RCU Review: Minnflyer on: Flutter

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FLUTTER

It's Cause, Cure and Misconceptions

By Mike Buzzeo (MinnFlyer)

Most of us are familiar with the term "Flutter". For those of you who aren't, it is when a surface or control surface of an airplane suddenly and often violently vibrates, frequently resulting in a catastrophic failure. However, the more I read and talk to others, the more I realize how little this phenomena is understood. With that in mind, I hope to shed some light on this subject and hopefully, dispel some myths.

What is Flutter?

First, let's see what flutter LOOKS like. My friend and colleague, Ken Isaac shot this video of Bob Levine's A-10 at Florida Jets last spring. Bob's plane suffered a severe attack of flutter. As you watch the video, notice a few things: The plane was NOT moving very fast when it began, and after the initial occurrence, the flutter stopped, but then it started again shortly before landing.

So why did it begin in the first place? And why did it stop only to start again later?

Simply put, Flutter is a ***Harmonic Vibration***. A harmonic vibration is really quite easy to comprehend, but describing it is a bit more complicated. So I will try my best to put it in terms that are easily understood.

What you must first realize is that everything in the universe will vibrate at a given frequency. That frequency depends on many factors, such as size, weight and a host of others, AND in most cases, that frequency can be changed. I'm sure that as school kids we've all slapped a ruler that is hanging over a desk to make it vibrate, and if you slide the ruler so that less of it hangs over the edge, the vibrations get faster. By the same token, a string on a guitar will vibrate at a certain frequency, but if you tighten it, or make it shorter by holding it against a fret, the frequency will change.

Ok, so we all have at least a basic understanding of what vibration is, but what is "harmonic" vibration? This is when an object is hit by an outside force which has the same frequency at which the object wants to vibrate. One example of this is a microwave oven. The magnatron in your oven emits microwaves at the same frequency that water molecules vibrate. The waves cause the water molecules to vibrate, the vibration creates heat, and your burrito gets cooked.

Another excellent example of this is something I witnessed many years ago when I worked in a music store. We had a wall of acoustic guitars. Sometimes we would plug in an electric guitar, crank it up, pluck one string (very loudly) and then stop the string. The electric guitar would stop emitting sound, but you could hear all of the acoustic guitars on the wall "singing" the same note that the electric guitar had just played (It really works! Go to your nearest music store and try it, they will all be amazed - right before they throw you out).

Now let's look at WHY this happens.

An "A" string on a guitar vibrates at 440 beats per second (This note is known throughout the music industry as "A-440" - This is usually the note that a musician plays at the beginning of a concert to which the rest of the orchestra tunes - but I digress). So we have an object whose speed of vibration (or Frequency) is 440 cycles per second (or 440Hz). Now we are sending vibrations through the air at the same frequency.

What happens is this: a shock wave hits the string and pushes it slightly. The string then moves in the opposite direction on its own power, and just as it returns to its neutral position, it gets hit again. Since it was already moving in the return direction, it will move a little farther when it gets hit the second time, and again it will move forward and back and get hit a third time. The string will start to vibrate because it is getting hit with a force equal to its own frequency. Meanwhile, the "E" string right next to it will not vibrate because it wants to vibrate at 329.63Hz so it is getting hit with the second wave before it returns to its starting point (which has the affect of putting on the breaks).

Harmonic Influence

Another example would be a child on a swing. Let's say that a certain child on a swing has a frequency of exactly one swing per second (1Hz). This will be true regardless of how high the child is swinging. The higher they go, the faster they will go, but they will continue to swing at one cycle per second. Now, if you put a heavier child on the same swing, they will swing slower. If you shorten the length of the arc (shorten the ropes), they will swing faster.

Now let's put the child safely away and put an automatic gun on the swing (for legal purposes, let me just say that you should obviously NOT try this experiment at your local playground). Now let's say that with the weight of the gun, the swing will swing at 1 Hz, and you set this magical gun to fire at one shot per second. It would look something like this:

Non-Harmonic Influence

But note that the gun must go off at the same frequency as the swing to keep the cycle going. If the gun went off too soon, the timing would be off twice as much on the next cycle, and would be off by that much more on the third cycle and so on until the gun was going off when the swing was on the return trip and act as a break.

