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Converting Giant R/C Plans Into Your Walter Mitty Fighter

By Vince Homer, EAA 162674, vhhomer@hotmail.com

The possibility of building a replica fighter has always fascinated me. As a longtime model builder, it seemed reasonable to use a scaled-up “giant-scale” radio-controlled (R/C) model as a base. After many false starts, I finally landed on a 70 percent P-39. Some readers might be interested in the various aircraft that I considered:

P-51, P-40, etc. – There are lots of giant-scale R/C models of these types of aircraft out there, and since many human-carrying versions are already available from companies such as Loehle Aircraft and WAR Aircraft Replicas, I decided to look at some not-so-well-known aircraft.

Kawasaki Hein, Helldiver, Fokker D-XI – The availability in the last 10 years of round engines in the under-200-hp range has made these aircraft possibilities.

F9F, L-39 Albatros, A-10 Thunderbolt (Warthog) Heinkel He-162, F7U Cutlass – Ducted fans have been written about for a long time, and it appears to be possible. However, other than the ill-fated Saunders JetHawk, no one has managed to build and fly one.

OV-10 Bronco, F7F Tigercat, Widgeon, P-61 Black Widow – These aircraft fascinated me, and to my surprise, most scale well with only slight increases in the fuselage cockpit area to accommodate those of us that don't have an 18-year-old's physique anymore. The OV-10 is the most promising in that there are giant-scale plans featuring simple construction and require no dimensional changes to fit a pilot and passenger. A 63 percent scale with a couple of Geo Metro engines seems promising. After all that fun, I have to admit that even if I did find the time and funds to build one of these, I don't have and probably never will have the piloting skills to fly any of them safely. Besides, the complexity of these projects would be a *forever* build time! I'm sure these are common problems for anyone considering a scaled warplane project.

Avia B-534 – This Czechoslovakian biplane was used from the 1930s until the Germans overran the country. The German Air Force used captured B-534s, and some escaped to Russia. This biplane features an inline engine and an enclosed canopy and represents a very good candidate for scaling with its large wing area.

Jack Bally's B-17 project featured in the June '09 issue of *Experimenter* is very encouraging. I really want to be at EAA AirVenture Oshkosh when it shows up for the first time. There's a Czech-built model engine manufacturer that is building round engines up to 45 hp, and I understand the B-17 builders are looking at using them.

I finally decided on the Bell P-39 Airacobra because of a long-time interest in the design, and I just wanted to build an aircraft that seemed to have been overlooked by the replica crowd.

My experience with homebuilt aircraft is mostly tire-kicking and hangar flying, although I have helped a few with projects and even started a single-place high wing original design in the 1980s. The wing and tail frames are still hanging in my shop in California. As an aerospace engineer who graduated in 1970 (when you couldn't buy a job in the airplane business), I have spent most of my time working in the oil business and remember just enough to make me dangerous, that is, with the exception of five years as a design engineer with Aero Union Corporation converting ex-military aircraft into fire bombers and supporting aerial refueling equipment.

70 percent P-39 cockpit and nosecone mock-up

The P-39 mock-up was built in a one-car garage while I was living in Saudi Arabia. Saudi isn't exactly a hotbed of private or homebuilt aviation activity. In fact, there is none. The idea of citizens flying around in their own airplanes doesn't appeal much to the government there. As a result, my project was a nonflying mock-up. My main purpose was to work out the many details of the conversion from

R/C model to homebuilt. The P-39 has the added wrinkle of its aft engine location.

I started with plans for a giant-scale R/C model, and after the cockpit and door dimensions were increased slightly, a quick trip to Kinkosand their enlarging drawing copier produced a set of patterns. The increased cockpit dimensions were necessary because the best size for a WW-II P-39 pilot was 5 feet 8 inches and 160 pounds or less, and I'm a bit taller and wider than that. When I tried getting into the mock-up once the canopy frame was complete, I found my contortionist ability to get in and out of cockpits had decreased with age and that I would also need to hinge the canopy top in a real version, much like some Spitfire models. If it's difficult to get in and out of the cockpit in normal circumstances, imagine what it would be like in an emergency! This should be a prime concern for anyone designing and building a replica.

