June 5, 1961

Aviation Week and Space Technology

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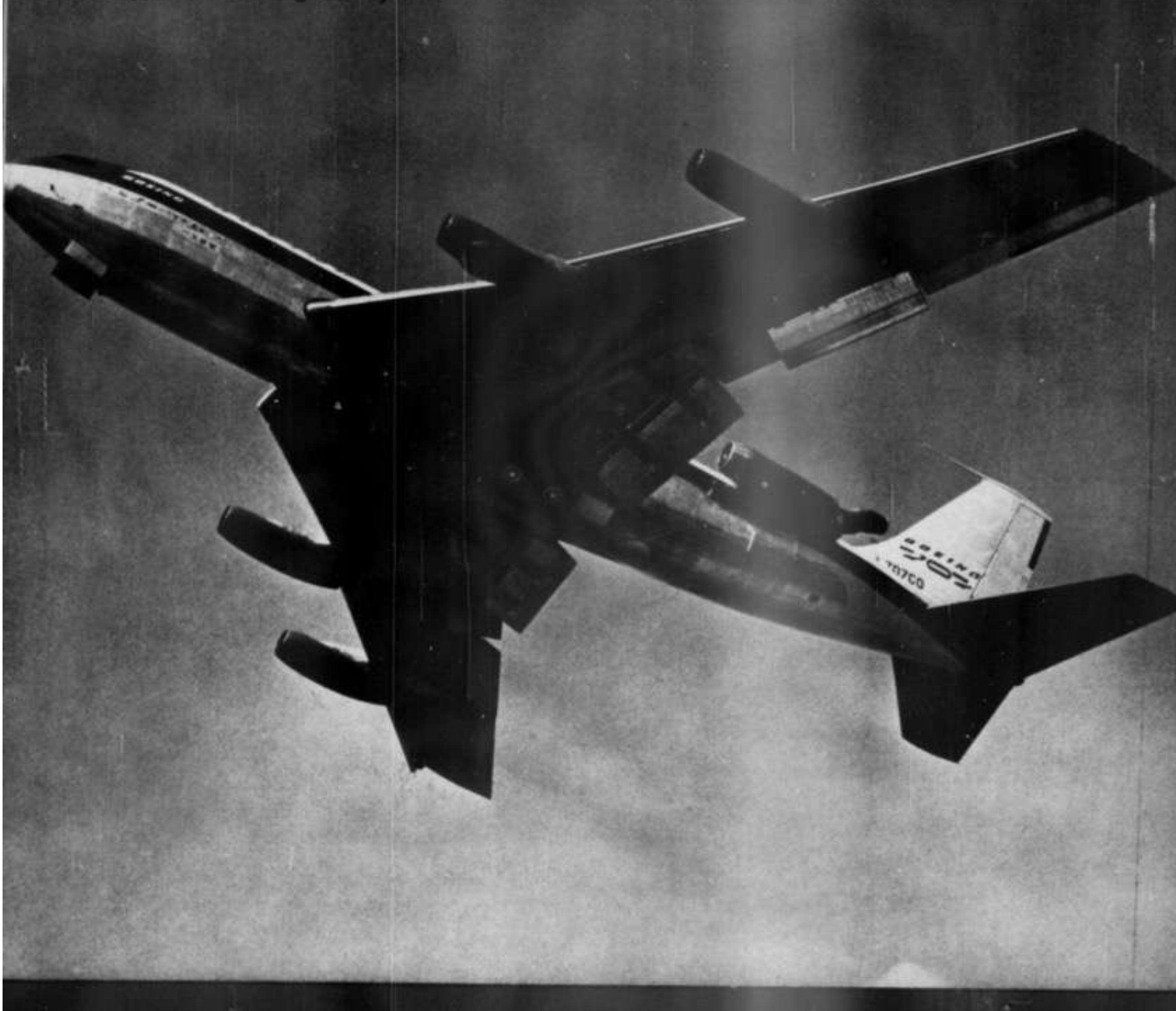

