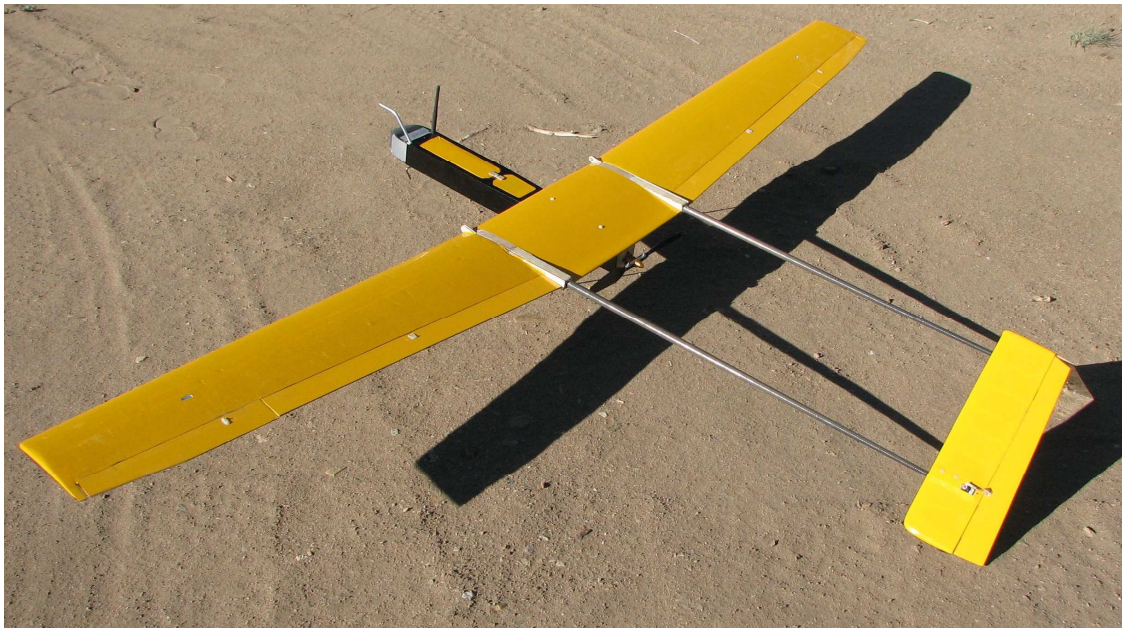


# Model Design for Airborne Sensors

Steven Sarns  
8/26/2010

New advances in technology are poised to revolutionize RC model design. The old process of pencil on paper plans to guide our trusty number 11 blade carefully around the complex curves of a myriad of parts that will be fit together and tossed nervously skyward has given way to a new paradigm. Now the modeler can simulate how well his concept will fly before it is built. The actual building process is facilitated through 3D Computer Assisted Design (CAD) software that will output a file to a laser cutting service so that the parts snap flawlessly together. Finally, instrumentation is now available so that the old “she flew right off the drawing board” idiom can be expressed in numbers.

These techniques are applied to a low-cost 2.5 meter model capable of carrying a 1 kg payload aloft. Design innovations include damage resistance, easy field assembly, flexible landing gear arrangement and efficient aerodynamics designed for electric or glow power. The advantages and disadvantages of various popular configurations, the design process and test procedures used to evaluate the resulting performance are described.



## Part 1 – Planform Tradeoffs

### Introduction

I watch with admiration as my friends fly upside down, loop-the-loop and sometimes even fly backwards. They, on the other hand, watch me fly sedately and wonder why I am not bored. The reason is because my model usually has my latest experiment inside. For a geek like me, the airplane is just the vehicle – its job is to fly; to carry my payload aloft and land without damage.

I need:

- Stability – sometimes I have to turn my attention elsewhere and it's nice to know that the airplane can fly itself for a while.
- Durability and easy repairs – because most of the flights are short duration, the airframe is subjected to an inordinate number of takeoffs and landings, and, truth be told, I am really not a very good pilot.
- Low cost
- Capable of slow flight to facilitate hand launch and low impact landing.
- Ease of transport – the airplane should assemble quickly and break down easily.

Other features that would be nice:

- Efficiency with wide performance envelope
- Electric power with long flight duration
- Generous and easily accessible payload space.
- Pusher configuration to minimize landing damage and reduce the payload / engine interactions.

A “40 Trainer” satisfies the first set of requirements quite nicely. They are slow, cheap, stable and durable. Although they are big, they are not really roomy because most of the room is already allocated to the servos and radio equipment. Repositioning the servos is required to make room inside for a payload. Access to the payload requires removing the wing. The tractor engine configuration makes camera installation difficult in order to avoid getting oil residue on the lens. They are not efficient flyers, consequently, the speed range is limited and if converted to electric power, the flight times are short.