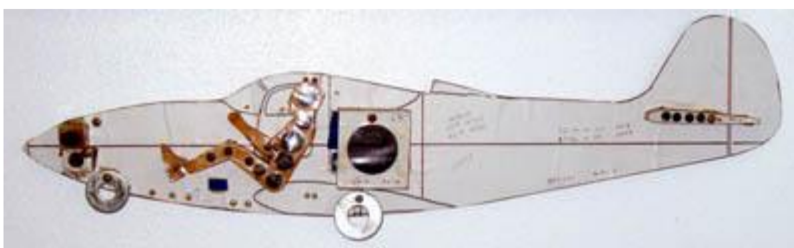
My first "sit-in-the-cockpit-and-make-airplane-noises" experience really sums this up; with the cockpit frame, seat, and panel in place, I tried to gracefully get into my creation. The combination of not having a wing to stand on and the small door opening proved daunting. I could get in, but getting out was another matter. I was halfway out when I managed to tip over the whole fuselage assembly landing on my left lower buttocks. The next day, it looked like I had been hit with a Gretzky slap shot, or maybe my wallet had exploded. The lesson: Bigger doors, or better yet, hinge the top section of the canopy.

The construction is a straightforward wood stringer/bulkhead approach with a glassed plywood skin, very much like some have done with Loehle aircraft. Originally, I was looking at a Mazda 13B engine, but lately, after looking at the partially built fuselage, I've been thinking that a Chevy V-6 or Buick/Olds/Rover 215 V-8 with a lower crankshaft centerline might fit better. The Mazda engine (also a wooden mock-up) is currently installed in the fuselage with a cog belt propeller speed reduction unit (PSRU) on the engine. This was needed to get the driveshaft below the pilot's seat.

Mazda with PSRU and driveshaft

The driveshaft is seen running from behind the seat, through a carrier, and to the nose.

Aft engine weight is certainly a problem as the original aircraft had heavy guns in the nose. Some of my friends from the Sports Car Club of America (SCCA) have suggested using Porsche 935 Turbo constant velocity (CV) joints for the drive shaft. If a V-6 or V-8 was used with the lower crankshaft line, a planetary PSRU would fit nicely in the nose, which also helps with the weight and balance. To check and play with the weight and balance, I made a small-scale profile fuselage with scaled weights. Weight scales to the third power, scaling is a subject for another article.



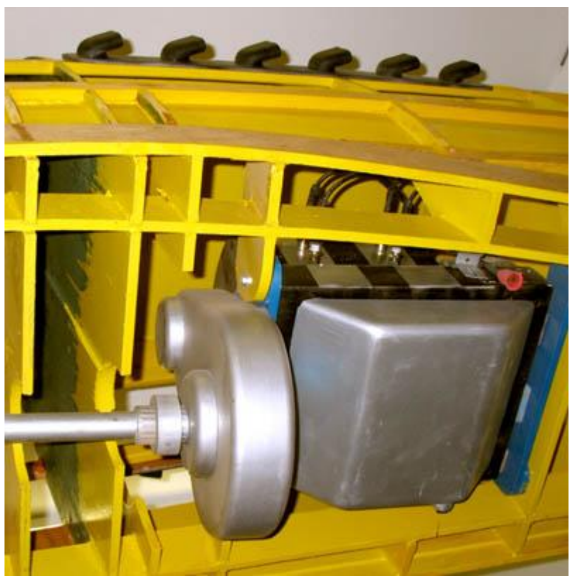
1/6 scale weight and balance fuselage

In order to test the cockpit layout, I have installed the pilot's seat, drive shaft, instrument panel, control stick, rudder pedals, and throttle quadrant. It all fits quite comfortably, and the visibility seems good. The instrument panel uses some red-tagged instruments I got (for a reasonable donation) from the fine people at the Oakland Aviation Museum in California.

The windscreen is a bent flat sheet, but the canopy top skylights are compound curves. To make those, I needed a mold. I found a 30-gallon plastic barrel with just the right curvature on the top portion of it. Using the curved barrel plastic as the outer surface of the skylights, the canopy frame skylight sections were filled in with plaster of Paris. The plastic was removed and a mold was made of the canopy/skylight area. This mold will be used to vacuum-form the skylight sections.

The door blanks were laminated with five layers of 1/8-inch plywood using the cockpit frame as an armature. The window areas were then cut out, and a pocket was left in the lower portion of the door so the window could be lowered. The window Plexiglas fits in through a slot in the top of the door frame. In a real version, I think I would make composite doors using the mock-up ones as plugs to make molds.