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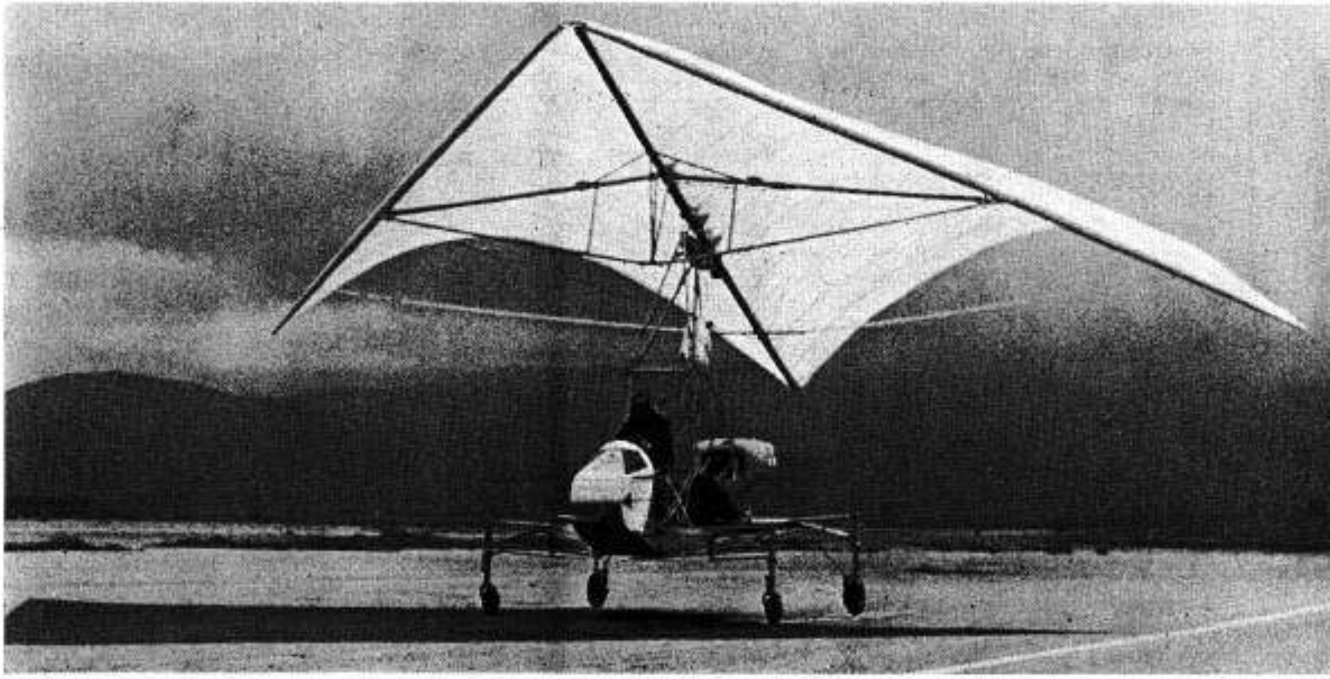


RYAN'S ROGALLO WING airplane consists of four-wheeled open frame body with high central pylon hanging beneath ribless delta wing.

Rogallo Wing Studied for Combat Mission

By Russell Hawkes

San Diego, Calif.—Ryan Aeronautical Co. has begun flight tests of an experimental Rogallo wing (AW Sept. 19, 1960, p. 57) airplane here in a program jointly financed by the company and the Army.

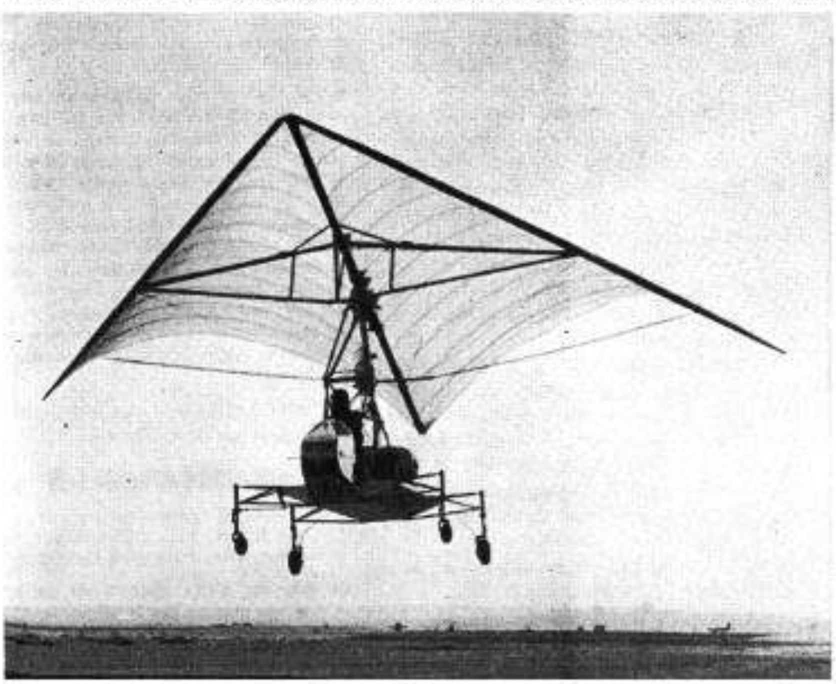
At present, Army's participation consists of a $100,000 contract from Transportation Research Command to pay for part of the test program now beginning. The design and manufacture of the testbed were funded by Ryan. Army aviation authorities hope the collapsible airfoil vehicle can be developed into a light, inexpensive, easy-to-operate aircraft for numerous battlefield roles.

At the other end of the performance spectrum, National Aeronautics and Space Administration has awarded Ryan a $150,000 contract to study the feasibility of equipping the Saturn S-1 space booster with a Rogallo wing to make it recoverable. It also has been proposed as a lift system for re-entry vehicles.

The concept was invented by Francis M. Rogallo of NASA and has been investigated in wind tunnel and unmanned scale model studies at NASA's Langley Research Center. Ryan has named its version "Flex Wing" and conducted further model tests before building the manned testbed. Ryan project engineer Cecil Craigo told Aviation Week that much of the data used in the design of the experimental Flex Wing airplane was obtained about 80 years ago in pioneer glider flights by Otto Lillienthal in Germany.

