helicopters; with tilting ducted-fan types such as the X-22 shown here - the four ducted fans tilt through 90° to go from hovering to forward flight; with buried-fan types such as the XV-5A airplane shown in this slide - here the fans in the wing give the vertical lift and then are shut down and covered over for forward flight. Investigations are also continuing on various problems of jet V/STOL configurations.

Let's leave the V/STOL area now and talk a little about spacecraft recovery.

The landing of all space vehicles recovered to date has been accomplished by means of parachutes which are relatively simple, well-proven devices. Since the simple parachute is limited to an essentially vertical and uncontrolled descent, other means of performing spacecraft landings involving controlled gliding flight are being investigated. This work can be roughly divided into nonlifting and lifting types.

The capsule type has very little if any lifting capability and must therefore be recovered by some auxiliary means such as a steerable parachute, rotor, or a parawing as shown here. The parawing is a light flexible auxiliary wing that can be packaged like a parachute and deployed when needed. Capsule recovery is, of course, only one of a number of proposed uses of the parawing. For example, the Army is actively developing it for cargo drop as shown in this slide. In this case the parawing is guided by radio control for precision delivery of air cargo. We have made wind-tunnel and model flight investigations to study the stability and control, gliding capability, and deployment of the parawing. I would like to show a film clip of a deployment test which was made using the radio-control helicopter-drop technique. The model shown in the movie is similar to this one hanging over here, but about twice as large. Notice that structural members of the parawing are inflatable tubes along the keel and leading edges. Wires run from the capsule to the apex and to the trailing edges of the tubes. The film is taken from the helicopter and shows a $1/3$ -scale capsule dropping away. The high-speed camera slows the motion to about $1/8$ normal model speed. (Drogue parachute stabilizes spacecraft.) (Parawing canister pulled from top of capsule.) (Inflatable tubes are pressurized to approximately 80 percent of final inflation but the ends of the leading edges and keel are still snubbed.) (Trailing edges released.) (Inflation completed and leading edge gradually released to bring parawing up to lifting condition.) In addition to evaluating the aerodynamic deployment sequence, various loads encountered during deployment were measured in these tests. In general, the investigations showed that parawings can be successfully deployed, however, the deployment process should be a sequence of carefully controlled and timed events.

Now in the lifting type the gliding capability is built into the configuration. The NASA has had a program underway aimed at finding the best shape for a multipurpose entry vehicle that would be suitable for a wide variety of missions. One such mission might be a reusable manned space ferry to resupply an orbiting space station. You will hear more about this program from hypersonic considerations later in the day - here we are concerned with the low-speed and landing characteristics.

