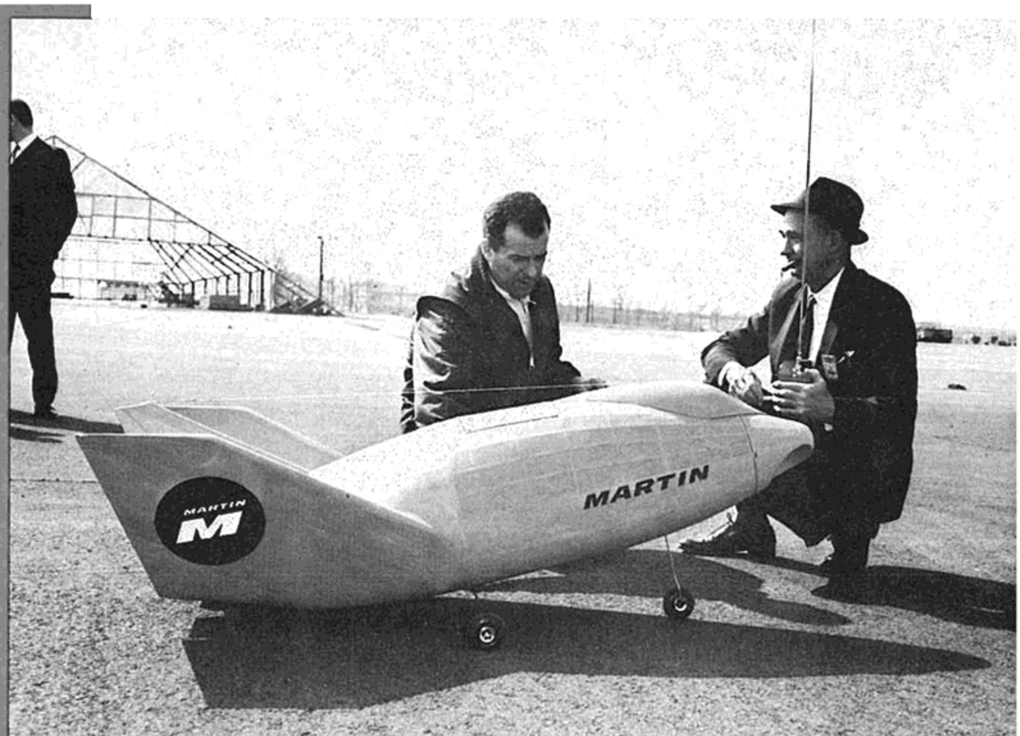
By WILLIAM CAMP



Bernie Lawrence and Bill Camp with ducted fan lifting body R/C model.

RCM EXCLUSIVE FEATURE:

FLIGHT WITHOUT WINGS

First Lifting Body R/C model to fly successfully from unassisted R-O-G.

ABOUT THE AUTHOR:

