Flight Testing Homebuilt Aircraft

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"Test Pilot"

The name conjures up images of macho excitement equaled by few other professions. The words inspire images of Tom Cruise, "the right stuff," leather jackets and screaming dives in which only the "test pilot's" skill, strength and incredible courage stand between a successful pullout and a large smoking hole in the ground. The test pilot has ranked in Hollywood with that of the secret agent for mystique. Unfortunately, test flying in Hollywood fiction is just that – fiction.

Today's test pilot is a highly trained professional, probably middle aged, a college graduate and a family person. The best test pilots approach their profession with the intellect and intensity of an orchestra conductor. This is not a bad analogy because the test pilot for a major test program is supported by tens, sometimes hundreds of experts ranging from mechanics to engineers and designers and by masses of special equipment from telemetry systems to spectral analyzers.

There are other test pilots who don't fit this image. Every year hundreds of amateur-built aircraft are completed, signed off by the FAA and flown, often by their builders. The pilots of these airplanes may not have the training, experience or extensive support of military and industrial test pilots but they are just as much test pilots as the professionals.

Unfortunately, lack of knowledge and training means that few homebuilt aircraft are properly tested. Simply flying off the hours mandated in the FAA phase one testing accomplishes little more than burning fuel. Furthermore, if approached with little knowledge and a poor attitude, it can be quite risky. The results can include accidents that wreck airplanes and hurt people or airplanes that fly poorly because the builders do not know how to make them fly better.

All is not lost, however, because amateur builders can use a few basic methods and techniques to do a perfectly adequate job of flight testing their own airplanes. The purpose of this book is to give you, the builder, tools to test your creation safely with professional results.

Although we talk a lot about specific techniques and tool, the most important thing to understand is the basic definition of flight testing. Flight testing is the step-by-step process of learning an aircraft's limitations, defining and fixing its problems and determining its capability and optimum flying techniques. Each step in the test process is designed to prepare both the pilot and the airplane to progress to the next step with a minimum of risk.

Understanding and working with this philosophy is important because there are few hard and fast rules in flight testing. Every airplane, every pilot and every test situation is different and will require different treatment. This book provides guidelines derived from years of painful experience but it is not a cookbook. It cannot cover every situation you may experience nor will it always provide the solution for your specific problem. Use this book as a guide to develop your own test program. It should help you decide what you are trying to accomplish and the best way to accomplish it.

This book breaks the flight test program down into four phases: preflight, first flight, envelope expansion and performance. Preflight is the phase of flight testing that prepares the aircraft to move under its own power. It includes things such as rigging, measuring weight and balance and fuel flow checks. The first flight phase starts when the aircraft moves under its own power and ends at the conclusion of the first flight. It includes taxi tests, landbacks, and the flight itself. Envelope expansion is the process of determining the aircraft's envelope and limitations and of making the aircraft fly properly within that envelope. The last phase, performance testing, is used to determine what the airplane can do and the optimal way to get the most from it.

This sounds like an awful lot of work. Why bother? Is it worth it? The phase one restricted period mandated by the FAA for amateur built aircraft is forty hours or less. It certainly would be easier to bore holes in the sky for forty hours, but what a waste! If you can discipline yourself to flight test your airplane properly you will increase your knowledge of your airplane and its capability tremendously. You will also notice a significant improvement in your own piloting skills. You may even find this business so fascinating that you spend way more time developing your airplane than the law requires. Are you still with me? Let's get started.

How to Begin

CHAPTER 1

The flight test process should begin when you first spread out your newly acquired plans on the kitchen table and begin figuring out how to build your airplane. You'll want to ensure that a number of design features are present; both for safety and to make the most commonly required modifications easier. If you are building from a kit or well-established plans, you may not feel that you have the freedom to make modifications. However most of the modifications we will discuss will not alter the basic design of your airplane. The may even improve features that are often poorly specified by the plans, if they are called out at all. Besides, this is your airplane, and most homebuilders are inveterate "improvers" anyway, especially when they can improve safety or accessibility.

In order to make our discussion more logical, let's discuss the design features system by system.

The Cockpit

The first consideration in a cockpit is space. You will need enough space to be comfortable for fairly long periods of time, to reach and operate all the necessary controls and to escape from the aircraft if necessary. Cockpits with size or configuration issues were much more common in the early days of homebuilding when individuals often designed their aircraft around their own physical configurations. Today, with well-designed kits intended for broad audiences, this problem is rare, however the exercise is worth doing especially of your body is of odd size or shape (as mine is: long back and short legs). Most builders discover cockpit space problems when construction is well underway. This leads either to a lot of cutting and splicing and rebuilding (and swearing) or to living with discomfort or awkwardness for the life of the airplane. An easier way is to discover these problems before serious construction is underway and to fix them as you build.