The landing gear was made of PVC pipe and wheelbarrow wheels. The prop is flat-bladed from plywood with a foam spinner I turned on my wood lathe. In fact, the entire mock-up is made of wood and PVC pipe fittings with the exception of the alternator, spark plugs, and a few other bits.



Attention to detail is over-the-top for a mock-up. The wood Mazda rotary engine even has real spark plugs, spark plug wires, and a real alternator.

At this point the P-39 is hanging from the ceiling of my shop awaiting its turn in the project queue right after the Himax and a couple other inevitable diversions. I would like to install a recently acquired 215 V-8 along with a drive line, PSRU, and propeller. A running version would make a nice display at Oshkosh. Anyone know where I can get a red-tagged, three-blade prop?

Two years ago (February 2010 issue of Experimenter) my "What Our Members Are Building" article spoke about converting giant radio-controlled (R/C) aircraft plans for the purposes of building a scale homebuilt aircraft. A similar article was published in June 2009 that showcased Jack Bally's 1/3 scale replica B-17. In this issue, I share my love for small- and large-scale aircraft in an inspirational and educational way that may help you create your own "Walter Mitty" fighter.

"We're going through!" The Commander's voice was like thin ice breaking. He wore his full-dress uniform with the heavily braided white cap pulled down rakishly over one cold gray eye. "We can't make it, sir. It's spoiling for a hurricane, if you ask me." "I'm not asking you, Lieutenant Berg," said the Commander. "Throw on the power lights! Rev her up to 3,500! We're going through!" The pounding of the cylinders increased: ta-pocketa-pocketa-pocketa-pocketa-pocketa. The Commander stared at the ice forming on the pilot window. He walked over and twisted a row of complicated dials. "Switch on No. 8 auxiliary!" he shouted. "Switch on No. 8 auxiliary!" repeated Lieutenant Berg. "Full strength in No. 3 turret!" shouted the Commander. "Full strength in No. 3 turret!" The crew, bending to their various tasks in the huge, hurtling eight-engined Navy hydroplane, looked at each other and grinned. "The Old Man will get us through," they said to one another. "The Old Man ain't afraid of hell!" - The Secret Life of Walter Mitty, James Thurber, 1939.

The possibility of building a replica aircraft has always fascinated me and has produced numerous mental movies during boring times. As a longtime model builder, it seemed reasonable to use a scaled-up "giant-scale" R/C model plan as a starting point. After many false starts, I finally landed on a 70% P-39. Some readers might be interested in the various aircraft that I considered:

Giant-scale R/C models are taken to the extreme in Europe where there is no limitations on model weight as there are in the United States. Here are some examples of what they're building and flying:

50% Rearwin Speedster

70% Cauldron

40% Staggerwing

P-51, P-40, Me-109, Fw-190, etc. - there are lots of giant-scale R/C models of these types of aircraft out there, and since many homebuilts are already available from companies such as Loehle, Titan, Falconair, and WAR, I decided to look at some not-so-well-known ones.

P-51

P-40

Me-109

Fw-9190

Aichi D3A1 Val, Helldiver, Fokker D21 - the availability in the last 10 years of round engines, particularly Rotec, in the under-200-hp range has made these aircraft possibilities. Aircraft with a fixed gear, such as the Fokker D21, have the advantage of being less complex.

Aichi D3A1 Val

Helldiver

Fokker D21

Rotec 3600

Rotec 2800

F9F, L-39 Albatros, A-10, He-162, F7U Cutlass, Me-262 - ducted fans have been written about for a long time, and it appears to be possible. However, other than the Jethawk, no one has managed to build and fly one. There was an active website about designing a reduced scale A-10 in the '90s, but that project seems to have disappeared. There's also a website, Mass Flow, that remains active; however, his progress seems to have stopped on the project.

F9F Panther

L-39 Albatros

A-10 Warthog

He-162

F7U Cutlass

Me-262 B-1 Flug Lehrer

OV-10 Bronco, F7F, Widgeon, P-61 Black Widow - these aircraft fascinated me, and to my surprise, most scale well with only slight increases in the fuselage cockpit area to accommodate those of us that don't have an 18-year-old's physique anymore. The OV-10 is the most promising in that there are several giant-scale plans featuring simple construction and requiring no dimensional changes to fit a pilot, passenger, and engines. A 63% scale with a couple of Raven Geo Metro engines looks great. After all the fun of running the scaled numbers on these complex twins, I had to admit that even if I did find the time and funds to build one, I don't have and probably never will have the piloting skills to fly it safely. Besides, the complexity of these projects would result in a "forever" build time! I'm sure these are common problems for anyone considering a scaled warplane project. You'll see this as a common theme out there in experimental aircraft land - lots of Walter Mittys with big daydreams.