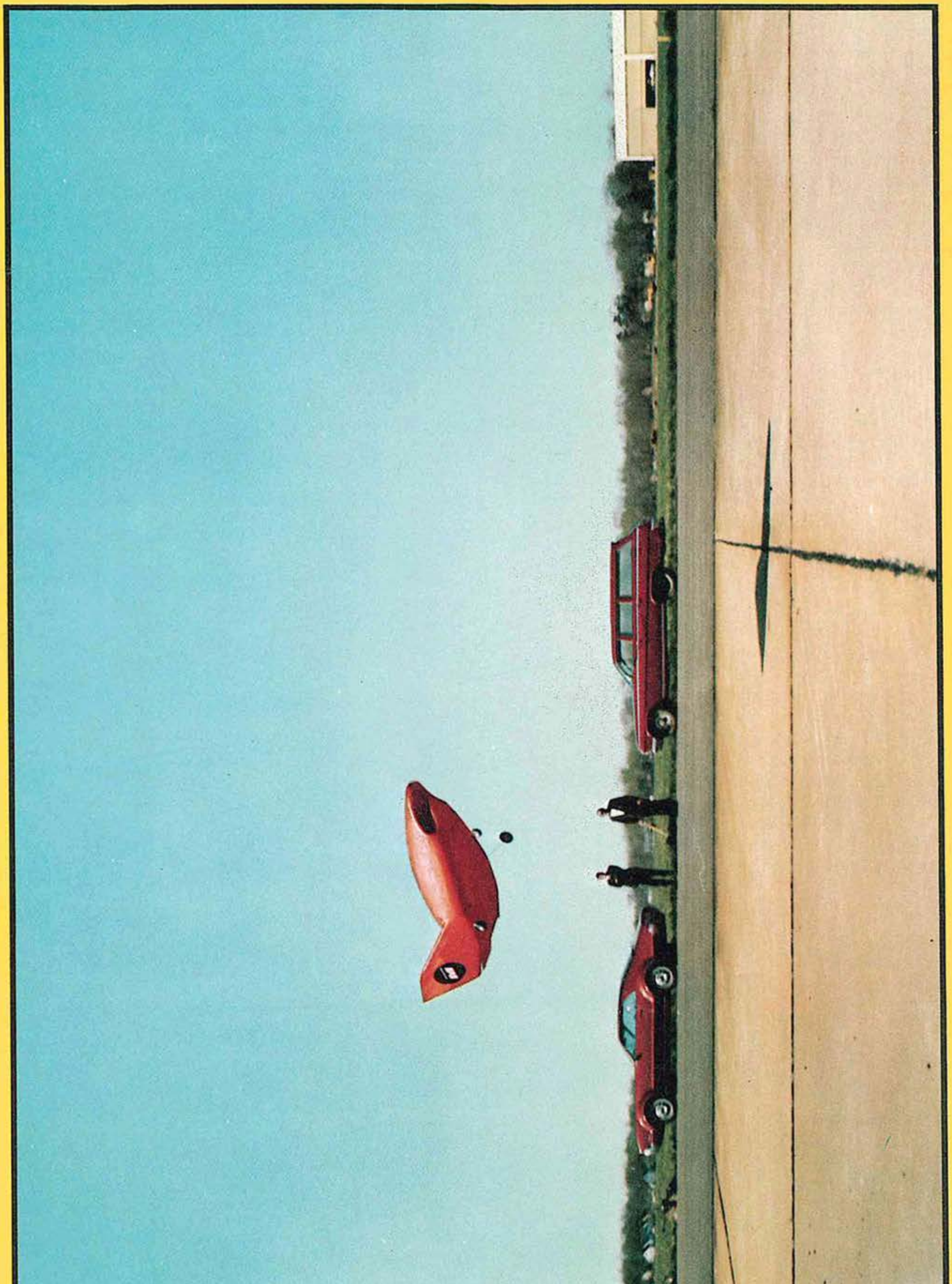
William Camp is a Senior Wind Tunnel Model Engineer, working for the Martin Company of Baltimore and currently on assignment in California on special projects, most of which are of a classified nature and cannot be described at this time. Mr. Camp was born in Montgomery, Alabama, on February 28, 1918 and later moved to Brunswick, Georgia, where he entered the Marine Corps. Out of a 4 year hitch, he served 3 years at St. Thomas in Puerto Rico. This was with Marine Squadron 3.

Over a period of many years, Mr. Camp worked on a great variety of Martin projects, with several years devoted to the development of Martin turrets as used in the B-26 Marauder and other aircraft during World War II. He was also involved in the giant "Mars" 4-engined seaplane program.

More recently, Mr. Camp has been involved with yaw controls used in high speed wind tunnels; also remote control stings (long rod-like arms that support a model under test). He has also been participating extensively in advanced methods for testing high temperature, high Mach number space-oriented vehicles and in Plasma Arc research. Mr. Camp has had extensive experience as a modeler and has attended special courses at John Hopkins. He earlier qualified as a Mechanical and Electrical Engineer through International Correspondence School studies.

The model pictured on these pages has an important and historic "first" to its credit. It is the FIRST Lifting Body radio controlled model to fly successfully after an unassisted take-off from the ground. We have qualified our claim to keep clear of the models that have been drop-tested from a "mother" ship. Much planning and work went into this project and the early attempts to get the model airborne during 1966 and early 1967 resulted in what must be termed "extensive taxiing tests". However, on the fifth attempt, during April of 1967, a most successful and sustained flight was made. The pilot of the model during all the early testing was Ron Wagner, a well-known R/C flyer from the Baltimore area. Both still and moving picture filming recorded the event and the spectator group included a considerable number of engineers and officials from the Martin Company. Flight tests were conducted at the Martin airport near Baltimore, Maryland.