## Design Tradeoffs

The Unmanned Aerial Vehicle (UAV) is the standard when it comes to carrying sensors aloft. The list of design considerations is long. One must continually balance the benefits of each approach against its downsides. The goal is a design that optimizes what is important for the mission against cost. The “mission” in this case is a stable platform that can be easily assembled in the field, robust enough to survive rough landings and carry a gimbaled camera with wireless video link. One principle that I have observed is the “80/20 rule” which proposes that the last 20% of perfection usually adds 80% of the cost.

There are four popular tactical (small; 2 to 3 meter) UAV planforms; the conventional tractor, the twin boom pusher, the single boom pusher and the flying wing.

The Conventional Tractor planform offers excellent aerodynamic efficiency, is well understood and can be designed to provide reasonable payload accessibility. However, the forward engine is like leading with the chin when it comes to a hard landing.



The Arcturus T-15 is a good example of the conventional tractor planform. The Honda engine's exhaust is routed out the top to reduce interference with the forward mounted camera.

The Twin Boom Pusher is the classic UAV configuration. The twin tailboom allows for classic elevator / rudder control with an unobstructed wing which promotes aerodynamic efficiency. The engine thrust line is favorable. The tailboom attachment system requires ingenious design to allow easy assembly and transport while avoiding manufacturing difficulties.



gallons of fuel.

The Aerosonde, originally made by RnR Products, represents the typical Twin Boom Pusher planform. This was the first unmanned airplane to fly across the Atlantic covering a distance of 3270 km in 26 hours and 45 minutes while using only 1.5

The Single Boom Pusher is also a popular configuration. Thrust to pitch coupling can be significant. Propeller efficiency can be a painful compromise between prop diameter and thrust to pitch coupling. The high engine location makes the use of low cost glow engines difficult due to the need for a fuel pump.



**Performance:**

Range: 10 km  
Duration: 90 Minutes  
Speed: 35 to 80 kmph  
Climb Rate: 185 m/min

**Specs:**

Span: 2.8 m  
Length: 1.8 m  
Weight: 3.8 kg  
Payload: 900 g

The Pointer was the first small UAV fielded by the Marines. Developed in 1988, this was a \$35,000 (system cost \$250k) RC controlled model with a fixed video camera mounted in the nose. The original duration was 15 minutes using a NiCd battery. The operator flew by watching a video monitor and pointing the aircraft at whatever was interesting.

Although less popular, the Flying Wing offers the possibility of best ease of transport and durability. The flying wing has always appealed to aerodynamicists as a potentially planform due to the low parasitic drag. results have been disappointing inefficiencies introduced in the wing ensure stability.



efficient  
However, the  
because of the  
design to

Boeing developed the Scan Eagle as a low cost (\$100,000) sea borne sensor

long duration,  
platform.

UAV	Wingspan	Max Weight	Dry Weight	Speed Stall	Speed Max	Endurance	Engine
T-15	3.1 m	20 kg	12 kg	50 kph	165 kph	12 hr	Honda 50cc
Aerosonde	2.9 m	13 kg	8.2 kg	58 kph	140 kph	26 hours	Enya 24 cc
Pointer	2.8 m	4 kg	4 kg	35 kph	80 kph	90 min	300 W
Scan Eagle	3.1 m	18 kg	10 kg	45 kph	128 kph	15 hrs	Enya 24 cc

## Planform Decision Matrix

Although there are other planforms and variations to the four illustrated, these four form a valid basis to discuss the pros and cons of each. This decision matrix shows the relative advantages and disadvantages of each.

Decision Factor	Conventional Tractor	Twin Boom Pusher	Single Boom Pusher	Flying Wing
<b>Aerodynamic efficiency</b>	Excellent	Good	Fair	Poor
<b>Propeller efficiency</b>	Good	Excellent	Poor	Fair
<b>Engine interference</b>	Poor	Excellent	Excellent	Excellent
<b>Stability</b>	Excellent	Good	Good	Poor
<b>Payload accessibility</b>	Good	Excellent	Good	Good
<b>Easy of assembly</b>	Good	Poor	Fair	Excellent
<b>Easy of transport</b>	Fair	Poor	Fair	Excellent
<b>Takeoff</b>	Excellent	Good	Good	Poor
<b>Landing</b>	Poor	Excellent	Excellent	Good
<b>Antenna separation</b>	Fair	Excellent	Good	Poor
<b>Manufacturability</b>	Fair	Poor	Fair	Excellent
<b>Durability</b>	Poor	Good	Fair	Excellent

### Aerodynamic Efficiency

Efficient design will extend the range and the performance envelope and allow a greater ratio of maximum speed to stall speed. Efficiency would best be served with the classic tractor planform as evidenced in competition where efficiency is everything. The twin boom pusher is a close second. Usually the single boom pusher suffers from excessive parasitic drag from the fuselage due to its high frontal profile. The flying wing is the least efficient due to the sacrifices needed to achieve stability.

