RADIO CONTROL

a way to a better design

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(Photo Courtesy Joe Alvarez)

The Polliwagen model. It has a span of 74 inches and area of 775 sq. in. A .60 engine was used to turn a 12 x 5 prop. The scale weight is 13 pounds. A full size plan sheet for the RC model of the Polliwagen is available for $5.00 from Harold Osborn, 1832 Conejo Lane, Fullerton, CA 92633.

ABOUT TWO YEARS ago I was peacefully debating what my next project was going to be — a racer, or a sport bipe, or that long postponed flying boat — when my friend, Joe Alvarez, came back from Oshkosh. The projects in my mind were ambitious, but in a lesser scale than you may be thinking . . . radio controlled model airplanes — that's my thing.

As I said, Joe had just returned from Oshkosh . . . I should say floated back, because although he was driving a car, he hasn't stopped flying since! It was sickening. You couldn't talk to him about anything else.

It was obvious that he was going to build his own airplane. Not much wrong with that, but the scary thing was that the way he rambled on about it, it looked like he was going to be the designer, too. I talked for hours, trying to show him how far out his thinking was. The trouble was that he talked back, and the next thing I knew we were putting ideas on paper and coming out with a general layout that not only fit the design goal, but it looked terribly attractive! Oh, well . . . I was looking for a project anyway.

If you are an aeronautical engineer with experience in the trade and are working in the design of a rather conventional aircraft, there is very little about your baby's performance that you couldn't calculate. Now, Joe and I are pretty smart — except for some dark areas that led us to a crazy business like this — but we don't have all the knowledge required for the task. Some good friends of ours do, however, and with their help we found out that our "calcubrations" and "guesstimates" were well within the ball park. And that was as close to the true thing that we could get without a wind tunnel and lots of brain power and money.

At this stage most designers have to make up their minds about freezing all the variables of the design at a certain point, and commit themselves — with a lot of money, time, sweat, tears and the patience of relatives — to building the real thing. Let me explain now why this is one of the most important moments of the whole venture.

Any design is the marriage of a large number of interrelated items. The same basic layout can be pushed around a rather wide range of performance by changing some of the values toward a certain goal. So far I haven't said anything that you didn't know. What you may not have thought about is what would you do in that situation? You may be bold and courageous, trust your genius a lot, and shoot for the far out limit of your design, knowing that at that far out limit some things may get critical and you may have to go back to the drawing board after the first tests. Or you may be as crazy as we are, but at the same time have sense enough to recognize that in this kind of game more than likely it is going to be a one shot deal; there are only a few guys that finish a homebuilt from the many that start them, and that is only to mention the ones involving the established and well thought out machines. Designing your own is **many** times more work. Therefore, you know in your bones that if you goof too badly, you may not have the gumption to get the hacksaw and start modifying, consequently having in your hands a very expensive winged dog. After that thought, logic leads you to a more conservative mood, from which your spirit can accept the compromising you are about to do in the name of Common Sense. And here is my point: because experimenting may be so expensive, your good ideas get pushed back in the areas of well treaded fields. You could have had a better airplane, but the risk was too high and you came out with just another airplane.

Well, experimenting is not **that** expensive; you can have access to it. I'm talking about a radio controlled scale model. It has been done for years, is economical and it works. Twenty years ago RC was only for "real" research. To control elevator, rudder, ailerons and throttle in a "proportional" way (the control surface deflecting at an angle in proportion to the deflection of the stick at the transmitter), the airborne radio equipment was as big and heavy as your color TV and used just about as much power. Nowadays you can have a jewel of a radio capable of controlling up to six functions for under four hundred dollars, with an airborne weight of under one pound, and so compact that you can fit it inside your right shoe and have more than half the room to spare. And the resolution! To say that the servos follow your commands with plus or minus one degree sounds technically good, but when you see a good RC pilot doing four point rolls at ten feet above the deck at 100 mph, you **know** that the degree of control is excellent, and the reliability must be, too, when he is trusting it that much.

So the equipment is here; now what? Let's talk some more. I think that the best way to get this matter across to you is to tell you how it was with us and the Polliwagen.