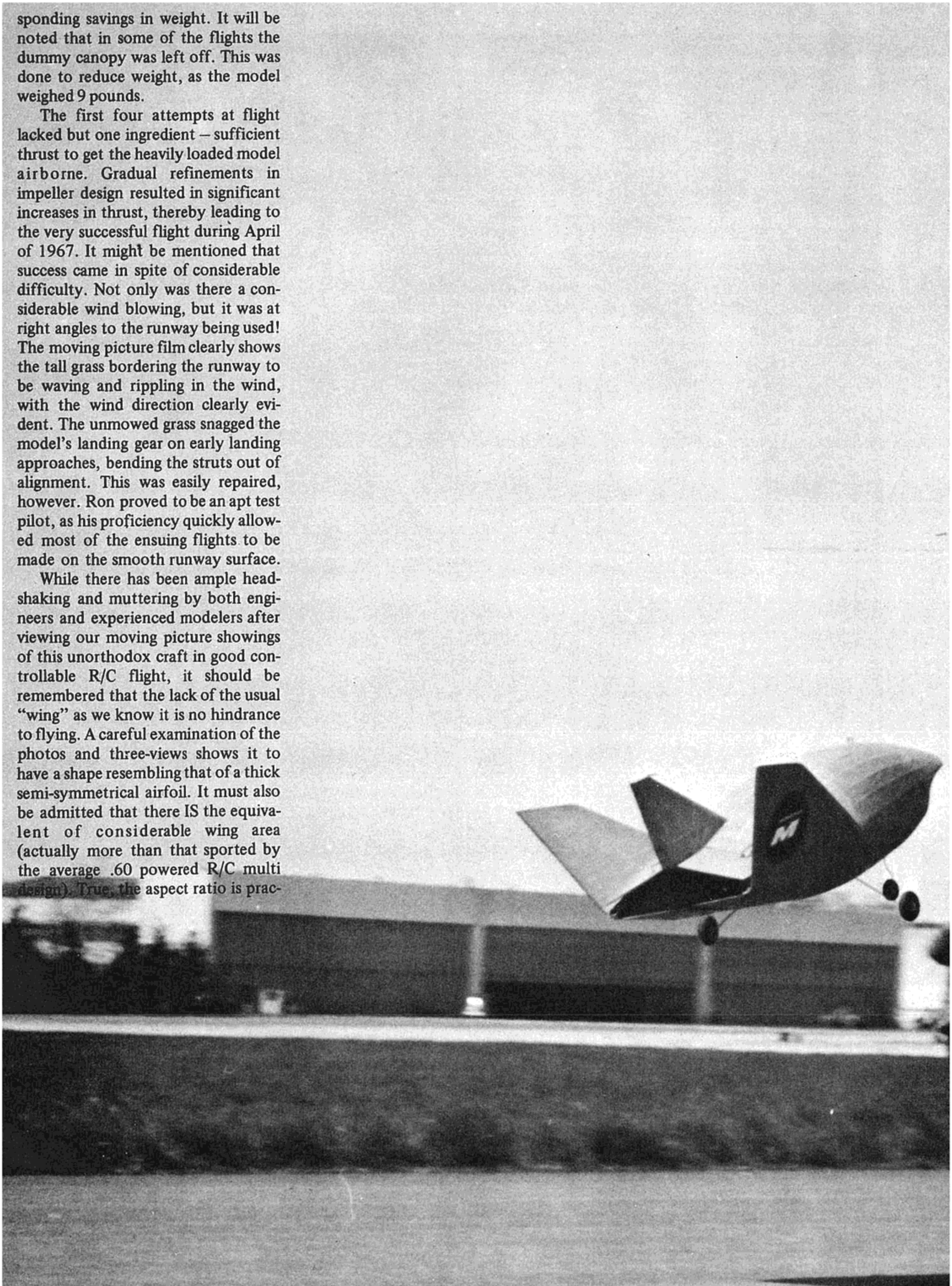
This model is very similar to the Martin XL-24 Lifting Body research vehicle (which partially explains the reason for the delay in getting this article published – it was necessary to wait until the Martin Company gave permission for this information to be published. A prior description of the full-sized vehicle was given in the July 1968 issue of Popular Mechanics. Minor simplifications were made to the original design to allow for easier construction of the model with corre-



sponding savings in weight. It will be noted that in some of the flights the dummy canopy was left off. This was done to reduce weight, as the model weighed 9 pounds.

The first four attempts at flight lacked but one ingredient – sufficient thrust to get the heavily loaded model airborne. Gradual refinements in impeller design resulted in significant increases in thrust, thereby leading to the very successful flight during April of 1967. It might be mentioned that success came in spite of considerable difficulty. Not only was there a considerable wind blowing, but it was at right angles to the runway being used! The moving picture film clearly shows the tall grass bordering the runway to be waving and rippling in the wind, with the wind direction clearly evident. The unmowed grass snagged the model's landing gear on early landing approaches, bending the struts out of alignment. This was easily repaired, however. Ron proved to be an apt test pilot, as his proficiency quickly allowed most of the ensuing flights to be made on the smooth runway surface.