So that is what harmonic vibration is. It is when an object is influenced by an outside force at the same frequency at which the object naturally wants to vibrate.

Now, let's equate this to an aileron (Note: As I mentioned earlier, flutter can happen to ANY surface, but since aileron flutter seems to occur most often, I will use it as a reference throughout the rest of this article).

Let's say we have a straight, constant-chord wing with a free-swinging aileron attached (I.E. no control horn, pushrod or servo). The aileron is 2 inches wide, and there is a slight gap in the hinge line. Now we get in a car and stick the wing out of the window and level to the ground (We're professionals kids - Don't try this at home).

With the car sitting still, gravity is making the aileron hang down, but as the driver starts to move the car, air pressure begins to lift the aileron. Once a certain speed is reached, the aileron is likely to flutter. This speed will vary depending on many factors, but for the sake of argument, let's say that the speed is between 60 and 65mph.

Now, we stop the car and add an inch to the aileron's width. Repeating the experiment will show that the aileron will now flutter at a different (probably lower) speed range.

If we then add a weight or counterbalance to the aileron, the speed at which it flutters will change again. If we seal the gap, again the speed we're moving will be different when the aileron flutters - BUT... In every case, the aileron WILL flutter. The only thing that will change is the speed at which you are moving when the flutter occurs (and that speed might even be faster than the car can go).

One final oddity is that if you develope flutter at 60mph, it may very well disappear at 70mph, because it may be that 60 - 70mph is the "envelope" in which the conditions are right to develope flutter in that particular surface.

Why does this happen?

As air moves over the wing, several vortices will develop in the airflow - a series of high and low pressure areas. If they put pressure on both sides equally, the pressures will cancel each other out (Fig 4). However: **IF** the vortices on top and bottom are out of out of sync, and **IF** they hit the surface with a harmonic resonance (the frequency at which the aileron wants to vibrate), the surface will try to flutter (Fig 5).