If you are building from plans or a kit and you can find someone near you who is building or has built the same airplane, go and sit in it, even if it isn't flyable. If you can't find one to sit in, or are designing a unique aircraft, a cockpit mockup is a good idea. It doesn't need to be fancy, but it should have the shape of the instrument panel, the important controls and the door or opening you'll use to get in and out. It should also be dimensionally accurate and be strong enough for you to get in and out and move around inside without breaking anything.

To use the mockup best you should configure yourself in a "worst case" configuration. If you intend to fly your aircraft in cold weather (if you live in the northern tier of the United States for example) wear your winter flying clothes. You will be amazed how cramped that cockpit suddenly becomes. If you are going to wear a parachute and/or helmet (I strongly urge you to wear a helmet) put them on and climb in. You should fit comfortably. This is not meant to be funny. If you are a particularly odd size (or any part of you is), or you are building one of those homebuilts with an oddly shaped cockpit, this could be a major problem. If you seem to fit, sit there a while and hangar-fly.

All the important controls should be easy to reach with no stretching, twisting or bending over. Controls that require you to lean forward or look down are particularly dangerous because rotating the head forward while the aircraft is maneuvering can upset your middle ear and cause vertigo. You should be able to get full travel on all the controls without your body or the airplane getting the way. Pay particular attention to controls you may need when you are under pressure such as engine controls, fuel pump switch, flap and landing gear controls (if you have them) and the master switch.

An area of serious concern is the fuel selector control. I would strongly encourage you toward a fuel system configuration that does not require you to change anything during normal flight. The high-wing Cessna's have had an excellent record for accidents due to fuel exhaustion because you normally set the fuel selector to "both" before takeoff and then leave it alone. Manipulating fuel selectors in flight is an invitation to trouble.

After sitting in the cockpit for a while you should still be comfortable. You should not feel stiff or sore and there should be not hard parts of the airplane poking into you. If you feel you need to stretch and can't, you probably have a limb in an awkward position.

Now close the canopy (your mockup has one doesn't it?). You should also have enough room so you can look back over your shoulder to the 5- and 7-o'clock positions reasonably comfortably without hitting your helmet on structure or the canopy. There should be at least an inch of clearance between your helmet and the canopy at all times.

Now try and get out of the cockpit with your helmet and parachute on. The canopy latch should be easy to reach and natural to operate. You should be able to climb out easily without wiggling or snagging on parts of the airplane.

This may seem like a lot of work even before you start to build. The time is well spent however because cockpit problems have a strong effect on how safe your aircraft will be to operate and how enjoyable it will be to fly. It is far more efficient to find a problem and design a fix from the beginning than to try and solve the same problem when you ship is half built.

There are several other items that you will want to provide in your cockpit. Every homebuilt must be equipped with a four- or five-point harness. The crotch strap in a five-point harness is intended to keep you from "submarining" or sliding out from under the lap strap under high loads. While always desirable, the crotch strap is particularly important with the semi-reclined seating found in sailplanes and some racers. A shoulder harness is cheap insurance, so get a good one, new with no visible wear. Never use a harness that has been involved in an accident. An aircraft harness is designed to stretch under load. Once stretched, its strength is reduced and it must be scrapped. The harness must be firmly attached to primary structure as shown in ***Figure 1.1***. The lap belt should approximately bisect the angle between the seat back and the seat pan and, when you are seated, it should rest across your hip bones.