While there has been ample headshaking and muttering by both engineers and experienced modelers after viewing our moving picture showings of this unorthodox craft in good controllable R/C flight, it should be remembered that the lack of the usual "wing" as we know it is no hindrance to flying. A careful examination of the photos and three-views shows it to have a shape resembling that of a thick semi-symmetrical airfoil. It must also be admitted that there IS the equivalent of considerable wing area (actually more than that sported by the average .60 powered R/C multi design). True, the aspect ratio is prac-



tically nonexistent. This, plus the all-up weight of 9 pounds and exceptionally large frontal area combine to make many engineers and experienced modelers apprehensive and disconcerted when trying to figure its flying abilities. Orthodox ideas and theory sometimes have to be chucked out the window when one is involved with an honest-to-goodness, really UNORTHODOX configuration such as this.

The model is capable of an inordinately wide range of flying speeds – far and away exceeding the capabilities of the average "normal" model. Top speed has approximated 40-45 m.p.h. in most of the flights thus far, which is about average. By horsing WAY back on the stick while simultaneously reducing power a little, our model can and does hover at near-zero forward speeds (try THAT on your .60 powered Funk and Wagnalls)!

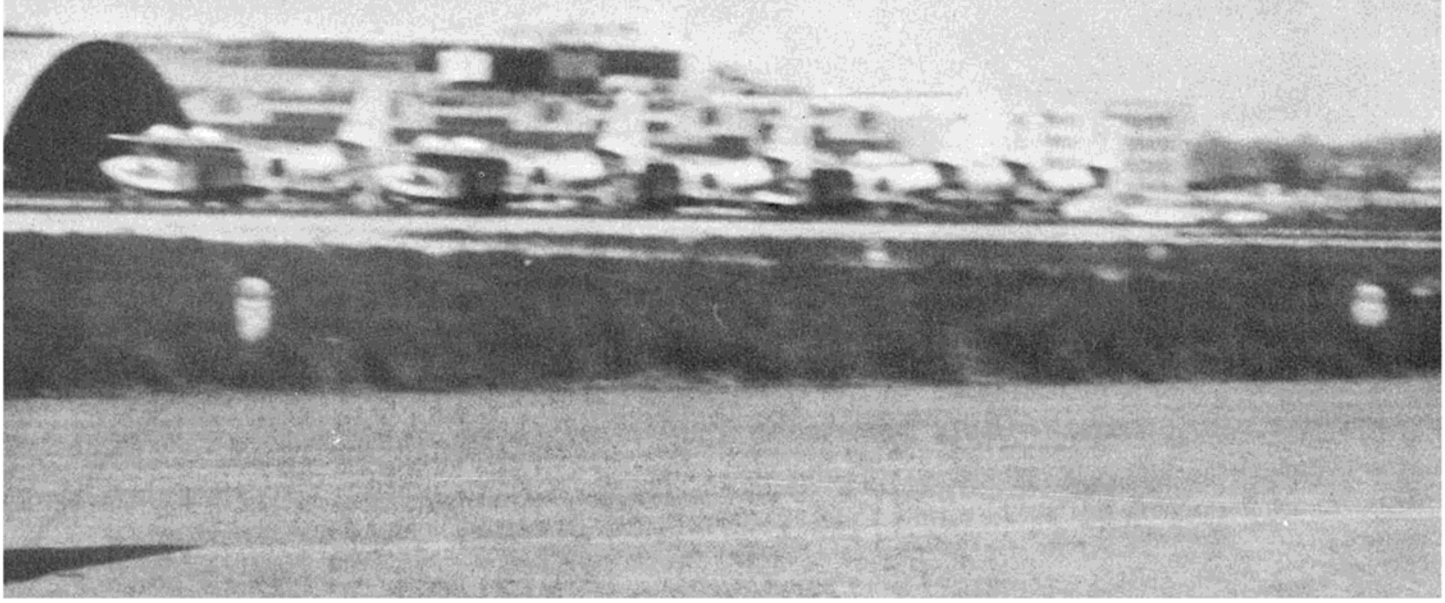
Construction of the model is orthodox, with a basic structure of 1/8" sheet balsa frames and 1/8" sq. balsa stringers. Part of the overall structure has 1/32" sheet balsa covering, but the entire model has orange silk covering. Two coats of orange pigmented dope were applied to obtain maximum visibility. The model is 5 feet long and the span is 24 inches at the base of the tip rudders. Overall span across the rudder tops is 38 inches. A Merco .60 provided the power in our original model, spinning a 7-bladed impeller (more about that shortly).