### Propeller Efficiency

Small propellers at high RPM are not as efficient as a large propeller at low RPM. The airframe must offer sufficient clearance for a large diameter prop. Practical implementations of the flying wing suffer because of the desire to move the engine as far forward as possible resulting in limited prop clearance. The single boom pusher usually is limited to a small diameter prop due to boom clearance considerations or thrust to pitch coupling.

### Engine Protection and Interference

The classic tractor configuration places the engine in front where it is subject to landing damage. Additionally, combustion byproducts of the engine contaminate everything behind it. Any pusher configuration solves this problem. Twin engine configurations are also effective, but to a lesser degree. Moving the engine all the way to the tail (like the Predator) is another solution.

## **Stability**

The conventional tractor has the least side frontal area. This maximizes spiral stability. Pusher configurations may suffer from spiral instability due to the large side area ahead of the CG. The conventional tractor, twin boom pusher and single boom pusher exhibit well controlled pitch stability due to the tail at the end of a long moment arm. The flying wing will require considerable sweep-back to place the wing tips at a sufficient moment arm to achieve the same degree of stability. Sweep-back degrades the efficiency of the wing by promoting span-wise flow. The location of the CG is more critical in the flying wing configuration. Additionally, the heavily loaded flying wing is prone to violent tip stalls.

## **Payload Accessibility**

If there is anything that I have learned from flying payloads it is that there is no such thing as too much space. The twin boom pusher and single boom pusher offer the most convenient configuration with the payload placed in front with unencumbered access from above. The conventional tractor will require the payload to be carried under the wing. The flying wing will be somewhat between these two extremes.

## **Ease of Transport and Assembly**

The conventional tractor and single boom pusher configurations usually have a tail that presents problems when it comes to packing the airplane into a container for transport. The flying wing offers the most compact package to transport with only 3 main components. The twin boom pusher can be tedious to assemble in the field.

## **Takeoff**

Operations will frequently be conducted without the convenience of a runway. Therefore takeoff must be a design consideration. Low wing loading facilitates takeoff. Hand launch is a desirable goal; however as payload and wing loading increase, the stall speed quickly rises beyond the ability of most arms. Pusher aircraft can be dangerous to hand launch although the single boom pusher can be hand launched without risk.

A bungee is the simplest method of getting a modest sized airframe aloft. Any pusher configuration lends itself to a bungee assisted launch with the propeller out of the way.

## **Landing**

The design considerations surrounding landing are critical to a successful airframe. Slow airspeed is one of the keys to the least damage as a result of landing. Any pusher configuration will offer good engine protection during landing.

High lift or high drag devices are best incorporated into a conventional wing as opposed to the flying wing.

One popular landing method is the "deep stall" ("dethermalizer" of old) favored by many small UAVs however this frequently results in damage to the empennage. The Pointer uses the deep stall landing with a specially designed sacrificial tail-boom.

## **Antenna Separation**

Several antennas will be required on most payload applications. It is important that power from onboard transmitters not be coupled into onboard electronics. The easiest way to ensure this is by separating the antennas. The flying wing offers the fewest choices of antenna placement.

### **Manufacturability**

The flying wing has the least number of components. The twin boom pusher has the most.

### **Durability**

The conventional tractor suffers the most when it hits the ground. Considerable damage to the engine / firewall usually results. The flying wing is outstanding when it comes to crash resistance. The most damaging event in a conventional airframe is when a wingtip catches on the ground. When this happens, the tail is whipped around resulting in damage to the rear empennage. Several factors mitigate the effect when a flying wing wingtip is caught. First, there is no empennage. Secondly, because of the sweep angle, less rotational energy is imparted to the airframe (particularly if the wing is caught by a bush or other flexible obstacle). The twin boom pusher is quite durable due to the strength of the central structure.

### **Other Design Considerations**

The twin boom pusher is the only planform that adapts well to the inverted V-tail. There are several noteworthy advantages to the inverted V-tail.

- The tailplane cannot be completely blanketed by the wing downwash
- Pitch and yaw response are not influenced by the propwash
- Reduced vortex drag due to fewer intersections
- Yaw produces favorable roll

### **Mission Specifications**

The design criteria were established as follows:

Range – 2 miles. A limited range is a result of three factors; one practical limitation and two legal issues. First, the maximum range of most RC control links is less than 2 miles. Secondly, it is against FAA regulations to fly a model aircraft beyond the **unenhanced** visual range of the pilot (binoculars or First Person View are not allowed). Lastly, it is very difficult to find a legal video transmitter that will transmit over 2 miles.

Airspeed – The limited range obviates the need for high airspeed. Consequently, a low stall speed to facilitate takeoff and landing is achievable.

Payload – 1 kg (2.2 lbs) of payload capacity. Payload weight includes flight batteries.

Duration – A minimum 60 minutes of flight under electric power with 50% of payload dedicated to batteries.

Ease of transport and field assembly – Unit must be able to be transported in a disassembled state and then reassembled quickly and easily.