I've been in RC for many years and doing some fairly successful designing of my own. I'm not championship material as a pilot (ask my buddies), but I can tell what is happening when the model is up there, whether it is something pertaining to the design itself, the air currents, the radio link, or twitchy thumbs at the pilot's end. In this hobby-sport it is well known that a good flying full size aircraft makes a good flying scale model. A Piper J-3 will fly "J-3ish" even scaled down to pea-size; a Mustang P-51 is a beautifully flying machine as a scale model. Some real airplanes with nasty habits will show their teeth as tiny replicas. So, naturally, I tend to think that if I can get a scale model flying as I feel it should, the scaled up version should fly accordingly. I know that this is the worst kind of "seat of the pants" engineering there is; it can be even dangerous. What to do, then? We asked our properly educated engineer friends, dug into the literature that we could digest, and tried to do some calculations of our own. It was apparent that on certain things there were as many opinions as authors, and since any one of these respectable cats is head and shoulders above my limited knowledge, I can't say who is less wrong. The fundamental items are well established, though, and the others can't be too far off. By this time we knew that the smaller the craft, the less efficient as a whole; it follows that if the small one flew well, the big brother should fly better. The question is how much better. Well . . . it seems that you can't really know **exactly**. You may get pretty close if you can measure the performance of your model with great accuracy, and if the scale ratio is not too large, plus some other **ifs** and **buts**.

"Why bother, then?", said Joe.

"Because," said I.

First of all, I had made up my mind about building the Polliwagen as my next project. Secondly, I felt that having the design in three dimension was going to help a lot.

We decided on a 1:4 scale. The Polliwagen is small enough to make a model that could be powered by a standard model airplane engine. We eventually drew up a set of plans for the model in which the outside shape is exactly to scale, but the structure follows more the dictates of model aircraft experience. A model can be proportionally a lot stronger than the full size craft; the weight penalty is not severe, and it can sustain severe pounding. Also, we made provisions for an easy way to make modifications in some areas where we were still in doubt about the final configuration.

Right off the bat, at the beginning of the construction, we found that some ideas we had about building the real one wouldn't work. Some seemingly simple curves became nasty kinks when we tried to form the fuselage. Had that been the only thing we were going to learn with the model, it alone would have been almost worth the effort. The number of additional details solved just by building the model made the balance so obviously positive that right here and now I can recommend the use of a scale model as a design aid, **even if you are not going to fly it**. Just to mention two items: the correct blending of curves from the canopy to the tail took two attempts; the engine cowl was a tour de force with two parallel ideas worked out in modeling clay until the right one was produced, cast in plaster and molded in fiber-glass. Can you imagine the work and waste of doing that in full size?

Our model doesn't have detachable wings as the big one will; instead, the whole wing is a single piece with the bottom of the fuselage, and it is attached to it with nylon screws. The wing was built following the well proven model technique of cutting foam cores with a hot wire guided by templates and then covering with sheet balsa. Extra care was taken in insuring that the Wortman airfoil was as accurately reproduced as it could be. The fuselage was made mainly of Polystyrene foam over a back up structure of plywood and balsa, covered with very light glass cloth and epoxy resin. The canopy is also foam and fiber-glass, and originally it was detachable, held in place by strong rubber bands hooked up internally. I'll tell you something about it in a minute.

There is one control each for elevator, rudder, ailerons, throttle, retractable landing gear and flaps; this latter is interconnected with the aileron's linkage in such a way that it moves the ailerons as flaperons for the first ten degrees or so, leaving them there as the flaps move to higher angles, up to 80^0.

A model of this size and type of structure may weigh somewhere between eight and ten pounds, and can be easily pulled around the sky by a .60 cu. in. engine, which can put out over one horsepower. There are some high performance bombs that can double that figure.

