

## *About the author, Chris Heintz*

Aeronautical engineer Chris Heintz, the designer of [Zenith Aircraft](#) Company's line of kit aircraft, is one of the most qualified and knowledgeable light aircraft designers today. With prior experience from Aerospatiale, de Havilland, and Avions Robin (France), Heintz has designed and introduced more than 12 successful kit aircraft designs. Recently, the ZENITH CH 2000 design was put into production as a standard FAA type-certificated production aircraft.

Heintz regularly shares his design and construction expertise as a speaker to aviation groups and students of aeronautical engineering, and is a regular speaker at both the EAA Oshkosh and Sun'n Fun fly-in conventions. An aeronautical engineer, Heintz has the unique ability of being able to simplify design concepts and to clearly explain and illustrate light aircraft design and construction.

Chris Heintz' articles were published in the Experimental Aircraft Association's (EAA) Light Plane World or Experimenter publications.

## **CHOOSING THE DESIGN OF YOUR AIRCRAFT**

*By Chris Heintz*

Whether designing an aircraft or deciding on a specific design to build, much the same process of thought is involved in order to come to the right decision. Almost all of what we will discuss in this article with respect to a basic design for a new aircraft can very easily be applied, and the same questions answered, to help you decide which aircraft design you should build and/or own. Going through this process should help assure that your choice of aircraft will be a useful and enjoyable part of your material assets in this life.

*A written* list of the qualities you would like to see in your aircraft is an absolute necessity. It might contain such requirements as:

- Ease of construction
- Low landing/take off speed
- High rate of climb
- Good cruise speed
- High ceiling
- Comfortable seating space
- Outstanding visibility
- Acceptable noise level
- Easy ground handling
- Good visibility during taxiing
- Good handling in the air
- Large panel to show off with full IFR

- Excellent low speed controllability

And the list could go on and on. There may be some very special things you need in order to make your aircraft truly useful for your individual life style, such as:

- 300 ft. roll take off and landing (because your private strip is only 600 ft. long).
- 40 lbs. baggage capacity (because your better half likes her creature comforts -but remember, you'll have to carry it to the motel!)
- 260 lb. pilot (because you do not like diets)
- good high altitude performance (because you live at 8,000 ft.)
- adaptability on wheels or floats (because you live in town but your cottage is on the lake)
- removable or folding wings (because hangars are too expensive).

After the first general list of desired qualities, and the second more individually specific list, a third more practical list should be developed, including such basic questions as:

- Can I build it?
- What's the total cost?
- Can I design it (or is the designer reputable so that I can trust his design reliability)?
- Will it have low maintenance costs?
- Will it be easy to maintain?

Now that you've made these lists, make a couple of copies and hang one on your workbench, one on your desk, etc. to look at and think about for a few weeks. Refer to them from time to time, adding as many things as you like until you feel you've got all the appropriate variables covered.

With all this information in mind, you have the framework to start looking at aircraft. As a designer of many original aircraft, I am not talking here about a "reproduction" aircraft, but a brand new design in which every part will be checked for adequacy according to present day, state-of-the-art technology. In other words, we're going to start from scratch and not consider a Cub wing on a Citabria fuselage with a Cherokee tail and a Cessna gear. Rather we're going to think about a new design where a 12 hp engine can take off with four people in 300 ft, at 3,000 fpm, cruise just below the speed of sound for 8 hours, come in a kit that can be built in 50 hours for less than \$3,000, with a designer who is willing to spend 120% of his time improving his design to the builders suggestions!!

All jokes aside, before I put someone into cardiac arrest thinking such an aircraft *could* exist, we have to stay realistic. Our machine will have to be built with known raw materials, using well proven techniques, and the design will be subject to gravity (earth attraction) drag (wasted energy), and powerplant efficiency just like any other. So, of necessity, we must start out with certain basic limitations, but we won't let that

discourage us because there are many proven, good designs available. We certainly can design one ourselves or find an already existing design that meets our needs.

Now, we'll go back to our lists and this time we'll strike out the unreasonable items. This is simply a matter of *common sense*. We all have common sense - it just gets a little bit damaged sometimes during our formal education, but if we are to have any success in life, we have to listen to it very carefully. If we dream the impossible we will become a dreamer unless we are geniuses. But experience tells us that geniuses are the exceptions, so the majority of us has to live with common sense. Reality puts us back on track when we listen too much to our dreams.

The next step after our lists have been made reasonable by common sense is to rearrange them. This time we'll combine all our variables onto one list and rearrange them in a decreasing order of importance.

Now, our list may look like this:

- Low landing speed
- Outstanding visibility
- Low cost
- Comfortable seating for two
- 400 lbs. (pilots and passenger and baggage)

or this:

- Low cost
- Design confidence
- Reasonable cruise speed
- Good handling (air and ground)
- Removable wings

Our list may still contain some incompatibilities, such as low cost and high cruise speed, or sexy looking design and low maintenance etc., so now is the time to eliminate the incompatibilities or change each one slightly to bring them closer together. Using the previous example, we could have acceptable cost (say \$30,000) and cruise at 150 mph or have a good looking airplane with acceptable maintenance (less than 1 hour to remove all fairings).