## Part 2 – The Design Process

The pros and cons of various configurations of airframes suitable for carrying experimental sensors aloft have been discussed. This is a detailed description of the design process.

### Planform Selection

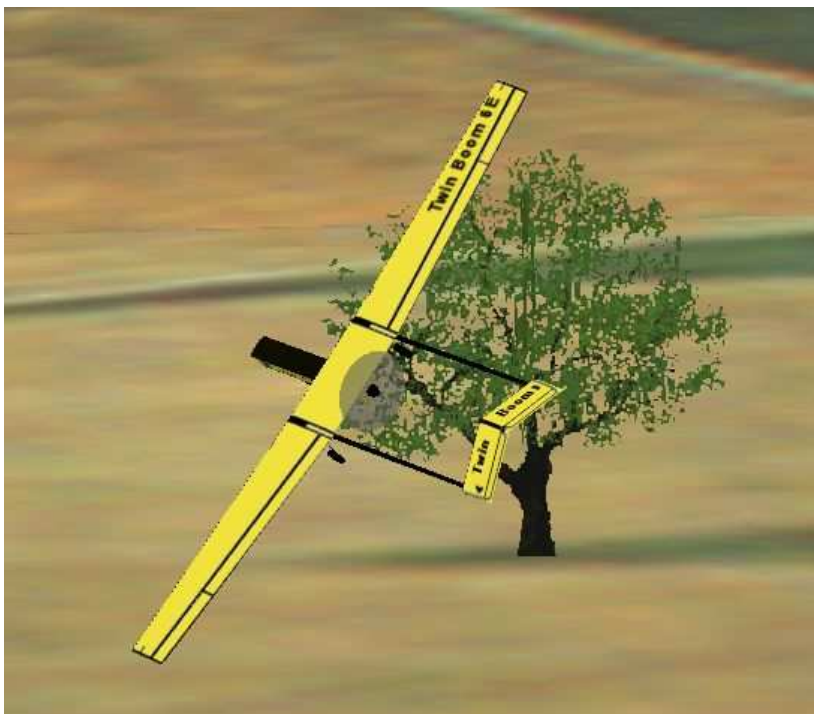
The Twin Boom Pusher was chosen as the most desirable configuration for the application. The choice was driven by several considerations:

1. I fly in an unimproved, sandy area where landings are always rough and frequently involve pouring sand out of the motor or engine. The twin boom pusher offers good durability and engine protection.
2. The twin boom pusher offers good stability over a wide range of CG locations
3. The camera can be carried ahead of the engine.
4. The twin boom pusher has the easiest payload access.

The design challenge is to devise a twin boom pusher that can be broken down for transport, quickly assembled in the field and strong enough to survive landing in unimproved terrain.

### Aerodynamic Simulation

The preliminary design was simulated using the FMS flight simulator to assist in determining



control surface sizes, horizontal tail volume, vertical tail volume and dihedral for optimal stability. This process is considerably faster than building a model, flight testing and modifying or repairing after each test flight.

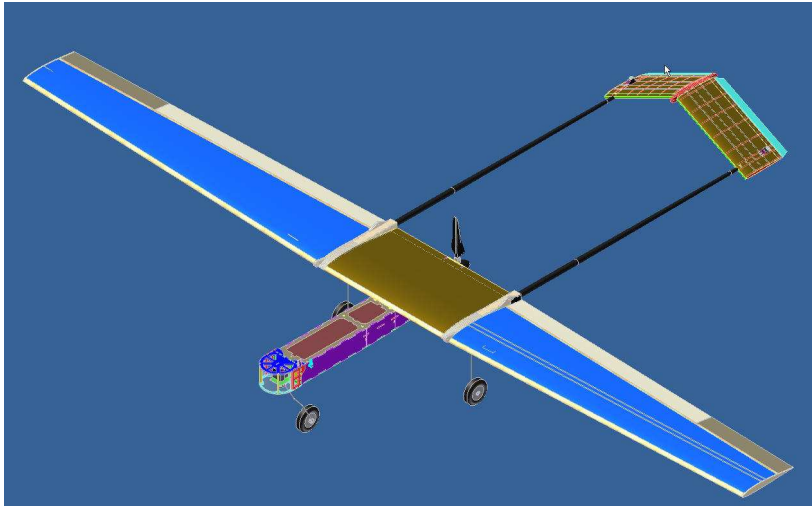
The FMS flight simulator is a freeware program that provides a relatively accurate flight prediction. Gary Gunnerson's web site [http://gunnerson.homestead.com/files/fms\\_models.htm](http://gunnerson.homestead.com/files/fms_models.htm) has links to the source, FMS resources and has a wide range of freely available models ready to download.

Gary's personal

assistance was invaluable in developing the simulation for the twin boom pusher model. Gary is also the moderator for the FMS forum at [http://n.ethz.ch/~mmoeller/fms/main\\_e.html](http://n.ethz.ch/~mmoeller/fms/main_e.html).