Craigo said the testbed aircraft has

WING FABRIC is Mylar bonded to nylon. Plane is powered by a 100-hp. Continental pusher engine (AW May 29, p. 30).



been designed to give maximum flexibility and scope to the experimental program and not to demonstrate performance levels for any particular application.

The airplane has a gross weight of 1,100 lb. without flight test instrumentation and 1,400 lb. with it. It consists of a four-wheeled open-frame body with a high central pylon hanging beneath the ribless fabric delta wing. It is powered by a 100-hp. Continental engine mounted as a pusher at the aft end of the fuselage.

The wing fabric is Mylar bonded to nylon and was made by the Lowell North Sail Co. More than 20 other materials are still being investigated for possible use. When at rest, the fabric hangs loosely between the longitudinal "keel" and a pair of tubular leading edges flexibly joined at the front end of the keel. Like a boat sail, it only assumes aerodynamic power when it has been inflated by the flow of air.

Primary wing members are each 28-ft. long and the area of the fully deployed wing is 555 sq. ft. A truss-type spreader just forward of the wing-fuselage link holds the wing members fixed at a leading edge sweep-back angle of 45 deg., calculated to give the best ratio of lift to drag. This sweep angle gives the wing a span of 39.4 ft. The keel and leading edges are made of aluminum alloy to aircraft construction standards.

Craigo says the spreader structure is not an essential part of a Flex Wing airplane and an operational version might not have it.

Spreader's Purpose

The chief reason for it on the testbed is to give the airfoil a constant configuration. Uncontrolled and unmeasured changes in its shape would make test data meaningless, and continuous correlated measurement of all the variables thus liberated is probably impractical. Redesign of the spreader bar to get controlled variations in the shape of the collapsible wing is possible but Craigo said Ryan is not far enough into the program to make such plans. Since it is there, the spreader bar is also used to carry part of the flight loads from the leading edges to the keel of the testbed wing but other ways of doing this may be used if Flex Wing aircraft reach operational status.

Ryan's first interests in the Flex Wing test program are to demonstrate feasibility and to investigate the operation of the concept at very low wing loadings—about 2 psf. In approximately 30 test flights from Brown Field, Otay Mesa, the experimental Flex Wing has not yet been taken out of the traffic pattern or to altitudes higher than 500 ft. However, Craigo says that the testbed should be capable of an altitude of 20,000 ft. later in the program and perhaps higher if an engine designed for high altitudes is installed.

While a total of nearly 70 flight and ground tests have been made in the program, Ryan is not yet producing much new quantitative data. First tests of a radical vehicle must be limited to showing that it can get off the ground and remain under control. Ryan has now proved this and is beginning more elaborate and intensive investigations.

Control System

Control system of the Flex Wing functions without benefit of conventional hinged surfaces and flaps by altering the balance of the aircraft. The body swings from hinges between the pylon and the wing keel. By pushing, pulling or turning his control yoke, the pilot moves the fuselage forward, backward or sideward relative to the wing above him, thereby moving the horizontal position of the center of gravity relative to that of the center of pressure on the wing. This causes the wing to tilt toward the new position of the center of gravity.

The principle is the same used in the control of hang gliders by Otto Lilienthal and other experimenters in the last century. The strength of the pilot's arms was used to lever the mass of his body laterally or longitudinally to change the attitude of the glider by altering its balance.

Craigo defends the mass-shifting technique of flight control as superior or potentially superior to the more conventional methods of using movable surfaces to change air flow patterns so as to move the aerodynamic center of pressure with respect to the fixed center of gravity. Mass-shifting affects the relative position of the two centers directly and there is no lag while the pattern of air circulation rearranges itself, he said.

The testbed aircraft is highly stable because of the pendulum effect produced by locating the wing on top of a pylon far above the airplane's center of gravity. Craigo said pendulum oscillations of the airplane are well damped and converge quickly. Directional stability is so great that Ryan engineers have given the testbed nothing equivalent to a rudder. When the pilot banks the airplane, the directional stabilizing force keeps the nose coming around in a balanced turn.

A parallelogram linkage between the wing keel and the top of the body pylon can be adjusted from the cockpit to produce some translational movement between the wing and the body.

Nylon cords or strapping between the leading edges and the keel keep the wing fabric from collapsing into the spinning propeller when there is no relative wind to keep it deployed.