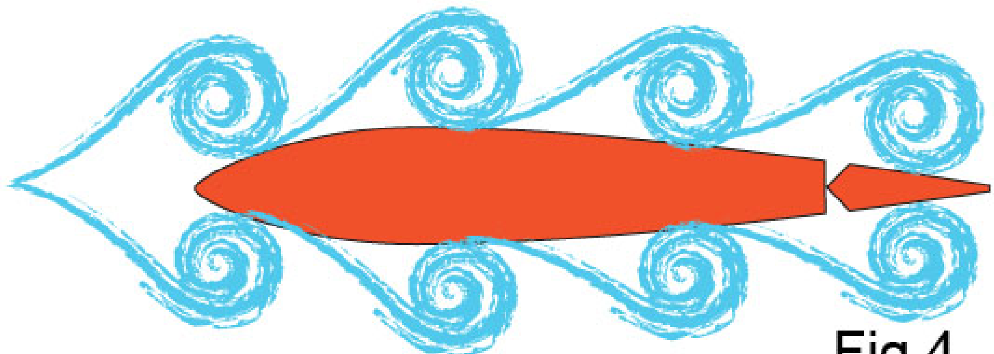


Fig 4

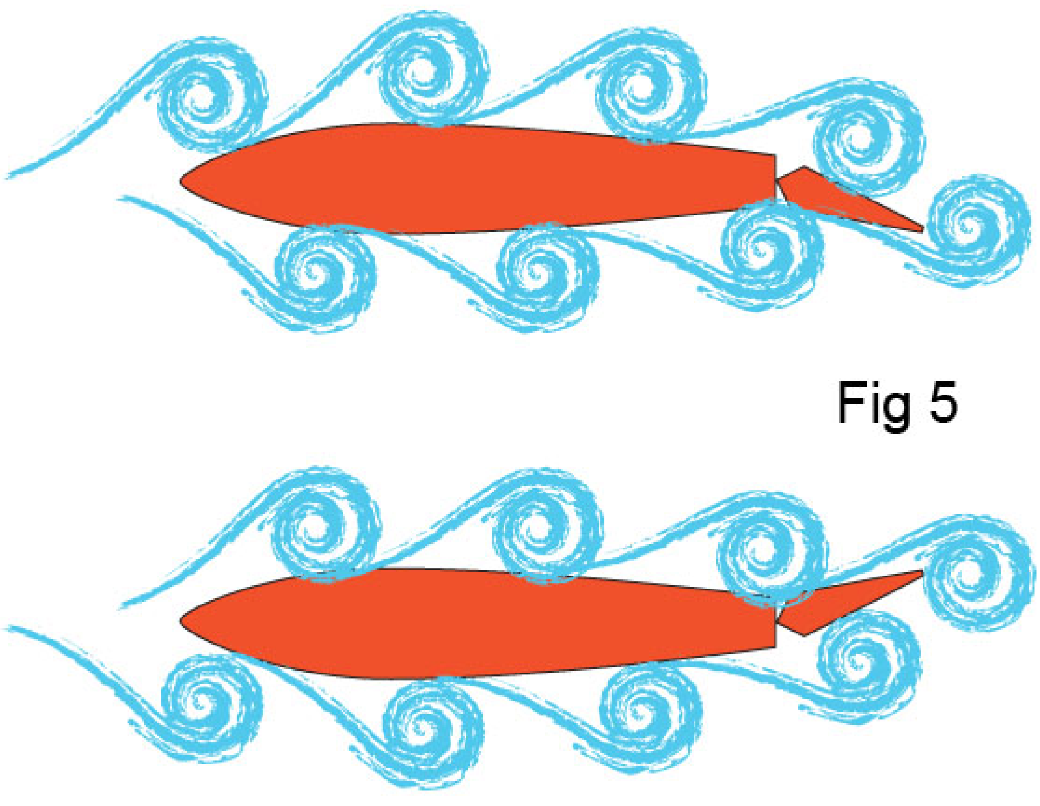


Fig 5

So how do you prevent it?

There are three ways to prevent flutter:

1. Design the control surface so that it will only flutter at a speed you will never attain. For example, if the aileron on your 40-size Piper Cub will flutter at 120mph, you'll never have to worry about it.
2. Add dampers (shock absorbers) to the surface to keep it from moving freely.
3. Mechanically hold the surface steady.

Looking at each one separately:

1. In most cases, we did not design the plane, so that option is out.
2. Adding dampers just isn't feasible on most models (not to mention the fact that hindering the surface's movement is the last thing many people want).
3. So our only real option is: Hold the surface securely!

Remember our example of driving a car with the wing hanging out the window? Now imagine you're driving down the highway, the aileron is fluttering in the breeze, and you reach out and grab it - It stopped, didn't it? You were able to stop it because (unless you didn't eat your Wheaties that morning) you're a lot stronger than the force which is creating the flutter. Plus, you probably grabbed the trailing edge of the aileron (where you have a mechanical advantage). Your servo will be linked to a control horn on the forward edge of the aileron where it has much less of a mechanical advantage, so the servo and all of the linkages will need to be strong and tight. No slop allowed here!

Why no slop? I have heard people say, "Well, there's only a little slop, so even if it flutters, it won't flutter much." - WRONG! To demonstrate this incorrect line of thinking, imagine you have a 6-foot long, steel pole buried 2ft into the ground and you want to remove the pole. It will only move it a little bit, so you begin to wiggle it. The more you wiggle it, the more the ground will soften and it won't be long until it will move so much that you are able to pull it out. The same thing can happen with flutter. That little bit of movement can put more and more pressure on a weak pushrod until the pushrod starts to flex. On the next cycle, the pushrod will flex more and so on until the flutter completely destroys the components. And the most unfortunate thing is that this can all take place in a matter of seconds!

Not all vibration is the same

Something else to consider is that just because you're holding one area of the aileron tightly, that doesn't mean it can flutter in another area. Remember, EVERYTHING will vibrate at some frequency. Of course, in most cases, securely holding an aileron's control horn is usually enough to keep it from vibrating at reasonable speeds, but the larger the surface, the greater the chance of this happening.