### Design Details

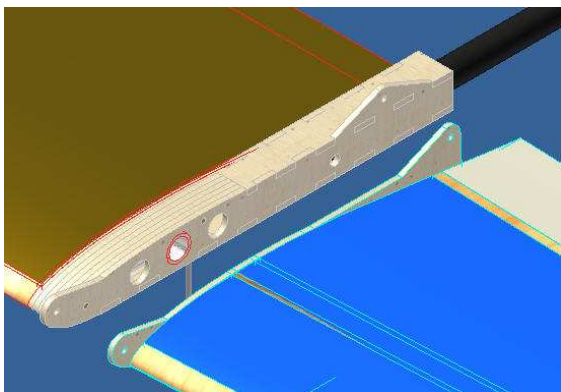
The design was created on a 3D CAD system in order to have the parts laser cut and increase the probability of a proper fit when assembled. A CAD based design also makes revisions and improvements much easier.



Profili2 was used as the primary airfoil evaluation tool. The MS2-9.5 airfoil was chosen for its wide efficiency range. An Excel spreadsheet was used extensively to evaluate the evolving overall design in terms of flight surface areas, center of gravity, tail volume requirements and the resulting predicted flight performance.

The central mechanical design issue that separates the twin boom pusher from a conventional tractor is the torsion exerted on the central wing structure by the booms and fuselage. This bending moment is not an issue with the conventional tractor. Ply sheeted foam was chosen for the central wing to take advantage of the high torsional strength of this construction method. A 5/8" aluminum tube main spar provides bomb-proof strength and a convenient joiner system. The central spar is designed to be the locus of all loads. The landing gear, booms, fuselage and outer wing panels are attached as directly as possible to this load bearing member. The result is a low cost, strong, easily manufactured central module around which can be attached other easily modified components.

Another critical issue with the twin boom pusher platform is the difficulty of devising a method of securely and conveniently attaching the tailbooms to the wing. A plywood "boom box" is the boom-to-central wing joining method. These are permanently attached to each side of the center wing section. A single nylon screw retains the tailbooms in the boom box. The boom to boom spacing provides clearance for props up to 18" in diameter.



#### Wing joint detail

The outer wing panels should be a low cost unit so that replacement in case of damage is painless. The outer wings are blue foam with four spruce spars. The outer wings slide onto the main spar with telescoping aluminum tubing. Two screws insure correct registration and securely fasten the outer wing panels to the central wing.

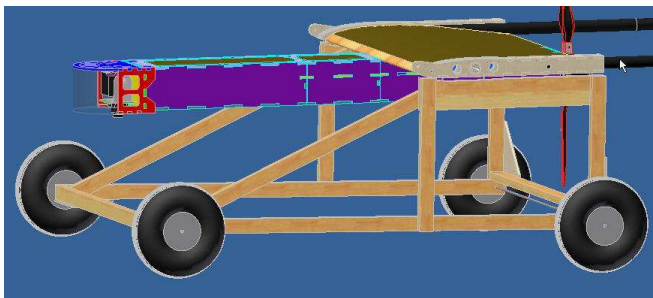
The inverted V-tail is built-up construction for light weight. Each half of the inverted V-tail is permanently attached to a boom box at the end of the boom. Two screws join the center of the tail halves.

These main modules are held together with frangible nylon retaining screws sized to break during a hard landing in an effort to minimize damage to the airframe.

Our test flights were conducted with a low cost 1.7" diameter, 770 kV, "Monster Power 32" brushless motor, a Master Airscrew 12" x 8" folding prop and powered with 11.1 Volt lithium polymer batteries. The folding propeller eliminates broken props when landing without a landing gear. The hub is tightened to prevent the blades from folding in flight. If the blades did fold during flight, it would be possible for one blade to fold over-center (because there is no fuselage to prevent this).

### Landing Gear

The issues surrounding launch and landing are critical to success because the plane will frequently be launched and landed away from prepared airfields. The landing gear design allows the user to chose between several configurations; tail dragger, tricycle, or bungee launched with or without a dolly.



Detail showing airframe on launch dolly

### Transportation and Field Assembly

The design goal of easy field assembly has been achieved. The aircraft is carried to the field with the fuselage attached to the central wing, tailbooms attached and the inverted V-tail halves connected. This structure is wider than a typical Conventional Tractor fuselage, but at only 20" wide, poses no problems in getting it into the back of most cars. Once at the field, the assembly consists of installing the outer wings.

Packing for shipping is also easy. With the fuselage removed and the tailplane folded flat, the result fits easily into a 12" x 24" x 48" container for transport by UPS or Federal Express.