EXCLUSIVE: I Flew the Flex-Wing

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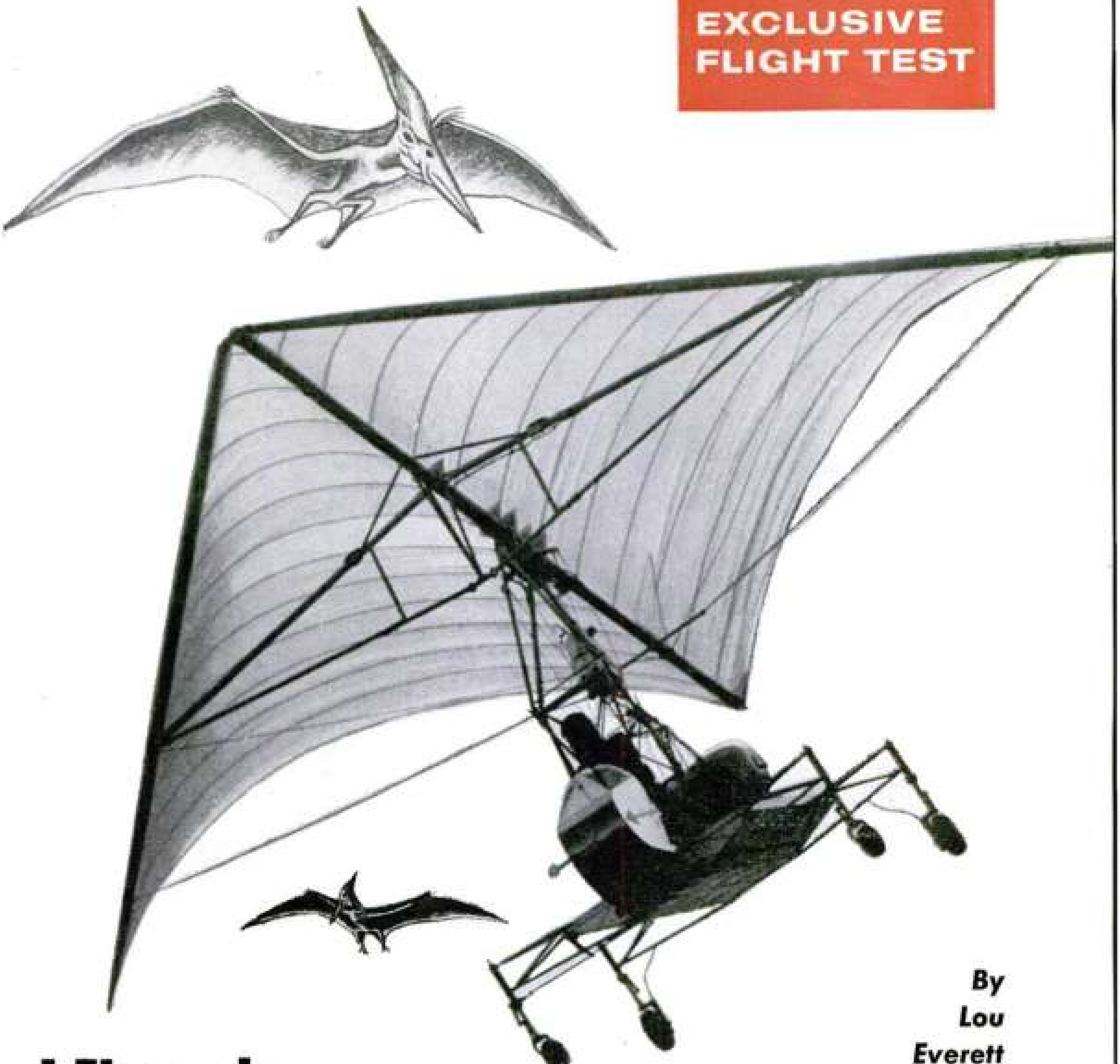


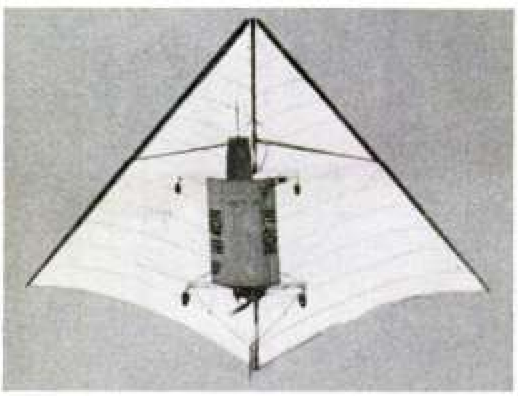
By
Lou
Everett
Test Pilot, Ryan Aeronautical Company

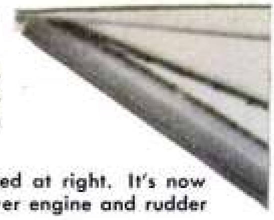
I Flew the Pterodactyl Flex-Wing
Hottest Thing in Aviation

NO ONE HAD EVER flown an aircraft like this before. It was a brand-new development of the Space Age. Yet at the same time it was a throwback to a flying machine in use millions of years ago.

The limp fabric of the arrow-shaped wing hung loosely from its supports. There were no control surfaces. The fuselage was an open platform on four wheels. In front, I was strapped to a seat from an old light plane and was holding the control wheel of a World War II bomber. Behind me the little 100-horsepower engine was warming up.

To a large extent the flexible wing was a nylon-and-aluminum copy of





MODEL GLIDER, left, and full-scale craft, below, show arrow-head shape of Flex Wing design

MAIN PARTS of craft are labeled at right. It's now being tested with 185-horsepower engine and rudder

the leathery membrane that the pterodactyls of the Jurassic Age used for gliding flight.