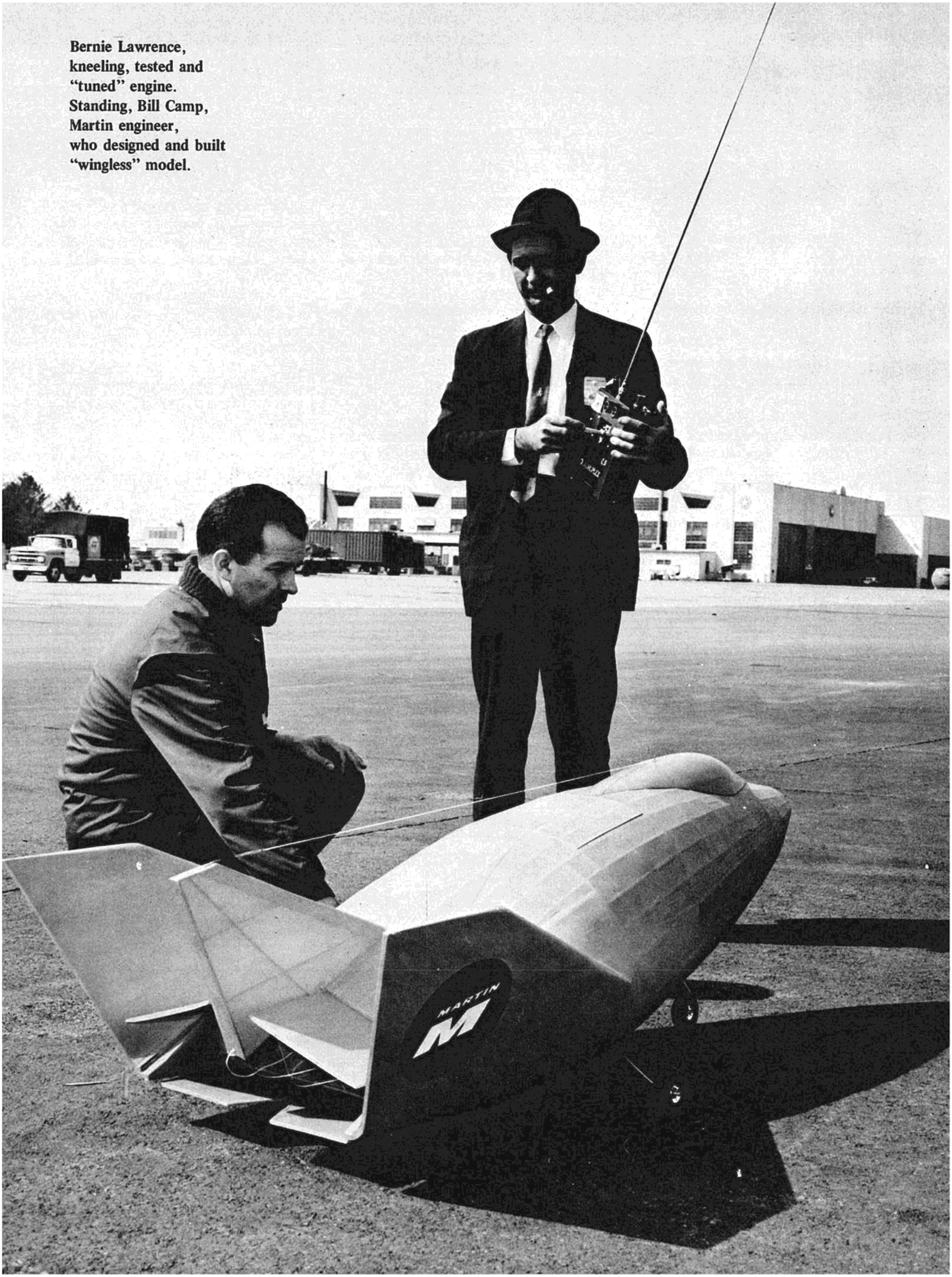
At the time of the tests, the popular proportional R/C gear on the East coast seemed to be the Dee Bee Quadruplex outfit, so this equipment was used without any modifications. Presently available proportional gear would cut the 27 ounce weight of the older Dee Bee receiver/servos/battery to half that figure. As a matter of fact, the newest "mini" propo gear weighs 8 to 10 ounces, allowing over a pound to be cut from total weight. Thus, a newer model could have even better performance. The original model incorporated both nose wheel steering and throttle control. Landing gear struts were 5/32" diameter steel wire, with a 3" nose wheel and 3½" main wheels.