### The Completed Model

Weight, ready to fly w/o battery	2.25 kg	4.9 lbs
Battery, 3 cell LiPo, 4.4 AH	.35 kg	.8 lbs
Length	1.6 meters	62 inches
Wingspan	2.5 meters	96 inches
Wing area	.58 square meters	876 square inches
Wing loading	kg/square meter	16 oz / square ft
Gross weight (MTOW)	3.6 kg	8 pounds
Minimum speed, flaps	25 kph	16 mph
Speed at minimum sink	30 kph	19 mph
Rate of Climb	3 m/sec	600 fpm
Duration with .5kg battery at 33 kph	1 hour	1 hour

## **Sidebar – The Law**

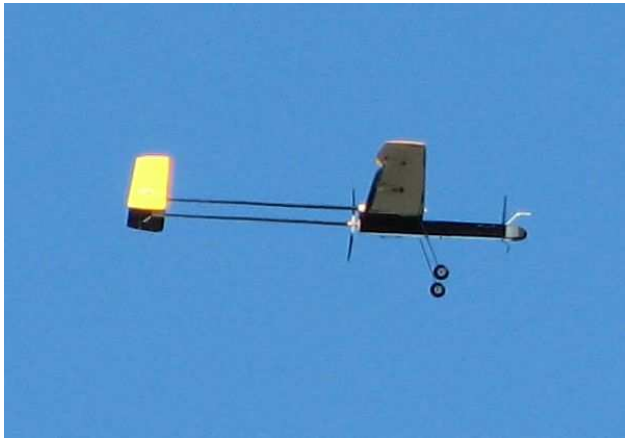
If you fly at an AMA site, you may be asked if you are within the legal boundaries of our sport. The good news is that it is possible to conduct airborne experiments within the law. The bad news is that there are pretty narrow confines hemming us in.

The FAA regulates anything that flies in the United States. The FAA issued AC 91-57 guidelines for model aircraft operations in 1981. As with anything legal, there are conflicting interpretations concerning the legality of what we are doing. However, that said, it is clear that a model aircraft cannot be operated for a commercial purpose such as taking photographs for a customer. It is also clear that model airplane regulations only apply to aircraft under the unenhanced visual control of the RC pilot. AMA officials have stated that model airplanes piloted over a wireless video link at an AMA sanctioned facility must be flown on a buddy-box equipped system with the “instructor” in visual contact with the aircraft at all times. Furthermore, the FAA has stipulated that video equipped models are limited to 10 pounds in weight and 60 mph maximum speed.

The FCC regulates all radio emissions. A special section of the regulations called Part 15 applies to those devices that do not require an operator’s license e.g. your wireless network router. Any legal transmitter will have an “FCC Type Accepted” label attached. License free operations are permitted in the 900 MHz and 2.4 GHz frequency bands. Operations in the 900 MHz band are limited by specifying the maximum radiated signal strength of 200 uV/m, effectively limiting the range to about 150 feet. Operations in the 2.4 GHz band allow a maximum power of 250 mW which, when equipped with good antennas, can reach further. The bottom line for legal long range wireless video is to get an Amateur Radio license. Since the requirement to master Morse code has been removed, the test is easy. A “ham” radio operator can legally output up to 1.5 kW of power.

## Part 3 – Testing and Evaluation

A design for a 2.5 meter Twin Boom Pusher model aircraft has been described. Now the testing begins.



Picture of Twin Boom Pusher in flight

### Testing and Performance Evaluation

The first test is the static load wing test. The model held up under 3G of imposed wing load. This was deemed sufficient for our purposes. Evaluation of the not-to-exceed airspeed at which the load on the wing exceeded 3G worked out to 124 kph (78 mph) flaps up and 109 kph (68 mph) flaps down.

### Test Configuration

Testing was conducted with a 3 cell LiPo 4.4 AH battery. The motor used was an Exceed "Monster Power 32" with a Kv=770 RPM/V,  $I_0=2.4A$  and  $R=.02$  Ohms turning a Master Airscrew 12x8 folding prop. The ready to fly weight was 6.1 pounds with landing gear and battery.

The motor / propeller / battery choice was evaluated on the bench by noting the power drawn by the motor at full power. This was logged at 30 Amps. At a nominal voltage of 12 Volts, the power supplied to the motor is 360W or about 60 W/lb – more enough to fly and climb with authority (a rule of thumb is that a minimum flight requirement is ~25 W/lb).

A short 8" folded foil RC antenna was installed due to the problems of routing a straight 39" antenna. This proved reliable at distances up to 1 mile.

### Stability

The design was test flown to evaluate pitch and spiral stability. The model was pitched down at approximately a 45° angle with power off and the elevator stick was centered. The angle of dive did not increase and the model returned to level flight after several "phugoid" oscillations. The test was repeated at 100% throttle. Spiral stability was checked by banking the model to 45° with power off and the ailerons stick was centered. The angle of bank did not increase and the model returned to level flight after less than 2 complete rotations. The test was repeated at 100% throttle.

These tests were repeated at various flap settings.

Stability could not be reliably achieved in all power configurations. Therefore, a flight restriction was imposed that prohibited full power unless the pilot was in clear visual control of the airplane. A "blind" recover procedure was created that would take advantage of the plane's most stable configuration; 20 degrees of flaps and 50% power with all flight controls centered.