Now we begin to face the naughty problems of scaling: should the scale weight be the cube root of the projected maximum gross?

$$3 \sqrt{1000 \text{ lb.}} = 10 \text{ lb.}$$

Or should it be the maximum gross times the cube of the scale factor?

$$1000 \ .(1/4)^3 = \frac{1000}{64} = 15.6 \text{ lb.}$$

The last way is the one accepted and used by the guys who are tops at the art of RC scale. Some of them have done a lot of homework and have correlated their figures with the actual results with different models. As with a real airplane, at full gross the Polliwagen model must be treated respectfully, especially during landing. It was not that we couldn't slow it down or that the sinking speed was too high; it is just plain simple inertia. When on the last leg, you better have the aircraft properly aligned and in the right slope, because it takes a little longer for the model to react to a command, and then the response could be an over-command if you were not thinking "heavy". Sounds like real life, doesn't it?

How much power is 1:4 scale of about 65 hp? This is one of the matters still not quite agreed upon. Some modellers maintain that the thrust is what should be scaled. The point is well made, and I agree with it. The trouble is to find the means to measure the thrust in a model and then translate that into horsepower.

(Photo by Lee Fray)
Polliwagen principals. Left to right: Henry Arance, Joe Alvarez and his wife, Lucy. We don't know how Joe folded and pleated himself down under and behind the Polliwagen model for this picture, because he unlimbers to around 6' 5" when he stands up. The model is the one described in the accompanying article.

Using the simple approach

$$65 \text{ hp } .(1/4)^3 = 1.0 \text{ hp}$$

It looks like a very good approximation.

So much for setting up. How about flying?

Like with a full size one, we started with taxi runs. Although the center of gravity was rather far back, making it more stable on the ground, the original version of the Polliwagen was just as nasty as any taildragger when taxiing in a crosswind. This, plus some other considerations, made up our minds about paying the price of weight and complication for the benefit of a nosewheel.

The first day we got a minor crash at take off — mainly pilot error — and a rough landing. There was only one rather short flight but it produced a lot of information, which properly digested started modifications that were tested again, and compared. One step at a time, to keep the issues clear.

The test flying uncovered some fishtailing, a vague uncertainty in the turns, and hard-to-control low speed approaches. Careful study of the pictures and movies taken during the testing made us suspect that the canopy was lifting itself from the fuselage. It was hard to believe because the rubber bands held the darn thing quite securely. We estimated that about two pounds pull was required to move the piece out of its socket. At the next flying session I made some high speed low passes and, sure enough, there was the canopy a good half inch above the windshield, making who knows how much turbulence all the way back to the tail. That was the main reason for the fishtailing. Some masking tape and another flight proved the point. This incident brought up something we hadn't thought about: the full size canopy will be pulling a lot more pounds from the latch than what the latch was designed for.

The other traits were cured by increasing the dihedral and enlarging the fin area. We have flown the model with the CG as far back as 45% of the chord. It was not fun, let me tell you! In that condition sudden up elevator will produce a neat snap roll. The whole show is touchy, but even at 45% it will come out of a spin if the pull out is done very gently. With the CG at 33% and a gross weight of 13 lbs. the model will not break into a stall when the speed is reduced at level flight; it mushes down without dropping the nose, all the while maintaining aileron control. If power is applied gradually it is possible to maintain altitude, and eventually increase speed to come back to normal flying. At that weight, and with the chubby scale fuselage, we expected that the glide of the model would be just a notch better than a brick. That was another surprise. Actually that was the best of the good news. The glide was exceptionally good, telling us that the apparently fat fuselage was a clean match to the glider type wing.

During all this testing, the model was painted blah white. No trim, no frills. The only color was some light blue on the Plexiglas areas. We knew that there were going to be modifications and scratches, and yes, perhaps a crash. When the testing was over, there were some scars and some not too neat modifications. By this time we had made up our minds regarding the color and trim scheme. (See Joe's article in the May 1976 issue of *SPORT AVIATION*.) It was pretty-up time. This was another way in which the model was useful. You will have to admit that it is easier to try the location of the trim on a model. If nothing else, you don't have to step back so far to get the general view. Besides, you will be surprised to see how some trim lines that looked so "natural" in the 3-view drawings, suddenly don't flow when looked at from almost any angle but the right angle.