This brings us to the next area of vibration. Let's go back to the guitar string analogy: If you pluck an "A" string, it will vibrate at 440Hz. If you hold the string down at the 12th fret (which is the middle) it will vibrate one octave higher or 880Hz. However, if you place you finger lightly on the string at the 12th fret, and simultaneously pluck the string and release your finger, the string will emit a lovely "Ping" sound (any guitarist can tell you that this is even called a "Harmonic" note). What is happening is that you have caused the string to vibrate not from end to end, but from end, to center, to end (fig 6).

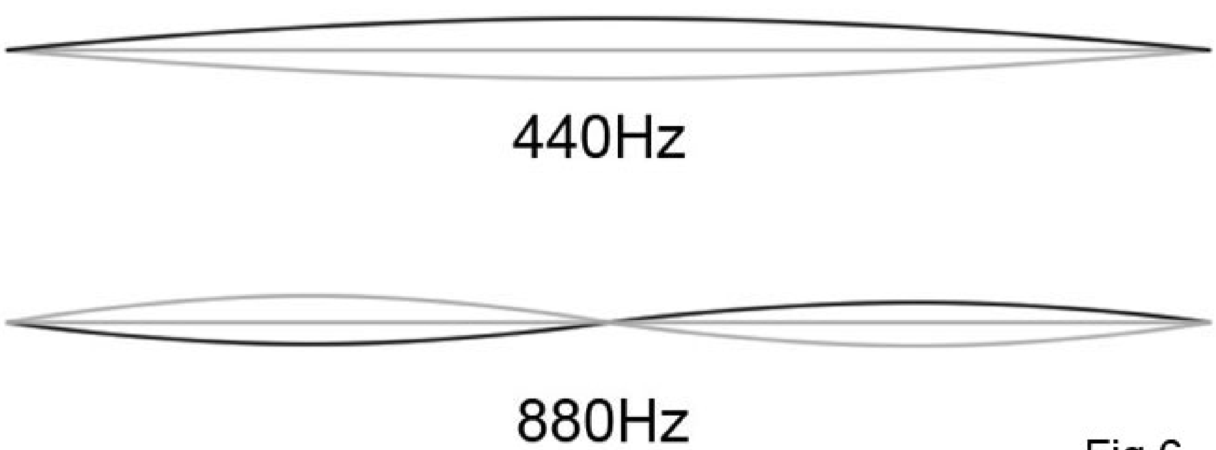
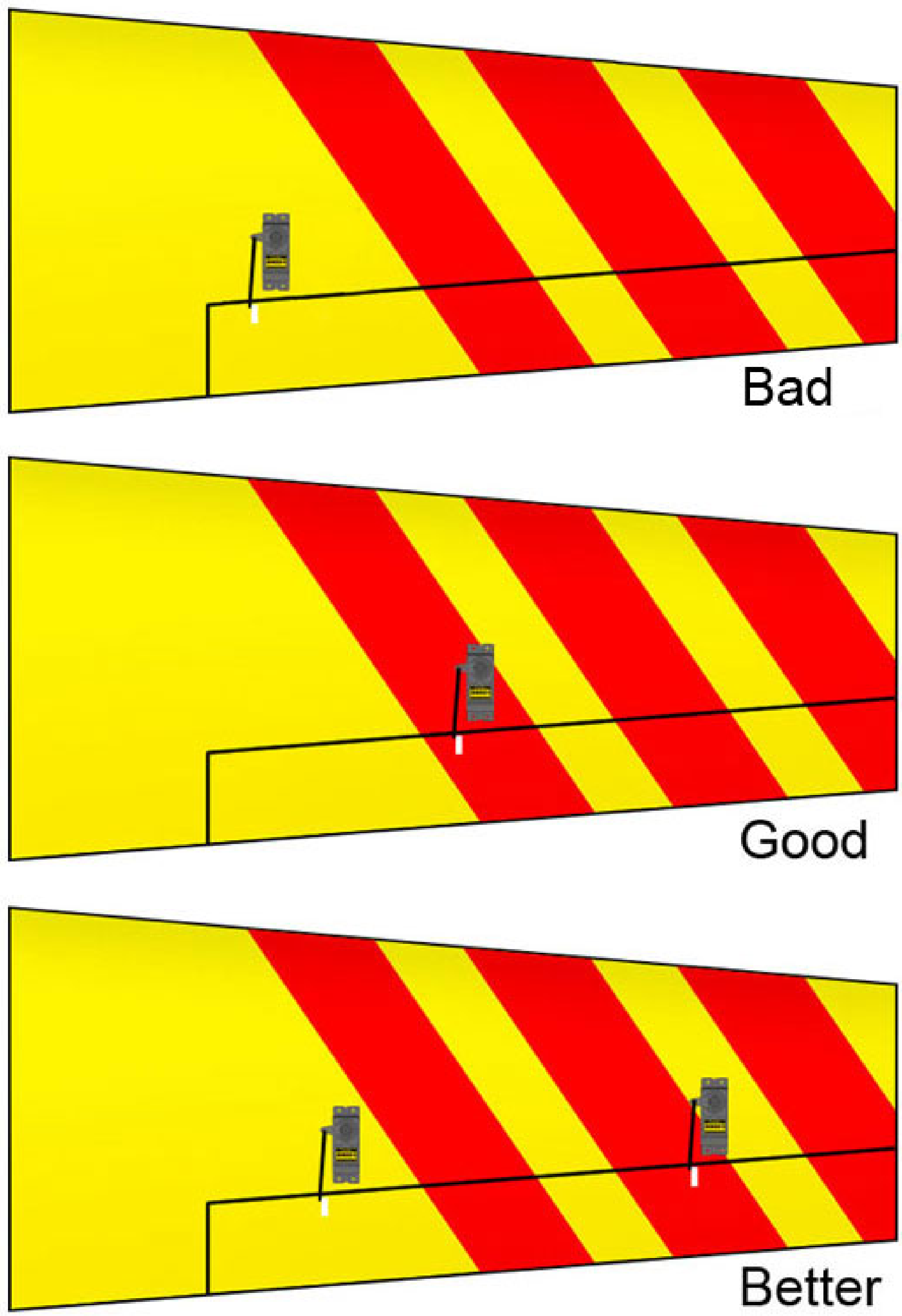