### **Instrumentation**

With the advent of inexpensive flight instrumentation, we can gain a new level of understanding of our model's performance and actually measure the impact of design tradeoffs such as a comparison of the cost in terms of power of a more aerodynamically efficient tapered wing versus a more easily manufactured rectangular wing.

The prototype was outfitted with a data logging instrumentation system that recorded key data including altitude, airspeed and power usage in addition to providing altitude and airspeed hold functions. Analysis of this data allowed quantification of the actual aerodynamic performance.

### **Calculated Aerodynamic Characteristics**

Best L/D for the MS2-9.5 airfoil occurs at an alpha of 5 degrees. In our design, this occurs at 38 kph (24 mph) with a total weight of 6 pounds.

Finding the configuration for minimum sink is a bit more complex. Minimum sink is found by evaluating the "power factor" defined as  $C_L^{1.5}/C_d$  or the (coefficient of lift to the power 1.5 divided by the coefficient of drag) at various airspeeds and various flap configurations. This is the flight configuration that requires the least power to stay aloft. Maximum duration flight is achieved with a flap setting of between 10 to 15 degrees at an airspeed of 34 kph (21 mph).

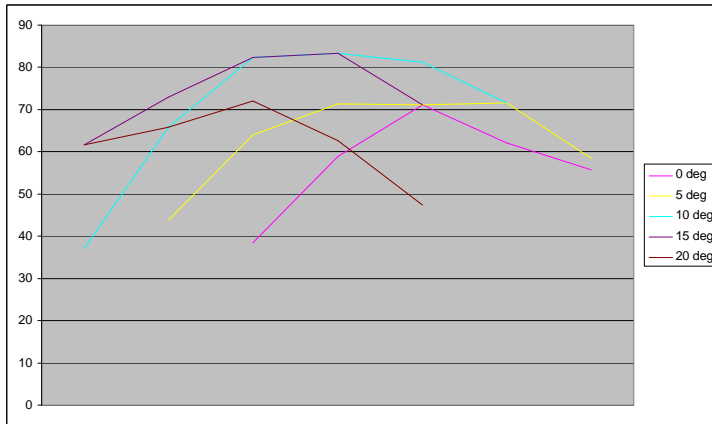


Chart of power factor for various flap settings

## Flying

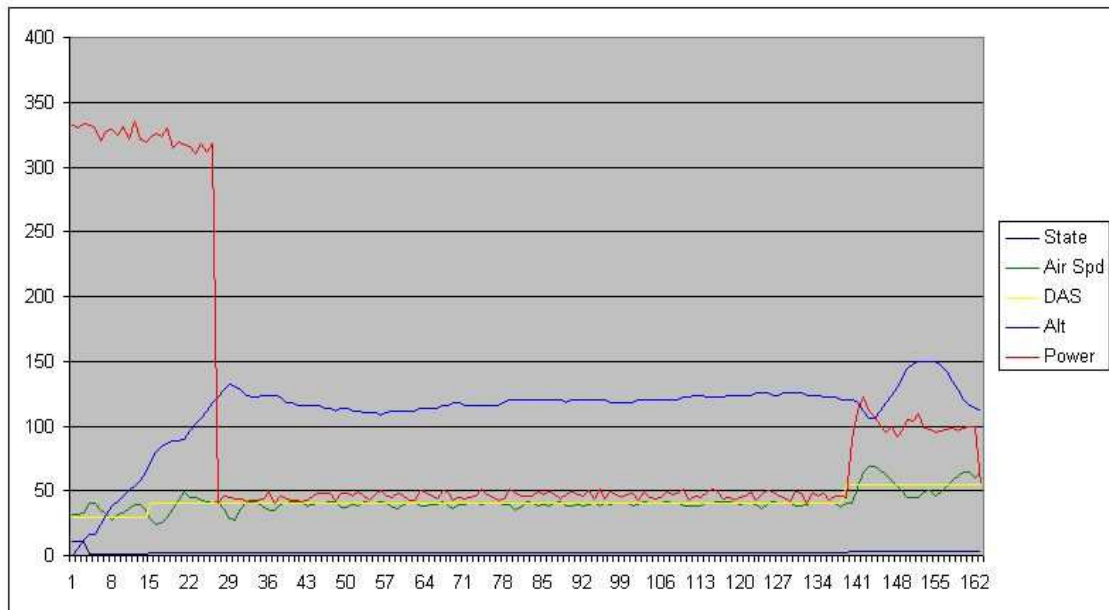
Although the model can be hand launched from a running start, there is not much time between the release and the need for full throttle. Therefore, hand launch is not recommended by the pilot or for the first flights. If a runway is available, launching is easy with a 50' takeoff run required. If you do not have a runway, then the bungee assist method makes launching a snap (ar ar). The model was tested with a tricycle landing gear configuration. The nose gear was replaced with a bungee tow hook. A 100 foot heavy duty high-start was doubled (50 feet long) and then stretched to 125 feet. The airplane was airborne in less than 10 feet with the motor off.