We have to be very careful when interpreting adjectives (what is good looking to me may be ugly to you, what is acceptable to him may be unacceptable to her!). In order to avoid misunderstandings on this subject, our civilization has unsuccessfully tried to quantify everything - and I say unsuccessfully because quantifying will stay just that as long as we deal with human beings and not strictly with machines. (I classify computers as machines, too, by the way)

We all know how the same statistics can be used to justify white or black, blue or red depending on the speaker's beliefs and skill of convincing others. But we are not in politics, not even at a sales or hangar flying session. We are simply trying honestly to design a good new aircraft. But we need figures so we have to write them down and as we work with gravity (weight), drag (pounds) and other physical qualities, we add onto our lists whatever we can quantify, being aware that some items (numbers) may have to be left blank.

Our list may look like this:

- Stall below 45
- Visibility 360 degrees
- Airframe cost below \$14,000
- Comfort ( )
- Must carry two (400 lbs)
- or this:
- Total cost below \$30,000
- Reliability ( )
- Cruise speed 120 mph
- Handling ( )
- Removable wing (7-1/2 ft. max)

Now, we have to start compromising. It is this *accepted compromise* which will make for a successful long-term choice. For example, one has to compromise between 360 degrees unobstructed visibility and a high wing: either you stay with a high wing (which needs hefty uprights) and reduce the visibility requirements, or you stay with 360 degree visibility and have to install a bubble canopy on a low wing aircraft.

The same applies for low stall speed, high cruise speed and low cost (here we have three variables). High cruise speed means large wing, high lift airfoil, low powerplant and fuel weight. Low cost means single wing (no retractable high lift devices) a small wing and low horsepower.

So, one goes down the list again and again compromising and keeping in mind that the items were listed in a decreasing order of importance. After making more adjustments to reduce any incongruities, the next thing we'll need to do is work with some calculations.

**Weight:** Statistics show that the empty weight of most aircraft is close to 60 percent of the load carried (passengers and fuel). As you have a good idea of the engine, add the fuel required for the desired endurance (as a rule of thumb, if the engine is rated at 100 hp, you'll burn 6 U.S. gallons per hour at 75 percent cruise and 1 U.S. gallon weighs 6.0 lbs. For example, with 120 hp and 3 hours range, you need 130 lbs. of fuel, so the gross weight (W) in lbs. equals 1.6 (occupants plus baggage plus fuel).

**Wing area:** You know the maximum lift co-efficient (CLMAX) of the chosen airfoil (if you have no better idea, use 1.4 no flaps, 2.2 for the portion with flaps, and 3.0 for flaps

and leading edge slots) and can calculate the wing area (S) knowing the desired stall speed:

$$\sqrt{\text{stall in mph}} = 19.75 \times \sqrt{\frac{w \text{ (lbs)}}{\text{sq.ft.}} \times \frac{1}{\text{CL}_{\text{MAX}}}}$$

Your **top speed** will be close to

$$\sqrt{\text{mph}} = 190 \sqrt[3]{\frac{\text{BHP}}{\text{sq.ft.}} + 100}$$

(for a very clean aircraft you may replace 190 by 210)

Your **cruise speed** is some 90 to 95 percent of the top speed.

You will have an idea of the **climb performance** by calculating  $\frac{W}{S} \times \frac{W}{\text{BHP}} = P$

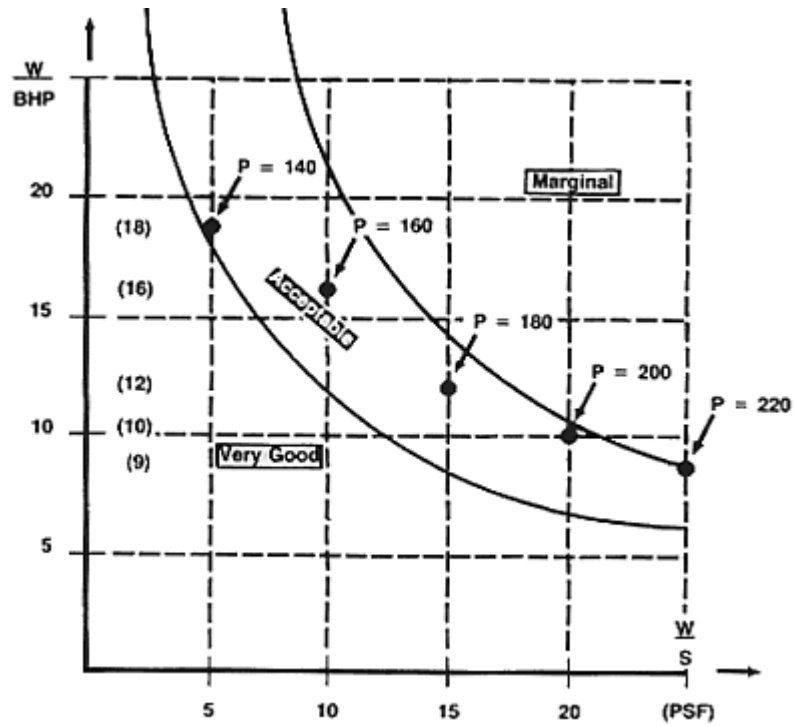
Where **W** = gross weight (lbs.)

**S** = wing area (sq. ft.)

**BHP** = Rated Brake Horsepower of engine

The "statistical" diagram below gives you very good take off and climb performance if your aircraft is below the curve.

These calculations are the basis for making some design decisions. Combining the results of these calculations with the variables on our list will begin to make our design choices fairly obvious, thus we are on our way to beginning the actual design, or choosing the design, that we are going to build.



This "statistical diagram" gives you very good take off and climb performance if your aircraft is below the curve.