Would the odd craft fly smoothly, as we hoped? Would it snake violently from side to side or possibly pitch up out of control and crash? The first lift-off was going to answer these questions and a lot of others.

I advanced the throttle and the machine started down the runway. Overhead, the fabric ballooned up into its airfoil shape. At 30 miles per hour the machine was getting light and I eased back further on the control column. We were airborne!

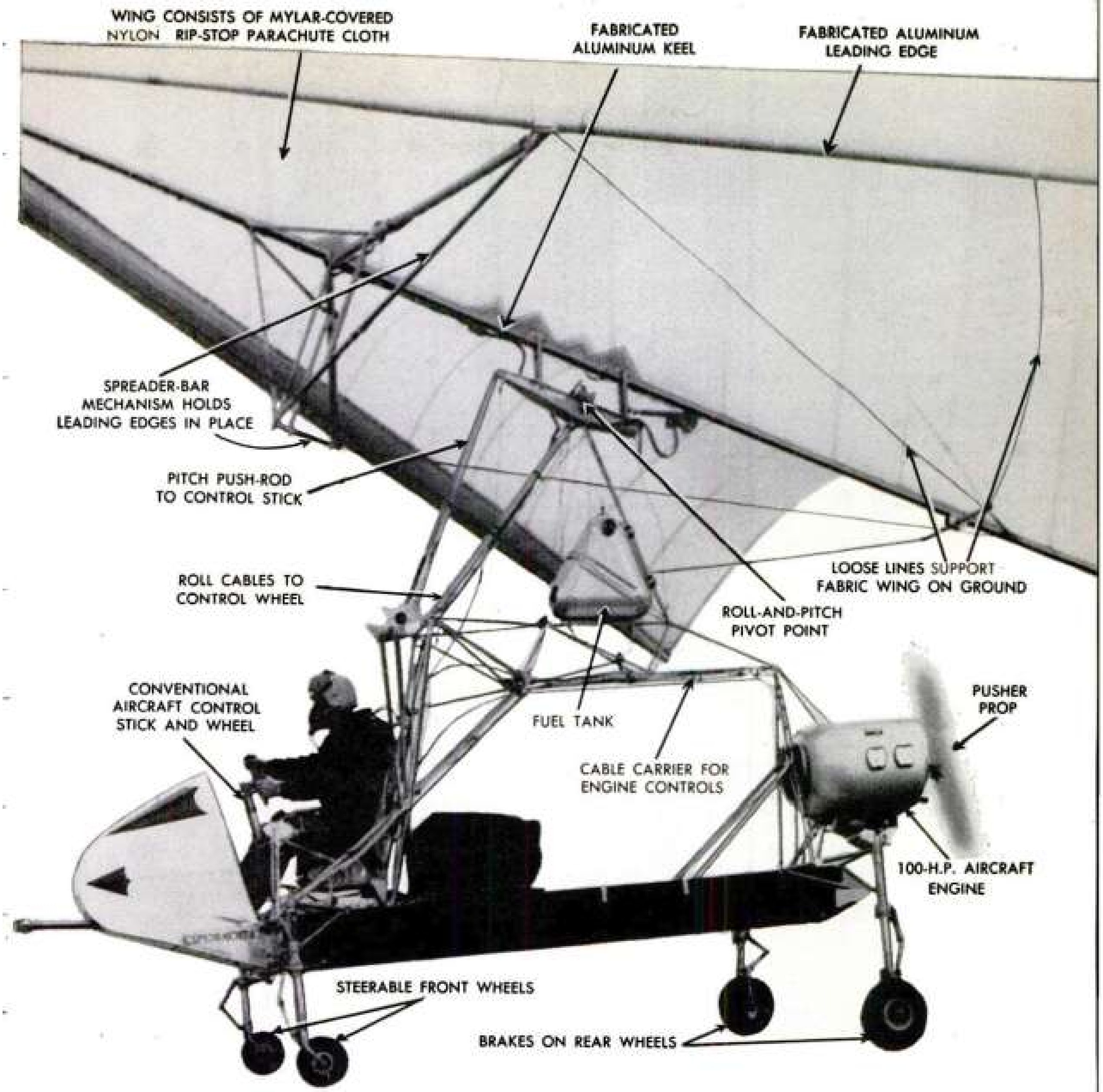
My sensations were different from those experienced in any other aircraft. The platform remained level during the climb, and so the upward motion seemed like that of a helicopter. Now and then the platform rocked gently back and forth or from side to side in gusty air, yet the cloth wing remained completely stable.

I tried a turn, rolling the wheel to the left, and the plane began a slow left turn. The platform itself remained level; it was the wing that shifted and caused the turn. The airplane was performing beautifully.

As project engineer and test pilot for the Flex Wing at Ryan Aeronautical Company I was feeling out the characteristics of a "test bed" that may be the forerunner of many different kinds of vehicles.