Under full throttle, the ship climbs with authority up to altitude at a rate of 600 feet per minute.

Landing is easy when the flaps are deflected. The descent rate is 300 feet per minute at 30 kph with 45 degrees of flaps. Higher rates of descent are possible with the full 90 degree flap deflection. Flap deflection produces moderate nose up pitch.

## Analysis of Results

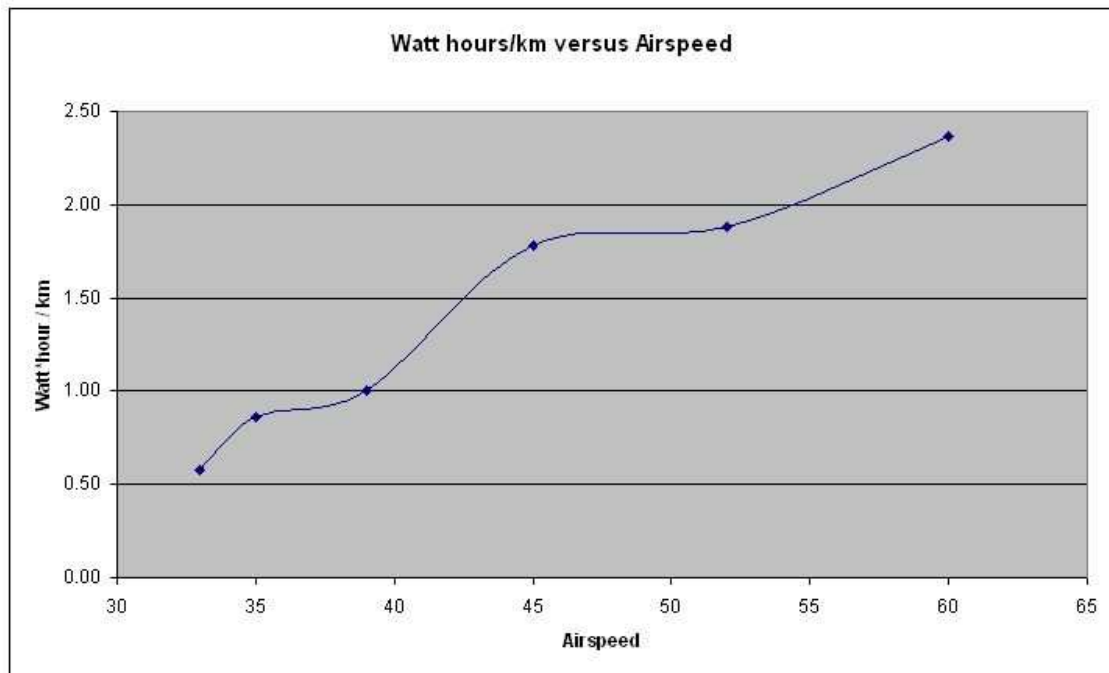
The test results were quite surprising. Here is a typical graph showing airspeed, desired airspeed, altitude and power. Power was calculated as the product of the current out of the battery times the battery voltage.



Graph of Airspeed (green), Desired airspeed (yellow), Altitude (blue) and power (red)

The good news was that surprisingly little power required for flight. The airplane would fly with just 30 Watts of power at an airspeed of 33 kph. The bad news was; this is too good to be true. I double-checked the sensor calibrations and repeated the flight tests with the same results. A further analysis of the total power removed from the battery compared to the integral of all of the power logged during the test flight showed close correspondence.

The next surprise came when I calculated the amount of power required to fly 1 kilometer. I had expected to see a minimum near 38 kph, the speed at best L/D for the airfoil. However, the data did not reflect this. As the following graph shows, the slowest airspeed (33 kph) resulted in the least energy needed to fly 1 kilometer.



Graph of energy required to fly 1 kilometer at various airspeeds

## Conclusions

The ability to simulate a model before construction is a wonderful convenience. The simulation accurately predicted many of the key performance characteristics.

Modern CAD systems are amazing. The strength of the resulting laser cut structure is much greater than hand cut parts because of the ability to create intricate interlocking components.

The ability to quantify the actual flight performance of a new model offers the opportunity for endless experimentation;

- What are the energy requirements for added payload?
- What is the energy penalty of the landing gear?
- How does wing shape affect efficiency?
- How does propeller/motor selection affect efficiency?
- How do various flap settings affect best hang time?
- What is the optimal airspeed and flap setting for best rate of climb?

I am sure that this new source of data will be keeping me off the streets for some time to come. Further information is available at [www.flying-eye.com/UAV.html](http://www.flying-eye.com/UAV.html). If you have any questions, you can email me at [sarns@co-isp.com](mailto:sarns@co-isp.com). Thanks for reading!