Let's explore now how you may get your design in model form. The ideal would be that you are a qualified RC pilot yourself, but if that were the case you would have done all this a long time ago without my preaching. The next best thing is to have a good friend who is a qualified RC modeler. If this is still not your case, then you will have to find one. I strongly advise you to refrain from buying some RC equipment, building your model and trying to fly it. I have taught several good full size airplane pilots to fly RC . . . and they have to start from the beginning like anybody else. The real airplane is flown from inside it, with the references moving around you. In the case of the model, it is the only thing that moves in a static set of references; to fly it you need a brand new set of visual-motor loop reflexes that have to be built up gradually. Unless you are a genius, it will take you more than a couple of years of intense practice to become proficient to the point needed for experimental scale RC. I believe that most homebuilders have more than enough on their hands building and/or designing their project — and certainly don't need to start another that is just as absorbing and demanding. Convinced? Hope so.

Let's start searching. Your best bet is to find the flying site of the local RC club. Maybe you are lucky and there is more than one club within easy reach. The friendly local hobby shop can tell you that, and if the owner happens to be an active modeler himself, you have made a connection. Many modelers will be interested, but only a few can really help you. The guy should have certain qualifications in good harmony, i.e., good pilot, some experience in design, be a decent builder, and get sufficiently motivated to hang on to a project that may drag for some time. Who knows, with a little bit of luck you may make a homebuilder out of him!

Let's assume now that you have a design to explore, with some preliminary drawings covering the basics. The first decision is what scale to use. The criteria for this is that you should have the largest model that can be handled with ease. The accuracy of the correlation model-prototype decreases with the increase of the scale ratio. On the other hand, you must keep in mind the availability of power plants suitable for your project, the cost and the feasibility of transporting it to a flying field. Also, fragility increases with size. I would say that for an airplane of conventional configuration the limits should be between five and ten feet wing span, with the estimated maximum scale weight under twenty pounds. Don't worry if the scale factor is a weird number, as long as it fits your needs; the burden of calculations is gone with the arrival of the pocket calculator.

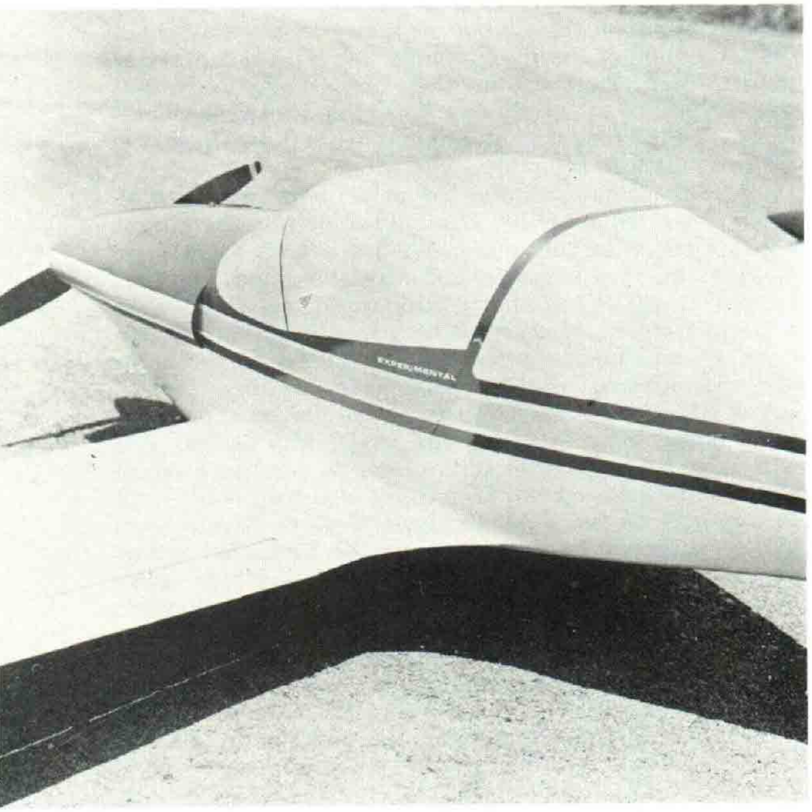
The model should be built like a model, with the emphasis on the flying rather than the looks or mechanical details. Some time ago I got involved in testing the model of a glider prototype, built by the designer. His knowledge about gliders was tops, and the workmanship displayed in the model was excellent, but the wing was warped to the point of being useless, the fuselage was three times heavier than it should have been and was twice as fragile. The hinges of the control surfaces were coming loose before we ever attempted to fly it. Experience in the trade is important.