Widgeon with wide fuselage

OV-10

P-61 Black Widow

F7F Tigercat

Avia B-534 - this Czechoslovakian biplane was used from the '30s until the Germans overran the country. The German Air Force used captured B-534s, and some escaped to Russia. This biplane features an inline engine (www.Raven-Rotor.com or www.Firewall.ca) and an enclosed canopy and represents a very good candidate for scaling with its large wing area. I have a set of plans for this aircraft digitized and modified in AutoCAD as a someday project. A draggy aircraft such as the Avia B-534 or the Helldiver would be a good project for a replica that would meet the light-sport top/stall speed, fixed gear requirements and still perform close to scale.

Avia B-534

Many years ago there was an article in Air Progress (that dates me a bit) about a proposal to build a scaled B-17. A recent article in the Replica Fighters Group newsletter detailed a 33% B-17 project that is very encouraging. I really want to be at Oshkosh when it shows up for the first time. Valach (www.TroyBuiltModels.com), a Czech model engine manufacturer, is building round engines up to 45 hp; I understand the B-17 builders were looking at using them, but as they are a bit pricey, the builders decided on something else. A reduced-scale glider version, the Me-163 rocket interceptor, was built in Germany in the '90s and flew well. Perhaps a better choice would be the version with a real landing gear, the Me-263. A powered version? That's a whole 'nother project!

Valach Motors 800-cc seven-cylinder 45-hp radial engine

B-17 Flying Fortress

Me-263

Full-scale Me-163 replica

The aviation industry has built many "proof of concept" subscale flying aircraft. One of the most interesting was the British Saro Shrimp built during World War II. Watch it in this great clip. https://www.youtube.com/watch?v=PyMnQR4bdpY

Saro Shrimp 50% scale flying boat with four (4) 45 HP Pobjoy Engines

More recently, Boeing built and flew a nonmanned 8.5% blended wing with three R/C jet engines. The company could have just as well built the aircraft manned at 25% had it not been for the difficulties with its insurance carrier and the FAA.

Boeing blended wing 8.5% scale R/C jet engines

I finally decided on the P-39 because of a longtime interest in the design, and I just wanted to build an aircraft that seemed to have been overlooked by the replica crowd. My experience with homebuilt aircraft is mostly tire kicking and hangar flying, although I have helped a few with projects and even started a single-place, high-wing original design in the '80s, and I have a Himax underway. As an aerospace engineer who graduated in 1970 (when you couldn't buy a job in the airplane business), I have spent most of my time working in the oil business and remember just enough aero engineering to make me dangerous. Over the years I did manage to work five years as a design engineer with Aero Union Corporation, converting ex-military aircraft into fire bombers and supporting aerial refueling equipment.

The P-39 mock-up (Photo 1 below) was built in a one-stall garage while I was living in Saudi Arabia. Saudi isn't exactly a hotbed of private or homebuilt aviation activity. In fact, there is none. The idea of citizens flying around in their own airplanes doesn't appeal much to the government there. As a result, my project was a nonflying mock-up. My main purpose was to work out the many details of the conversion from R/C model to homebuilt. The P-39 has the added wrinkle of its aft engine location.

If you're considering a project of the magnitude of a scaled aircraft, I recommend building at least a cockpit mock-up to make sure that you fit, have decent visibility, and can get out easily in the event things go south. I will admit my P-39 mock-up is a little over the top, but I needed a project at the time. For past projects I used corrugated (cardboard) put together with white glue and painted with house paint. You would be surprised how decent a mock-up can be built in that fashion, and when you are finished your kids or grandkids will have a ball playing in it. Contact www.Uline.com for sheets of single, double, and triple wall corrugated.

Photo 1, 70% P-39 mock-up

Photo 2, Mazda with PSRU and driveshaft

I started with plans for an 86-inch wingspan, giant-scale R/C model. After the cockpit and door dimensions were increased slightly, I made a quick trip to Kinko's, (FedEx Office) and with their enlarging copier I produced a set of patterns that were glued to plywood and the parts cut out on a bandsaw. One other option I have used with R/C plans is to have them digitized and then imported into a CAD program. The necessary dimensional changes can be made in CAD, and the files can be printed full scale at most Kinko's type business centers. Once you have plans in a CAD format, you can take them to a waterjet or laser cutter or someone with a CNC router (wood only) and get all your flat plywood and metal parts cut out with a degree of accuracy that you will never get with your jigsaw or bandsaw.