The Flex Wing may be an answer to the

RADIO-CONTROLLED MODEL goes through taxi tests at Langley Research Center of National Aeronautic and Space Administration. The principle of the flexible wing originated with Francis M. Rogallo of the NASA



desire for a cheap and roadable personal aircraft. It could be the solution to the Army's need for an airplane that requires no more training than learning to drive a truck. It might be used for towing cargo behind a helicopter, increasing the helicopter's pay load up to sixfold.

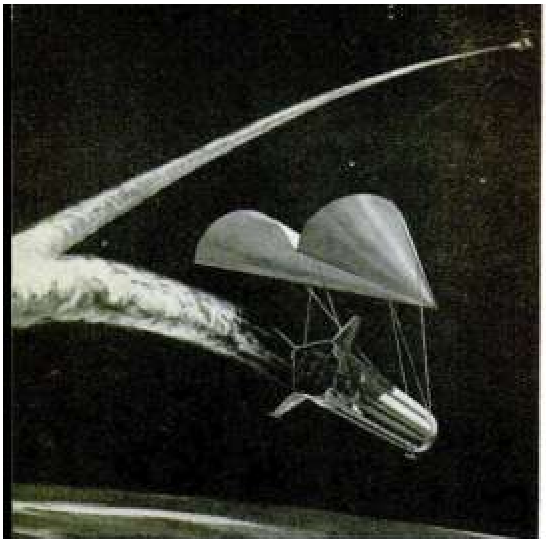
As a temporary auxiliary lifting device, it could help get heavy transports up out of short fields. Used literally as an airbrake, the lifting surface could reduce the landing speed of a Mach 3 transport from 220 knots to no more than 69 knots.

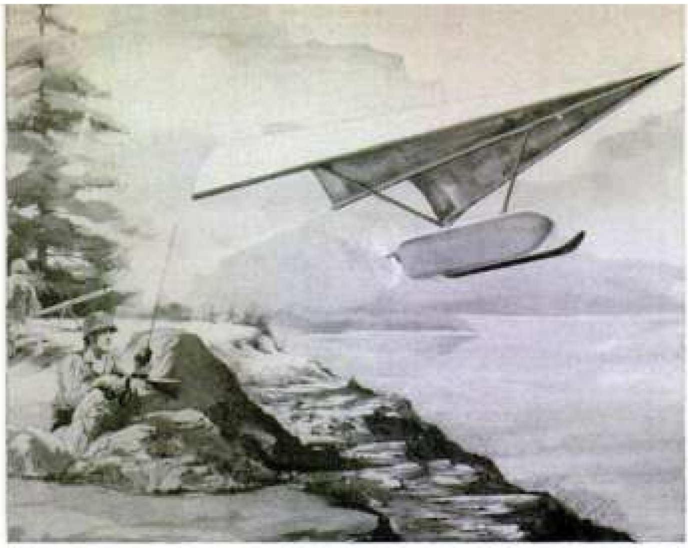
As a small paraglider it could allow a paratrooper to spot-land just where he wished. Collapsed to minimum space on the jump plane, it would automatically spread its leading edges when released. The paratrooper could steer in any direction and control his rate of descent to land where he wanted.

Larger paragliders steered by radio are being considered for lowering heavy rocket boosters and space craft back through the atmosphere. In fact the first dramatic use of the Flex Wing may be for returning a Mercury astronaut's capsule to a slow landing at an airport, avoiding the hazards of an ocean recovery.

Our test bed at Ryan is not a prototype for a production airplane. It is for research alone, hence all its cables and linkages are exposed. We can make adjustments without opening a lot of panels.

Supported above the fuselage at a single pivot point is a V-shaped frame that con-





Wing will return rocket boosters, carry TV, tote cargo . . .

FLEX WING PARAGLIDER could bring burned-out Saturn booster back to earth

RADIO-CONTROLLED DRONE could be used for observation duties, relaying television pictures back to its launching site

sists of a central fore-and-aft aluminum tube called the keel and two side members or leading edges that sweep back from the nose of the keel to form an angle of 50 degrees. Spreader bars hold the two 28-foot side members in place.

Attached to this frame is the "rag" wing, 555 square feet of nonporous fabric. The original wing consisted of nylon sealed with Mylar but this has been replaced with Dacron cloth sealed with a resin as the Dacron is more durable in sunlight. The wing is simple, lightweight and inexpensive.