Control of the model in flight was through the use of "elevons". These aileron-like control surfaces were situated to the right and left of the center rudder. Due to the thickness of the boat-tail type trailing edge (6" at the center and over 2" deep at the extremities), duplicate elevons at the bottom matched those on the top surfaces. All four elevons could be moved in unison in the same direction, affording pitch control: up elevons for climbing, down elevons for diving. In addition, they were rigged for differential movement (right pair moved up when left pair moved down) to obtain roll control. This function was exactly the same as normal aileron usage.

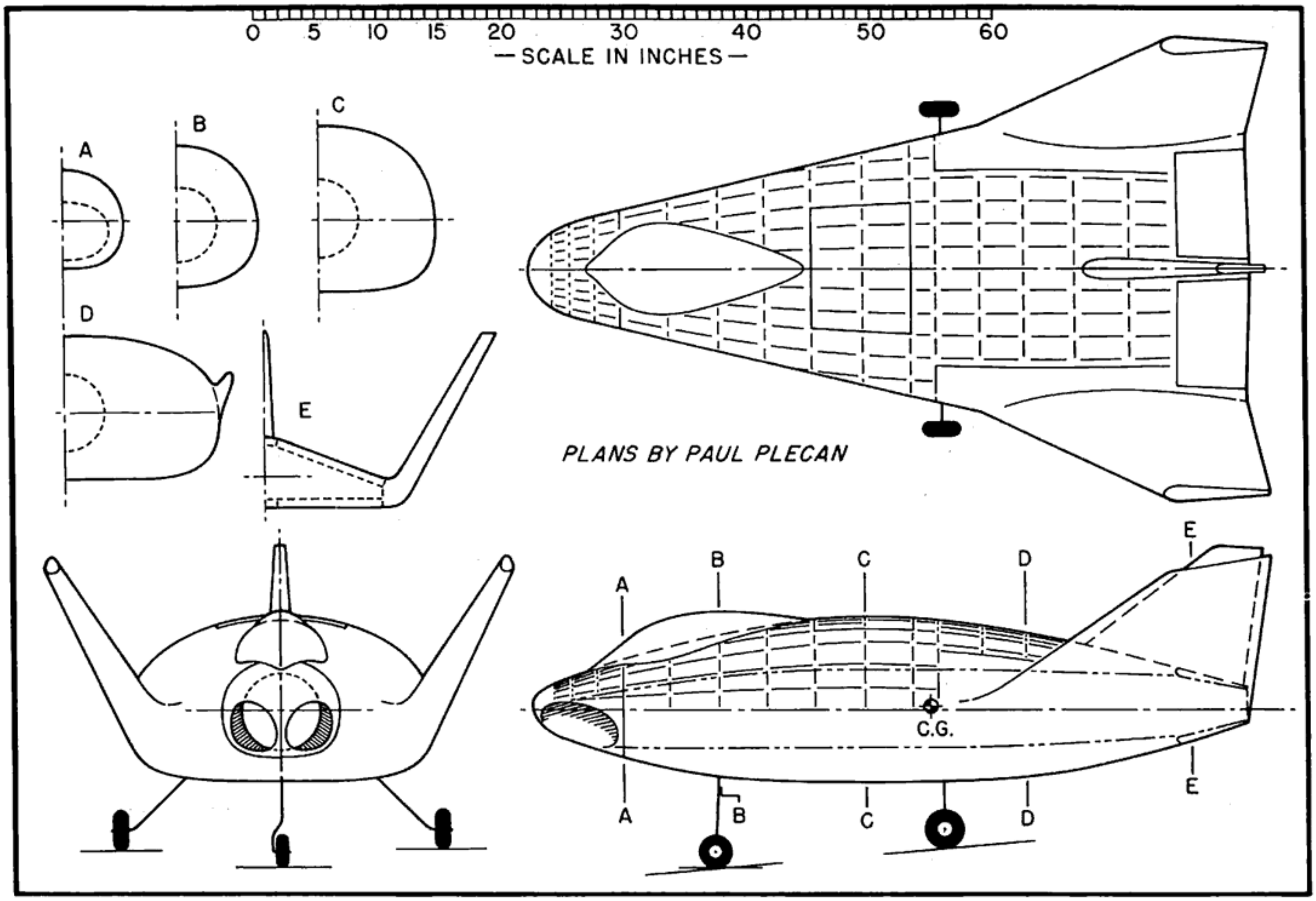
While a good .60 engine provides more than ample power, our problem was translating the power into thrust. Due to the configuration of the model, a ducted fan was mandatory. The first impeller was easily made by joining two stock props, but thrust proved to be inadequate. Numerous impellers were tried – from four to eight blades of varying blade outlines. A 7-bladed impeller with constant-chord blades proved best, providing a considerable gain in thrust over any of the previous configurations. Hub diameter is 1 5/8" and overall impeller diameter is 6½". The inlet area is what governs the size of the impeller – it is best to have the duct a very simple straight-through constant-area type. While it doesn't hold true in other areas, the duct should be as perfectly round as you can make it in the area of the impeller, as it is very important to have a constant impeller-to-duct gap of 1/32". Enlargement of the gap reduces the air-moving efficiency of the impeller. Reduction of the 1/32" gap produces scorched impeller blade tips and a black scar around part of the duct wall.