Fig 6

Through the same principle, an aileron can be held firmly at one end while the other end is developing flutter. It's sort of like when you hold a ruler against a desk and smack it. One end of the ruler is held firmly while the other end is vibrating.

This is why your control horn should not be all the way to one side or directly centered on the aileron. This is also why many large-scale planes use two servos (spaced apart from each other) on each aileron instead of one very powerful one - They can now hold and control the aileron at two points instead of just one.



So, what steps can you take to avoid having your plane shake itself to death?

This, like many things will vary from one model to the next, but generally, the bigger the plane/control surface, and the faster it will fly, the more strength you will need. In all cases, a first priority is hinges. All hinges should be secure (including the torque rod if one is being used). For most 40 to 60-size planes, 2-56 pushrods are usually adequate, but if the pushrods are unsupported (as in the case of an aileron servo mounted in a wing) for more than 5 or 6 inches, you may want to consider stepping up to 4-40 rods. Now, if that were a 40 to 60-size high-performance or 3D plane, you might want to go right to 4-40 rods.

Larger planes usually require at least 4-40 pushrods. Many people go so far as to use titanium or carbon fiber tubing, and of course, the bigger the surface, the stronger your servo should be.

But I want to emphasize that there is **no given rule**. It is entirely possible to have a plane that breaks every rule - sloppy hinges, loose linkages, servos with play in them, etc. and never experienced flutter. How is this possible? The answer is simple: because that plane has never flown in or through the envelope where flutter would occur on that particular model.