The increased cockpit dimensions were necessary because the best size for a WWII P-39 pilot was 5 feet, 8 inches and 160 pounds or less; I'm a bit taller and wider than that. When I tried getting into the mock-up once the canopy frame was complete, I found my acrobatic ability to get in and out of cockpits had decreased with age, and as a result, would hinge the canopy top in a real version, much like some Spitfire models. If it is difficult to get in and out of the cockpit in normal circumstances, imagine what it would be like in an emergency! This should be a prime concern for anyone designing and building a replica.

My first "sit in the cockpit and make motor noises" experience really sums this up: With the cockpit frame, seat, and panel in place, I tried to gracefully get into my creation. The combination of not having a wing to stand on and the small door opening proved daunting. I could get in, the cockpit was very comfortable, and the visibility was great, but getting out was another matter. I was halfway out when I managed to tip over the whole fuselage assembly landing on my left lower butt cheek. The next day it looked like it had been hit with a Gretzky slap shot or maybe my wallet had exploded. The lesson: Bigger doors, or better yet, hinge the top section of the canopy.

The construction is a straightforward wood stringer/bulkhead approach with a glassed plywood skin, very much like some have done with Loehle aircraft. From the photos you can see the various fuselage bulkheads and stringers, most of which were as per the original plan. I did add extra stringers to stiffen the structure. The plan I used had a very good fuselage carry-through structure that is shown on Photos 1 and 2 in the 3 to 5 o'clock position.

Originally, I was looking at a Mazda 13B engine, but lately after looking at the partially built fuselage, I have been thinking that a Chevy V-6 or Buick/Olds/Rover 215 V-8 with a lower crankshaft might fit better. The Mazda engine (also a wooden mock-up) is currently installed in the fuselage with a cog belt PSRU on the engine. This was needed to get the driveshaft below the pilot's seat (Photo 2). Aft engine weight is certainly a problem as the original aircraft had heavy guns in the nose. Some SCCA (Sports Car Club of America) racing friends have suggested using Porsche 935 Turbo CV joints for the driveshaft. If a V-6 or V-8 was used with the lower crankshaft, a planetary PSRU would fit nicely in the nose, which also helps with the weight and balance. To check and play with the weight and balance, I made a small-scale profile fuselage with scaled weights (weight scales to the third power of the scale factor). See Appendix A for the description below of the visual weight and balance method I used.

In order to test the cockpit layout (Photos 3 and 4), I installed the pilot's seat, driveshaft, instrument panel, control stick, rudder pedals, and throttle quadrant. It all fits quite comfortably and the visibility seems good. The instrument panel uses some red-tagged instruments I got (for a reasonable donation) from the fine people at the Oakland California Air Museum.

Photo 3, cockpit

Photo 4, cockpit looking forward

The windscreen is a bent flat sheet, but the canopy top skylights are compound curves. To make those, I needed a mold. I found a 30-gallon plastic barrel with just the right curvature on the top portion of it. Using the curved barrel plastic as the outer surface of the skylights, the canopy frame skylight sections were filled in with plaster of Paris. The plastic was removed and a mold made of the canopy/skylight area. This mold will be used to vacuum-form the skylight sections.

The door blanks (not shown) were laminated with five layers of 1/8-inch plywood using the cockpit frame as an armature. The window areas were then cut out, and a pocket was left in the lower portion of the door so the window could be lowered. The window Plexiglas fits in through a slot in the top of the doorframe. In a real version I think I would make composite doors using the mock-up ones as plugs to make molds.

The landing gear was made of PVC pipe and wheelbarrow wheels. The prop is flat bladed from plywood with a foam spinner that I turned on my wood lathe. In fact, the entire mock-up is made of wood and PVC pipe fittings with the exception of the alternator, spark plugs, instruments, and a few other bits.