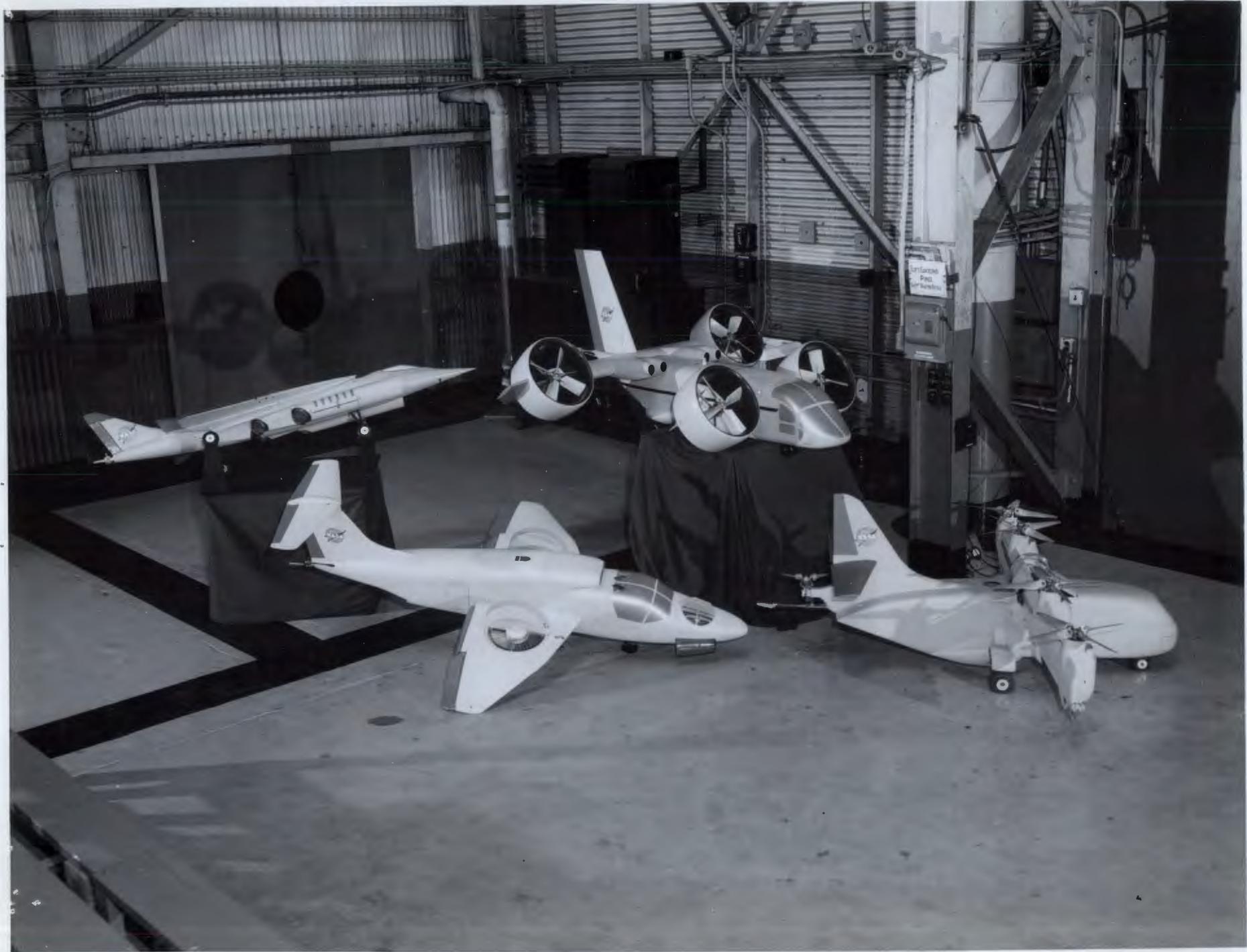
The NASA has been working on various types of entry vehicles for the past 7 or 8 years. At both Ames and Langley we investigated a number of shapes representative of vehicles that might be suitable for reentry. These models on your right show some of the configurations used in this work. They all have, roughly, a delta or triangular plan form but the cross sections go all the way from a winged vehicle like this one which has a delta wing with a body on top of it - to this lifting body type which has a modified half-cone body. The other shapes could be considered either very thick delta wings or perhaps, triangular bodies.

Currently these two lifting body types are undergoing extensive investigation by the NASA. This one called the M-2 configuration and this shape which is the HL-10. We can't change the basic shapes much just to fix up the low-speed characteristics. Mainly we have worked with the tails and control surfaces and have made other minor changes in the cross sections to improve the low-speed lift-drag ratio for better gliding capability and to improve the handling characteristics. This scene shows a flying model of the M-2 configuration in this tunnel and this shows the HL-10 flying model. This is a shot of the HL-10 in the spin tunnel. In this technique the model is launched in the vertical wind stream in a spin. The motions and recovery procedures can then be studied. Notice that this shows a different tail configuration, twin canted tails in addition to center vertical tail. In addition to the investigation with these small-scale models, we also have large-scale tests underway. This photograph shows the M-2 configuration in place in the 40- by 80-foot tunnel and the HL-10 is presently under investigation up in the test section behind you. This model is full scale and gives you a good idea of the size of vehicle we are talking about. In addition to the center vertical tail shown on the model, twin vertical tails of various sizes canted out from the sides will also be tried. We already have some flight-test experience with the M-2 configuration at our flight-test center at Edwards in California with a lightweight plywood test vehicle and these next movie scenes show a flight. The test bed is not powered but is towed up to altitude by a DC-3 airplane - released - and makes its gliding approach. This test vehicle weighs a little over a thousand pounds which results in a wing loading of about 8.

The next step in this program will be an award of a contract for construction of test vehicles of each of these two designs that will enable us to investigate the low-speed flight characteristics at operational weights. They will be built using aircraft construction practices and the weights can be varied from about 4000 to 8000 pounds, giving us a wing-loading test range of 25 to 50, which is representative of operational vehicles. They will be taken aloft under a B-52, as we're doing now with the X-15, and released in gliding flight for low-speed investigations.

In summary, I have indicated the large range of concepts requiring low-speed study. I have shown you examples of how we use our facilities and techniques in this work, and have tried to show that even in this age of space flight, low-speed research is still needed not only because of the problems resulting from the new high-speed shapes but also because of the advantages of low speed itself.

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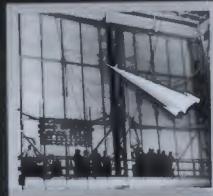
FLIGHT



FORCE TESTS



FLYING MODEL TECHNIQUES



ANALYTICAL



V/STOL

TILT-WING DEVELOPMENT



SPACECRAFT

NON-LIFTING



LIFTING



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