I once wrote a review of a large-scale plane where the manufacturer recommended standard servos and supplied 2-56 pushrods. Had I bought this plane for myself, I probably would have beefed things up a bit, but since it was a review, I wanted to assemble it as per the instructions (my philosophy here is that it's better that I have a failure with a review plane than you have one with yours). I got many flights on that plane over the next few seasons with no issues whatsoever. Why not? Because the plane was not prone to flutter. Through its aerodynamic qualities, be it by design or just dumb luck, the plane had no flutter issues anywhere in its flight envelope. Of course, it could be that if it were able to go 20mph faster, it may have turned into a pile of sticks (Something to think about if you're one of those people who like to over-power your planes!)

The bottom line here is, don't go crazy. There's no need to put carbon fiber pushrods or high-torque servos on your 40-size sport plane. Just try to keep all of your linkages tight, use servos and pushrods that are up to the task, and when in doubt, make it a little stronger. The wider the control surface is, the more of a mechanical advantage it has so the more important strong servos, heavy-duty pushrods and tight linkages become.

Remember: Flutter is not something that is GOING to happen; it is something that CAN happen IF all of the conditions are right AND your equipment is not strong enough to overcome it.

How can I tell if my plane has flutter?

There are only two ways to detect flutter: The lucky way and the unlucky way.

If you are lucky, you will hear a low-pitch vibration (similar to a baseball card in a bicycle spoke) coming from your plane, SLOW DOWN immediately, land the plane and inspect all control surfaces. Check the covering too, as a piece of loose covering can produce a similar sound.

If you are unlucky, you will know you have flutter when you see one of your wings explode, or have a stab fly off in mid-air.

Finally, let's touch on the "gap" myth.

I can't close this article without commenting on one of the biggest myths surrounding the flutter issue - The gap!

In recent years people have come to the misunderstanding that having a gap between the wing and aileron (or stab and elevator, etc) will cause flutter... **It-will-not**.

Hopefully, now that you understand what DOES cause flutter you can see that having a gap may (or may not) change the speed at which flutter occurs, but it is not and never will be a CAUSE. In fact, some large-scale 3D pilots are now intentionally **leaving** a gap because it creates a really cool whistling sound when they do a snap roll (Hey, whatever blows your skirt up).

There was a time when I always sealed my gaps - even though they were minor. As time went by, I dropped the practice due to the fact that it was time consuming and I found no noticeable difference. Sealing does very little if the gap is small, but if the gap is excessive, sealing it can greatly improve a surface's effectiveness. So it's never a bad idea - Just don't assume that it's going to prevent Flutter!

Pattern and other precision airplanes can also benefit from sealing the gap much the same way that an Olympic swimmer benefits from shaving off all of his body hair - when the competition is that tough, every little bit helps. But sealing a narrow gap on a sport model would have about the same affect as shaving off your body hair to take a dip in the lake. (Take THAT mental image home with you tonight!)

So if you WANT to seal your gap, go right ahead, but learn to do it properly (You can cause more problems by sealing it incorrectly than if you had just left it alone to begin with).

Hopefully now you have a better understanding of what causes flutter and how you can prevent it. For some really dramatic videos, I suggest you do a YouTube search for "flutter". It's amazing how much damage it can do!

Contact Info

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Email Me

Picture of "Kid on Swing" courtesy of my grandson and future flier, Anthony
(Hey, if you want your kid in an article, write one!)

Comments on RCU Review: Minnflyer on: Flutter

Posted by: GraemeEllis **on 10/03/2010** Profile
Excellent article - I always worried about having gaps in control surfaces. Thanks for clearing it up!

Posted by: DelGatoGrande **on 10/05/2010** Profile
On the (bad/good/better) draw wings the servos are placed wrong.IMHO the link need to be 90degrees with the hinge line/cheers

Posted by: MinnFlyer **on 10/05/2010** Profile
You are correct. Brain f@rt on my part :-) but mainly I wanted to show the placement.

Posted by: Cpt Crash **on 10/05/2010** Profile
Outstanding article. Good science, scary video, yeow! Haven't had a problem with it, but suspect one day it will bite. Just hope I'm ready.

Posted by: sprgfvr02 **on 10/06/2010** Profile

Posted by: sprgfvr02 **on 10/06/2010** Profile
Great article. I'm new (1 yr) to R/C, and recently built a Tiger 60. I have a little gap between ailerons and TE. My instructor said I have to close the gap if I decide to go faster. This article cleared that fear up for me. Thanks.