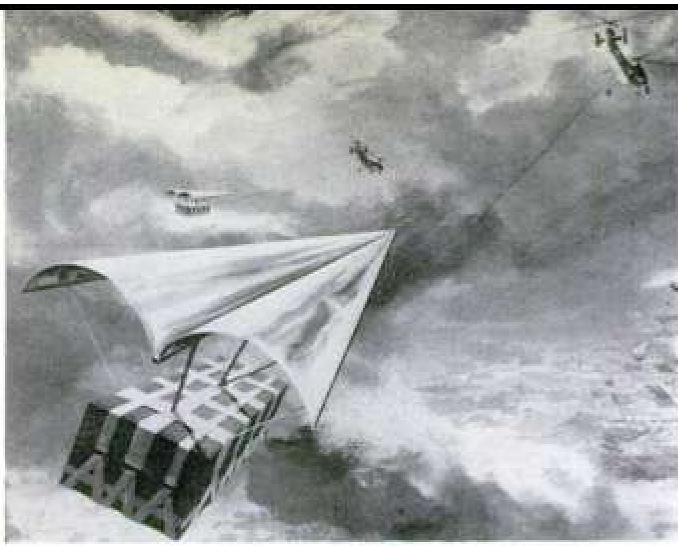
Control is by "C.G. shift"—that is, by shifting the plane's center of gravity in relation to the wing's center of pressure. The fuselage is literally hinged to the wing, so when the pilot pulls his control column back he actually moves the fuselage aft a slight distance in relation to the wing itself. With the center of gravity moved aft, the wing automatically tilts to a climb attitude.

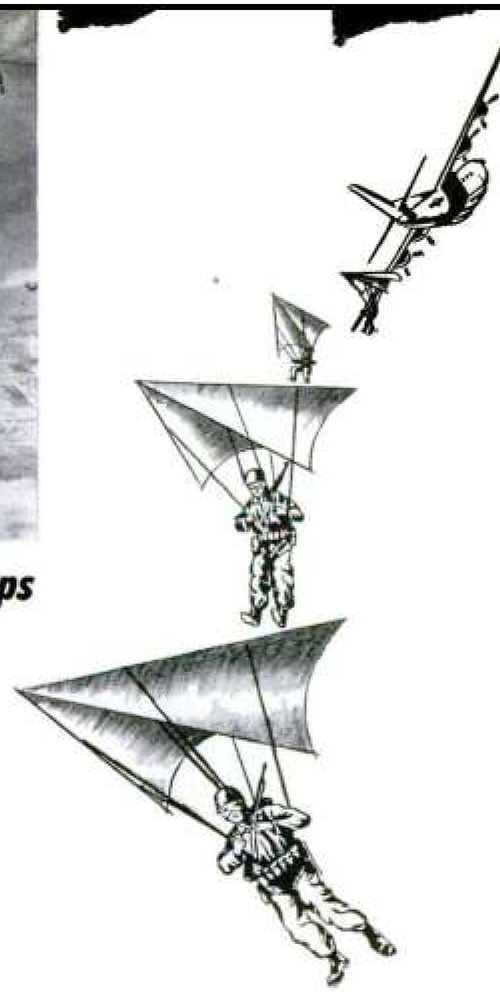
To descend, the pilot pushes the control column forward, moving the C.G. forward and causing the wing to reduce its angle of attack. To make a turn the pilot applies left or right wheel, shifting the C.G. so that the wing rolls in the desired direction.

A rudder was recently added to provide better control when taking off or landing in a side wind. The original engine has been replaced by a larger 185-horsepower engine to provide better climb characteristics. In a production aircraft a power-control system probably would be used, since it takes a heavy hand to maneuver the present machine. A simple power-control system can be designed. It would eliminate the rocking-chair effect created by air gusts.

DRONE for the Marines will resemble this prototype. It will be radio-controlled and can be used for such tasks as TV reconnaissance of the enemy

MOTIONLESS, the wing of the craft lies limp. The wing is composed of 555 square feet of Dacron cloth sealed with resin. It's a lightweight and relatively inexpensive wing





. . . and gently land paraglider troops

HELICOPTER may be able to increase payload as much as 400 percent by use of flexible-wing cargo carrier

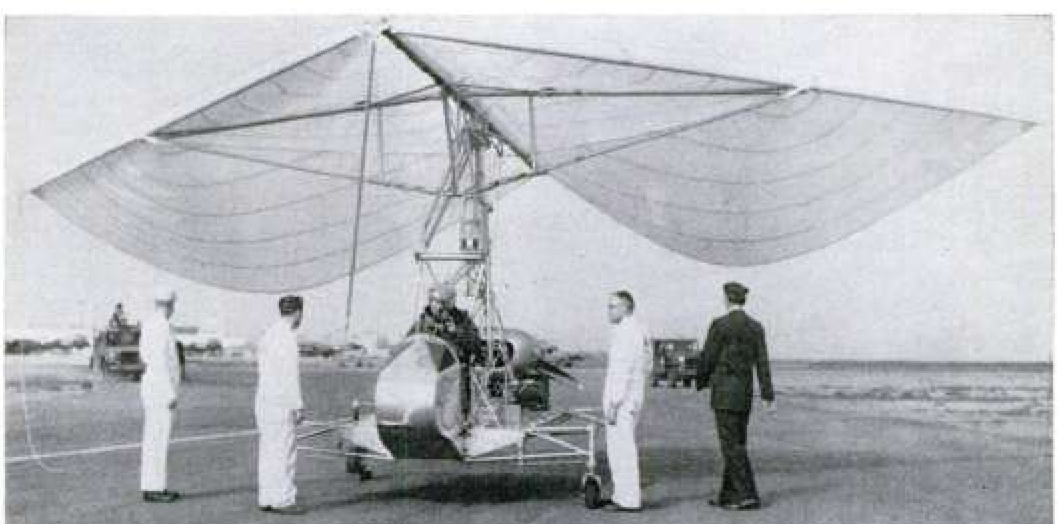
Ryan has no plans at present for building a production Flex-Wing aircraft. The wing is not a high performance airfoil, though it is an efficient weight carrier. It could make a good slow-speed utility vehicle.