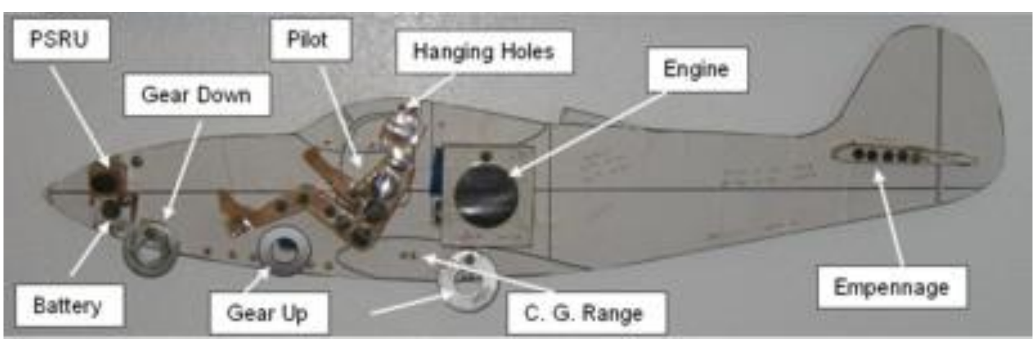
At this point the P-39 is hanging from the ceiling of my shop awaiting its turn in the project queue right after the Himax and a couple other inevitable diversions. I would like to install an engine along with a drive line, PSRU, and propeller. A running version would make a nice display at EAA AirVenture Oshkosh or Copperstate Fly-In. Anyone know where I can get a red-tagged, three-bladed prop?

To summarize:

1. Hundreds of R/C aircraft plans available in scales up to 1/2:1.
2. Giant-scale R/C plans lend themselves to wood construction.
3. Plans can be digitized and used as a basis for redesign as needed and for CNC parts cutting.
4. Conversion of wood designs to metal or composite requires a complete redesign.
5. RC Plans using fiberglass or foam construction also require complete redesign.
6. The scaled-up aircraft may become aerodynamically more stable than the model.
7. Scaling laws apply as long as the model is large (see Appendix B). The lower the scale change, the better. That's why it's wise to choose a giant-scale R/C model as a starting point and not a 20-inch wingspan stick and tissue version. The magic of Reynolds number effects come into play when comparing very small models to homebuilt-size aircraft.
8. Obviously, the pilot and passengers don't get smaller. Usually the cockpit must be enlarged. No one will notice a few inches wider or taller. My P-39 mock-up deviates from scale by 4 inches wider and 3 inches taller and larger doors. Did you notice?
9. Major support structures such as wing spars, engine mounts, and landing gear must be redesigned.
10. Your design must go through a stress check by a qualified person. Just because it looks good, it may not be something to trust your fragile body with.
11. Weight and balance estimates are crucial. The70% P-39 C. G. test showed a serious tail heavy problem that necessitated moving components forward.
12. Airfoils may need to be changed for the lower Reynolds numbers and (nonscale) flight speeds.
13. Basic performance and stability calculations must be done. This may result in empennage area adjustment, control surface area changes, and incident angle adjustments.
14. Lastly, if you're an R/C modeler or know one, you can build a model, apply scaling laws for weight and power, and even add some readily available in-flight data recording equipment. You can even add an in-flight video camera in the cockpit with a down link. Then you can fly your ship and collect some data just like Walter Mitty would.

Appendix A

Visual Weight & Balance



1/8 Scale W & B Fuselage

The procedure for making a working W & B model as shown above is quite simple and offers a good way to visualize how all the bits fit and affect the aircraft design.

Paste a scale plan on a piece of 1/4-inch ply. Pick a convenient scale to keep it a reasonable size, about 24 to 30 inches spinner to tail.

Double or triple the fuselage outline thickness in areas as necessary to represent the weight distribution. The purpose is to make the fuselage outline weight distribution represent that of the full size.

On the plan above the CG range is shown as two circles in the wing chord outline.

Drill several holes in the fuselage such that they line up over the CG range as shown by the wing chord marks. With a mid-wing or high-wing aircraft, you will be able to use holes drilled in the wing chord CG range.

All the major aircraft item locations should be shown on the plan along with the CG range of the aircraft.

Glue, hook, and loop in all component locations on the fuselage plan. Make the pieces larger than the actual component location if it can be moved.

Estimate or get the actual weights of all the aircraft components. If you actually have a built R/C model, weighing the components and applying the appropriate scale factor may give you a ballpark idea of the full-size component weights. However, since there will be many redesigns based on the stress analysis, this may not be accurate. Another source would be reference books such as:

Airplane Design Part V: Component Weight Estimation, Jan Roskam, 1999

Simplified Aircraft Design for Homebuilders, Daniel P. Raymer, 2002.