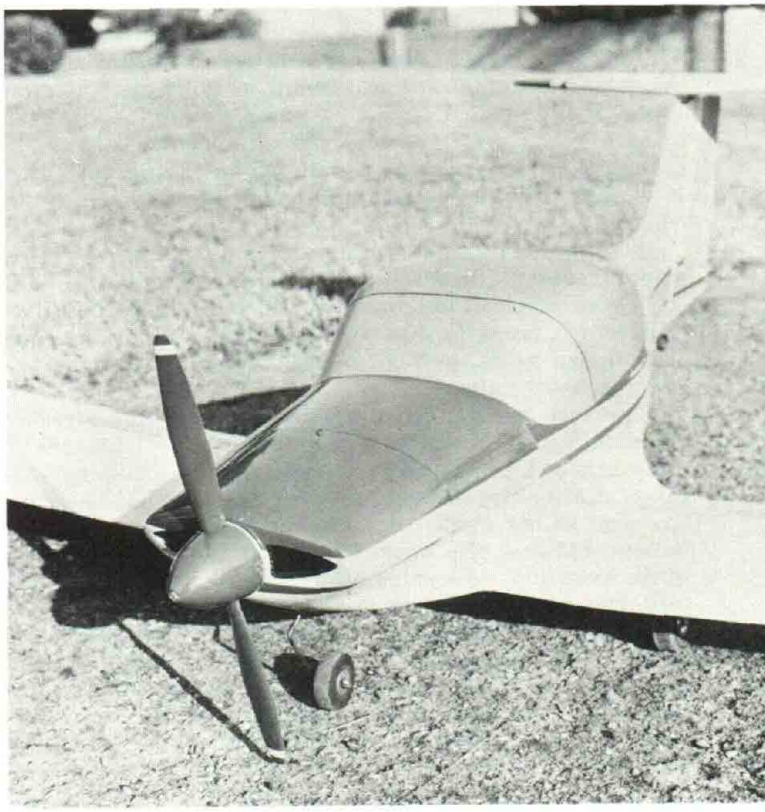
Keep the weight down and make provisions for ballast. Using again conventional type aircraft as an example, the model should come up weighing considerably less than the calculated maximum gross of the prototype. The first flights are going to be a lot easier that way. After the major problems have been ironed out, weight can be added in steps.

The radio control equipment is the single most expensive item. Maybe you can reach an agreement with your modeler partner about using his. Don't start dreaming about eight or ten channels right away; you will hardly need more than four — elevator, rudder, ailerons, throttle. Maybe a fifth for flaps and a sixth for retracta-

(Photos Courtesy Joe Alvarez)

Close-ups of the nose and canopy areas of the model. The author points out that the model more than proved its worth just in working out the rather severe compound curves of the fuselage . . . much cheaper on the model than on a prototype airplane!





ble landing gear. What else do you need, brakes? It is done with the down elevator command. Steering? The steerable nose wheel is connected to the rudder.

Let's take a look at the formulae. If we call the scale factor S, it will be given by the ratio of the size of the model to the size of the prototype. In the case of the Polliwagen the scale is 1:4.

$$S = \frac{1}{4}$$

$$\text{Model weight} = \text{Prototype Weight} \times (S)^3$$

$$\text{Polliwagen} = 1000 \text{ lbs.} \times (1/4)^3 = \frac{1000 \text{ lbs.}}{64} = 15.6 \text{ lbs.}$$

$$\text{Model Power} = P \times S^3$$

$$\text{Polliwagen} = 65 \text{ h.p.} \times (1/4)^3 = \frac{65 \text{ h.p.}}{64} = 1.0 \text{ h.p.}$$

$$\text{Wing Loading} = \frac{W}{A} \text{ Prototype} \times S$$

For speed calculations,

$$V \text{ Prototype} = \frac{V \text{ Model}}{\sqrt{S}}$$

If the power applied to the model is scale, the model will fly in scale. Speed, rate of climb, take-off run, etc., are data that can be processed by the scale factor to obtain the values of the full size. The angles of climb and stall should be the same, like the L/D ratio, with due consideration to Reynolds Number.