Cecil Craigo, program manager, suggests that a Flex Wing would make a very good flying pickup truck for, say, a rancher. It could be about the same size as the present test bed, trimmer in appearance with the control system enclosed in fairing. The present low platform would be retained for easy cargo handling and the landing wheels would be left exposed. Their drag is unimportant at low speeds.

With the pilot and enough fuel on board for an hour and a half of cruising, the craft would weigh 1000 pounds and could carry 1000 pounds of cargo. It would take off in

(Continued to page 260)

TROOPS could come down swiftly, yet land gently. Maneuverability of wing would let them pick dispersed landing spots



I Flew the Flex-Wing

(Continued from page 89)

300 feet fully loaded at around 30 miles per hour and cruise at about 75 miles per hour.

This machine could be converted into a road vehicle in a few minutes by unfastening the safety locks and folding the wing's leading edges back alongside its keel. Motive power would continue to be furnished by the propeller.

With a vehicle like this a rancher could do all sorts of odd jobs. He could inspect his fences from the air, carry supplies to water holes, transport machinery and laborers to distant points and do his own crop dusting. He could move calves or sheep from one range to another. With the wing folded back he could travel on the surface into hilly areas far from suitable landing places.

"If he wants to go to town," Craigo says, "he could change his cloth wing for a smaller one in about half an hour. The small wing hasn't the carrying capacity of the larger one but it provides more speed. And the rancher could fold it back for street use in town."

What's the price? This hasn't been worked out but it's probable that a sturdy vehicle could sell for well under $10,000 including the small speed wing for long trips. This craft would be almost foolproof and could be flown with minimum instruction.

Don't Try a Build-It-Yourself

But don't try to design or build one yourself. Design factors are very precise and even a small change can make a tremendous difference in safety or handling. As an example, we recently scalloped the trailing edge of the wing to try to eliminate the slight flutter that occurs at the back of the cloth. It was a small change and yet it shifted the center of lift so far forward that the plane was too hazardous to fly until we repositioned the hinge point.

The principle of the Flex Wing originated with Francis M. Rogallo of the National Aeronautic and Space Administration who has since been in charge of Flex Wing research at NASA's wind tunnels at Langley Research Center. Models have been tested in free flight in wind tunnels and have been dropped, as gliders, from helicopters. Larger gliders with simulated pay loads have been released from rockets at altitudes of up to 200,000 feet. Powered models controlled by radio have been flown.

From this research several outstanding characteristics of the Flex Wing became apparent. It has twice the lifting capacity of a parachute per unit of surface. It is extremely stable and returns to its normal attitude after any kind of disturbance. These features make it ideal for "untenanted" applications and for use as a glider, either towed or free.

Ryan Aeronautical's interest in the flexible wing comes in part from a NASA contract to evaluate its use as a paraglider for returning Saturn boosters to safe landings. One glider that is being studied has rigid leading edges, another has leading edges that are inflated pneumatically into shape. Either would be folded and stored inside a fairing on the booster and would automatically deploy after burn-out to be steered by radio to a selected landing site. Landing speed would be about 70 miles per hour on extended skids or on a soft inflated runway. North American Aviation has a somewhat similar study contract.

Recovery of the booster would save some $5,000,000 if it could be used again. Recovery would be even more important if the booster malfunctioned in flight. The physical evidence of what went wrong could then be studied in detail. And recovery of boosters points the way to the safe recovery of future space craft such as the return to Earth of Apollo capsules and their crews from the moon.

Wing Built of Steel Mesh

We are peering only a little way into the future when we discuss that idea. A heavy space craft would start its plunge through the atmosphere at fairly high Mach numbers even after an initial braking by retrorockets. The Flex Wing paraglider would then slow the craft so effectively that aerodynamic heating would be minimized. The wing could be built of stainless-steel mesh bonded with thin titanium sheet.

Many other kinds of chores have been suggested for the new wing. Small Flex Wing drones could perform photo or TV reconnaissance missions with less than the usual amount of radio control because of their inherent stability. Steered back to base, they could be landed at slow speed. Larger drones could be used in antisubmarine warfare to carry depth charges or homing torpedoes that would be dropped in the vicinity of hostile subsurface craft.

Under radio guidance, cargo Flex Wings could deliver supplies in ship-to-shore operations and return to the ship for more loads. A different application may be to use helicopters to tow Flex Wing gliders to the area of a drop site and then release them, after which the gliders could be steered to safe landings in response to radio commands.

Other jobs are being suggested all the time. The fact is that we don't yet realize all the possibilities of the brand-new and yet millions-of-years-old flexible wing. ★ ★ ★