Paste scale-size pictures/drawings of these parts on appropriate-size blocks of wood.

Determine the scale weights for all items. Weight scales as the third power of the scale factor. For example, my P-39 W & B model is 1/8 scale, meaning the weight scale factor is (1/8)3 = 0.00195. Therefore, my 400-pound engine scale piece should weigh 0.78 pound or 350 grams.

Weigh each scale component. Add weight. I used lead shot glued in a hole drilled in the blocks to get the component weight up to your calculated scale values.

The pilot figure is a little more complicated. You must weigh it so that the CG of the figure is correct. One way to determine your personnel CG is to sit in a kid's swing in the position you plan on using in your plane. Slide the swing seat to a point where you can maintain your position without holding on. Your CG is at the point where the swing ropes are. This point tends to be around your belly button. Weigh your scale pilot and passenger(s) to balance at this point.

Attach the other half of the hook and loop to your component parts. For some components, I used short screws as it was easier.

Stick the parts on the fuselage with double sticky tape or Velcro.

Hang the whole assembly from one of the holes in the top of the fuselage.

With the mid- or high-wing versions, the CG determination is direct. With the low-wing version, you extend hanging wire to the CG range marks on the wing chord.

Move the hanging point until the model is level.

If the hanging point is in the CG range, you're good to go.

Be sure to check tanks full/empty, gear up/down, and solo versus passenger(s).

If you can't get level in the CG range, start moving what components you can, try a lighter engine option, or go on a diet.

Below is an example of the full scale and 1/8 scale weights:

Component	70% P-39 component weight (pounds) estimate	70% P-39 1/8 CG model Weights (pounds) (grams) Scale factor = .00195
Wing	240	.470 lbs (213 gr.)
Tail	40	.078(35)
Fuselage	250	.500 (221)
Nose gear	30	.059 (27)
Main gear	60	.118 (54)
PSRU	40	.078 (35)
Prop	40	.078 (35)
Battery	20	.039 (18)
Instrument	30	.059 (27)
Engine	400	.780 (350)
Empty weight	1150	2.24 (1018)
Pilot	200	.390 (180)
Fuel (at CG)	250	.49 (221)
Gross weight	1600	3.12 (1416)

Appendix B

Scaling Laws

Model scaling laws

Scanned by Nick Hein from "Design of the Aeroplane" by Darroll Stinton. (c) 1985

These factors may be used to determine the scale performance and specifications of a reduced or increased scale project. However, in the case of very high-performance full-scale aircraft, the reduced scale version may be designed to operate at lower than scale speeds, wing loadings, roll rates, and power loadings in order to produce more of a sport category aircraft. (Added by VHH.)

Scaling factors

X = full-scale linear dimensions/project linear dimensions

Design example for 70% scale project (X = 1.43)

Parameter	Conversion	Full scale	70% Project
Linear dimensions	Full scale//X	Span 35.8 feet	35.8/1.43 = 25.03 ft
Area	Full scale//X^2	Wing 174 ft^2	174/2.04 = 85.09 ft^2
Volume, mass, force	Full scale//X^3	Gross weight 2645 lbs	2645/2.92 = 906 lbs
Moment	Full scale//X^4		Full scale/4.18
Moment of inertia	Full scale//X^5	Pitch 1364 slug ft^2	1364/5.98 = 228 slug ft^2
Linear velocity	Full scale//$X^{1/2}$	Max 144 mph	144/1.20 = 120 mph
Linear acceleration	Full scale		Same as full scale
Angular acceleration	Full scale x X		Full scale x 1.43
Angular velocity	Full scale x $X^{1/2}$		Full scale x 1.20
Time	Full scale/$X^{1/2}$		Full scale/1.20
Work	Full scale/X^4		Full scale/4.18
Power	Full scale/$X^{3.5}$	Rated 160 hp	160/3.50 = 47.8 hp
Wing loading	Full scale/X	15.2 lb/ft^2	15.2/1.43 = 10.63 lb/ft^2
Power loading	Full scale x $X^{1/2}$	16.5 lbs/hp	16.5 x 1.20 = 19.8 lbs/hp
Angles	Full scale		Same as full scale
Rpm	Full scale x $X^{1/2}$	Rated 2740 rpm	2740 x 1.2 = 3288 rpm

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