Posted by: flyingagin **on 10/06/2010** Profile

Posted by: flyingagin **on 10/06/2010** Profile

Posted by: flyingagin **on 10/06/2010** Profile
What effect would adding Boost Tabs have on flutter?

Posted by: MinnFlyer **on 10/06/2010** Profile
Again, it will change the "tuning" of the surface. So IF flutter is going to happen, it will happen at a different frequency - of course, the Boost Tab is susceptible to flutter on its own.

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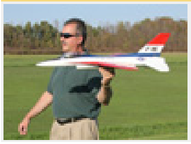
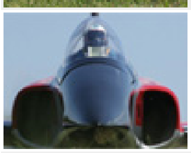
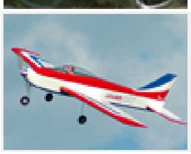
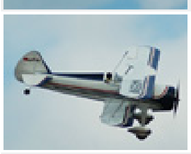
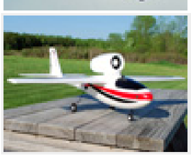
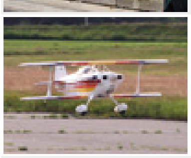
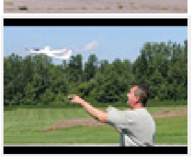
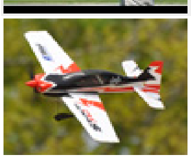
	Great Planes	ElectriFly F-16 Falcon	Great Planes ElectriFly recreates the General Dynamics F-16's innovative design in a ducted fan ARF that combines scale looks...	12/11/2011 **New!**
	ElectriFly	52.5 inch Mister Mulligan ARF	The ElectriFly 52.5" Mister Mulligan ARF is a great looking replica of this legendary 30s racer that is packed with great fea...	12/11/2011 **New!**
	FlyZone	Super Cub RTF	Flyzone has recently introduced a new micro plane: the Super Cub. With a wingspan of just under 18", it's a perfect plane for...	12/11/2011 **New!**
	Seagull	Pilatus Porter PC-6	The Seagull Models Porter can be built with either a 2 or 4 stroke nitro engine, or the kit includes the parts for an EP conv...	11/20/2011
	Hangar 9	Sundowner	The Sundowner 36 flies as good as it looks! We did some very large loops and strong vertical runs so it has plenty of power t...	11/20/2011
	E-Flite	Habu 32 DF ARF	E-flite's new Habu 32 DF ARF takes ducted fan performance and engineering to new heights with a combination of the E-flite De...	11/20/2011
	E-Flite	Leader 480 ARF	The Leader 480 was designed to be a 'precision aerobatics' plane with the great styling of a classic pattern plane. When it b...	11/06/2011
	Electrifly	Super Stearman	I first saw the Electrifly Super Stearman at the Toledo Expo 2011. While looking at all of the new designs, this little aerob...	11/06/2011
	Electrifly	Syncro	That pretty much describes the Electrifly Syncro. It's two very different airplanes combined into one. First, a unique electr...	10/23/2011
	Great Planes	Christen Eagle GP/EP ARF 42.5	Great Planes has recently introduced a new 42.5" version of this air show favorite. When I first saw this plane at Toledo I w...	10/23/2011
	Cox	Sky Cruiser	The COX Sky Cruiser is everything a first plane should be; simple, stable, and easy to fly. This Ready-To-Fly (RTF) electric ...	10/23/2011
	E-Flite	UMX SBach 342	The UMX SBach 342 is a great looking rendition of the full scale two seater version, and designed by Mike McConville himself,...	10/09/2011

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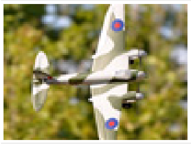	ParkZone	ultra micro Mosquito	The ultra micro Mosquito is provided with a phletora of nice scale features such as a transparent canopy, an authentic mossy ...	10/09/2011
	Tower Hobbies	Razor 3D	The original Razor3D was almost a blend between a pattern and an acrobatic aircraft that also had surfaces large enough to al...	10/09/2011

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