The way to extract the data from the model is a matter of ingenuity, patience, and good piloting. Lots of movies taken with the task at hand in mind — don't get cinematographic, be strictly business — will help enormously. For instance, you could establish the angles of incidence at various speeds if the takes are done standing in the bed of a moving pick-up with the model flying at camera level; the horizon is the reference. The footage won't win you praise at the family gathering, but the information will be there. Slow motion takes of take-offs and landings will educate your pilot the same way they educated me when confronted with a model loaded almost twice as much as what I've been used to flying.

Probably the one item that we couldn't pin down to our satisfaction was stall speed. If somebody has any ideas about how to do it without breaking something, please send them along — we may all benefit from it.

This is an ample field in which to exercise your technological muscles. It is up to each one to map his own rate accordingly to his wants and possibilities. Let me state clearly once more that a model will not give you all the answers, but it will allow you to get a lot closer to the design goals. You may not be absolutely sure of the top speed of your prototype, but you will know as an experimental fact which modification made your model faster, and whether it affected the other characteristics. The true value of the method lies in the possibility of evaluating safely and economically that "marriage of compromises" of which we talked at the beginning, by manipulating the variables until the best combination is achieved.

I've had lots of help from people to whom I can't repay directly. I guess that a way to dilute this debt is to try and help other people. If you have any questions, drop me a letter and a self addressed stamped envelope. You will get an answer.

CALENDAR OF EVENTS

The following list of coming events is furnished to our readers as a matter of information only and does not constitute approval, sponsorship, involvement, control or direction of any such event.

Preparation and printing of an issue of SPORT AVIATION requires approximately two months. All items for inclusion in Calendar of Events must be received by EAA Headquarters two months in advance of the issue in which it will appear.

JANUARY 17-23 — LAKELAND, FLORIDA — 3rd Annual Midwinter Sun 'n Fun EAA Fly-In. Contact Sandy Rickert, 502 Jamestown Ave., Lakeland, FL 33802.

FEBRUARY 20 — LYONS, OHIO — Mini-Chili Fly-In sponsored by Toledo EAA Chapter 149 at its regular meeting. 9 A.M. Rain Date — February 27. Newbury Field.

APRIL 2 — MINNEAPOLIS/ST. PAUL, MINNESOTA — Seventh Annual Minnesota Sport Aviation Association Dinner Meeting. Combined with VariEze Seminar during the day conducted by Burt Rutan. Dinner in evening. Contact: George Wilson, days (612) 633-6170, ext. 3514 and evenings (612) 421-1845.

APRIL 29 - MAY 1 — CHINO, CALIFORNIA — Southern California Regional EAA Fly-In. Formerly held at Corona. Contact Guy Veasey, 23276 Buckland Lane, El Toro, CA 92630.

MAY 14-15 — QUINCY, FLORIDA — Fabulous Fifth Fun Fly-In sponsored by EAA Chapter 445. Contact Bob Hayden, P. O. Box 5182, Tallahassee, FL 32301.

JUNE 24-26 — HAMILTON, OHIO — Waco Reunion Fly-In. Contact Ray Brandly, 2650 W. Alex Bellbrook Rd., Dayton, OH 45459.

JULY 30 - AUGUST 6 — OSHKOSH, WISCONSIN — 25th Annual EAA Fly-In. It's not too early to start making your plans for the BIG one.

(Photo by Ted Koston)

Dick and Dan McCormick and P. W. Steiner of Rockville, Maryland own this sharp little Aeronca Champion. Champs and Cubs were the mainstays of the training fleet of the late 40s and well into the 1950s. The Champ's principal selling points over the Cub were that it was soloed from the front seat and offered the best visibility of any of the 65 hp puddle-jumpers of the era. It was also roomier and a little faster . . . but somehow never achieved the charisma of the Cub.