The impeller blades were cut from high grade 1/16" plywood. After trimming to rough outline shape, one blade at a time is soaked in hot water for 15 minutes and then clamped between two 1/4" sheet aluminum forms and left to dry out in front of an electric heater (glowing coil type) or over the pilot light of a gas stove, preferably overnight. About noon or later, the next day, the impeller is completely dry and retains its pitch and camber indefinitely. The aluminum forms for forming the blades are merely 1½" by 4" blanks of 1/4" thick aluminum stock. The paired blanks are clamped in a vise with 3½" of the 4" length projecting from the vise jaws. A large adjustable wrench is used to grasp the tips of the blanks, twisting until an 18° difference is achieved between root and tip. Our engine was mounted tractor style (prop upstream of engine). While no great effort was made to confine the engine in a nacelle or otherwise streamline it, anything extraneous was kept out of the airstream. The engine bearers blended into a horizontal platform arrangement that acted as an airflow straightener with a vertical sheet support under its center to give





Bernie Lawrence, kneeling, tested and "tuned" engine. Standing, Bill Camp, Martin engineer, who designed and built "wingless" model.



an overall "T" configuration.

The 1 5/8" diameter hub was cut from aircraft quality plywood (7 ply), carefully scribed at 51.4° intervals on its face near the perimeter (dividing the diameter into 7 equal parts). The rim was then marked for the 7 blade positions at 45° to hub face. A hacksaw blade was used to cut the slots for the impeller blades, but check the width of the cut, since some hacksaw blades may be thicker than others. Slot depth is critical since a shallow cut causes the corresponding blade to project beyond the others, throwing the impeller out of balance. Of course, the 18° blade twist if figured so that there is less pitch at the tips than at the root, the pitch being "true" and the blades about 3/32" camber at the mid-point of the blade length. The camber seems to result almost automatically when bending the impeller blanks – the 3/32" dimension is not critical, but it is important that the blades be as similar to each other in outline and camber as you can make them. Any dissimilarity reveals itself in unwanted vibration, and it is tricky trying to balance a seven-blader!

Framework construction of the lifting body began with the lower half being assembled on a flat workbench area. The formers had been made in upper and lower halves, the parting line being the horizontal center line. Thus the bottom half of the fuselage was made first, including the stringers and sheeted areas. Once the cement has set quite thoroughly, the framework can be removed and handled, as the sheet covering imparts torsional rigidity to the structure.

The duct is formed over a 6 9/16" diameter cylindrical form in two pieces. The fore and aft sections are made as complete tubes, with an overlapped bevel seam. The 1/32" plywood is generally an aircraft grade 3 ply type, and should be formed with the outer grain running fore and aft. There are two hatches on the top of the body; one is up forward for access to the radio gear, the other is over the

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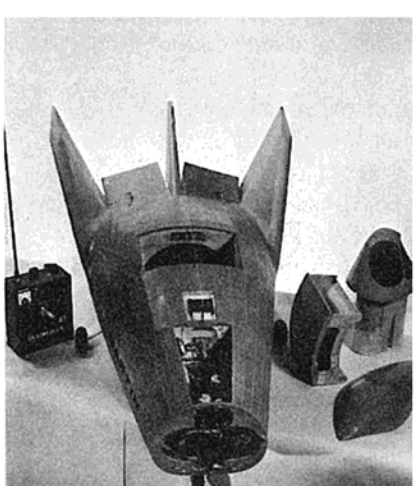
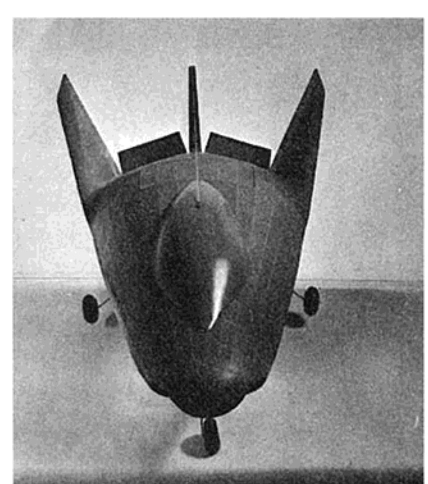
Note that servos are mounted above and below duct.



Front view of model (elevons in full "up" position).



FLIGHT WITHOUT WINGS

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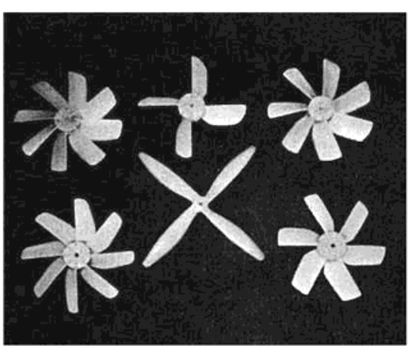
area just forward of the impeller to allow access to that area. The duct around the impeller and just aft of it is butt-joined to obtain a perfectly round shape. Once the ducting and body framework is joined, a very rigid structure of great strength is obtained, as the plywood duct becomes extremely strong when made integral with the rest of the structure. Make the hatches as snug-fitting as you can.

In the original model, balance moments were calculated and checks were made during construction, but despite this, the Center of Gravity proved to be a bit too far back. The receiver and servos had to be positioned further forward to achieve the 57% C.G. location as specified in the three view. The percentage figure given is predicated on body length. For those interested in making a similar model, it would be best to shift the engine location 3 or 4 inches forward, so that the servos could be mounted further aft with a corresponding shortening of all operating linkages (less weight and better pushrod rigidity).

The engine needle valve had an extension added to it to allow for fuel flow adjustment from the outside of the model. The engine access hatch is best mounted forward of the impeller, in a negative pressure area. The negative pressure helps keep the hatch in place. Downstream of the impeller



Types of impellers that were tested best one is the 7-blader.

is a bad location for any hatch, as the pressure tends to pop the hatch out, calling for strong latches. Starting can be made quite easy through the use of a friction starter powered by storage batteries. A Penford or Rand starter can easily be adapted for this use. An extension shaft is the easiest route, allowing the starter to be used through the nose air inlet, with a spinner being fitted to the impeller to give contact surface for the starter clutch or connector to rub against.

A ducted fan arrangement has to have all hatches sealed well enough for air leaks to be at an absolute minimum, so that all the thrust created by the impeller goes out the tailpipe. It is especially important that all ducting DOWNSTREAM of the impeller be free of openings (or leaks). An air leakage at any point between the impeller and tail outlet will very seriously affect thrust. To put it succinctly and very simply, it is the amount of air you pump out the tail pipe that makes a ducted fan model fly. EVERYTHING that helps efficiency in this area helps enormously. If you have any new approach for a new and different ducted fan arrangement, please remember that sharp bends in the duct are to be avoided ENTIRELY and the more area in the duct that is sheeted and SMOOTH (for easiest movement of air throughout the duct length), the better chance your new design has of being a roaring success.

Of numerous variations we have tried, it seems that a straight-through duct of constant cross section is by far the best. From the inlet, through the impeller section and on to the tail pipe area, the cross section area should remain approximately constant. The tail pipe should NEVER funnel out to a larger cross sectional area, as this reduces the velocity of the air mass. The air velocity must exceed the expected cruising air speed by a definite margin just to maintain level flight. Choking or necking down the efflux area to 80% can be done to raise the air velocity effectively, but the reduction in area should not exceed the 80% figure. We have tried not to theorize or give opinions – these are the results of actual tests, not ivory tower theories.

Because of the inherent stability and superior hovering capabilities of this configuration, it is the writer's opinion that this design has great potential as a jet transport of the future. While it would be presumptuous to predict a top speed figure, we know that this is one type of aircraft that could slow down to a near-zero speed to approach a fog-enshrouded airport in complete safety. It could change STOL concepts quite dramatically. How about USTOL? (Ultra-short take-off and landing?)

The author would like to thank Bernie Lawrence for the help he gave the test program in running and "tuning" the Merco .60 we used in the tests at Baltimore. Also Ron Wagner, John Rickey and Joe Putegnat. And numerous other friends in the Martin organization who helped in arranging for the color moving pictures that were taken of the flight tests. I might add that it takes a lot of faith to carry a project of this type to successful completion; so to those who helped prop up my sagging morale at times, my sincere thanks. ●