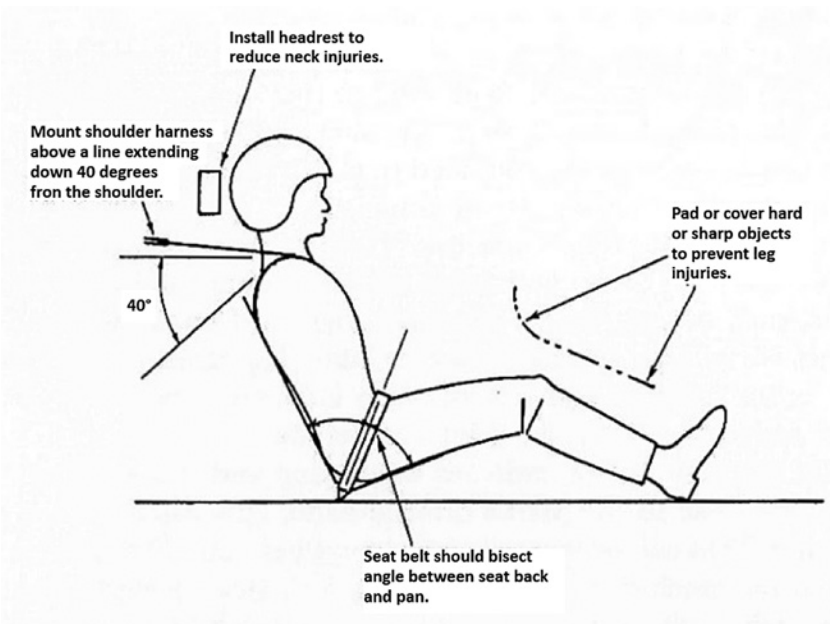

Fig. 1.1 – Making a safe cockpit

The conventional wisdom among homebuilders has been that the shoulder harness should be mounted level with or above he pilot's shoulder. This is because in case of a violent stop the pilot's upper body pitches forward over the lap strap and is restrained only by the shoulder harness. If the shoulder harness is mounted too far below the level of the pilot's shoulder, it can apply damaging compressive loads to the pilot's back as the upper body swings forward. Many homebuilders have intentionally mounted their shoulder harness level with or above the pilot shoulder to avoid this problem. Although this is good practice, research in the automotive industry (Studer 1989) has shown that a downward angle of up to 40 degrees is acceptable as shown in ***Figure 1.1***.

You will not always be flying with a parachute and other people, who are different sizes, will be flying your airplane so it is good practice to provide for seat adjustment. The simplest way of doing this is to provide seat and back cushions of varying thicknesses. These can be held in place with strips of Velcro. One of these can replace your parachute when the test flying is finished.

The cockpit technology and capability available to homebuilders today allows many of us to equip our aircraft with displays, nav-com systems and weather information that would put a twenty-year-old airliner to shame. The design of cockpits and instrument panels is a complex science and deserves a separate book, but whatever the technology in your cockpit the parameters you should be sure you have are:

- Airspeed
- Altitude
- Sideslip (ball race or turn and slip indication)
- Load factor (accelerometer or g-meter)
- Heading (compass)
- Engine RPM
- Engine manifold pressure (if you have a constant speed prop)
- Engine oil temperature and pressure
- Engine cylinder head temperature (if you have an air-cooled engine)
- Engine coolant temperature (if you have a liquid-cooled engine)
- Fuel level
- Fuel pressure (if your aircraft has a fuel pump)
- Electrical system health (ammeter or voltmeter or both)
- Rate of climb

Off all of these, airspeed, altitude and load factor will be the most important during envelope expansion.

Determining the layout of instruments and switches in your cockpit is another time when a mockup can pay off. A mock-up panel will, first of all, give you a feel for how good your visibility is going to be. All the instruments and switches you need to use in flight should be easy to see and reach without stretching or craning.

The instruments you use every few seconds in flight, such as the airspeed or sideslip indicators, and those that will be critical for test points, such as load factor, should be right in front of you and as high as possible without blocking your visibility. Instruments used less often, such as altitude and rate of climb indicators, can be lower on the panel and farther from the pilot's centerline.

By the same token, switches used often and those critical to flight should be close to the pilot's throttle hand and switches used once or twice per flight can be located almost anywhere that they can be reached without too much stretching or twisting. Switches critical to flight are items such as the fuel boost pump, landing light(s), and the master switch. These should be located together, close to the throttle and they should on "on" in the same direction.

In setting up your "switchology" there are some things to think about. First is the concept of "flow." For many modern business aircraft and transports the location of switches, controls and displays is intentionally set up so that pre-flight, pre-takeoff and pre-landing checks move logically around the cockpit. Even if you use a checklist for each of these (and you should) moving sequentially up the panel from below and from right to left reduces the chance of errors.

A second consideration is minimizing the chance of errors when you are under pressure. It's never too early to start organizing your emergency checklists and thinking through how you would carry them out. An engine failure for example would probably call for mixture full rich, fuel boost pump on and switch tanks. Logically then the mixture control and fuel pump switches should be close together and easily distinguishable. In case of a forced landing the master switch should be easy to locate. So if you are putting all of your switches in a nice neat row the fuel boost pump switch should be at the end of the row closest to the mixture control and the master switch should be at the other end and they both should be guarded.

There is an accepted convention for the direction of switch motion in an airplane. In order to turn a switch on, thus activating a device or function, the pilot's hand must move forward or up. For example, if a toggle switch is located on a center console with the toggle facing upward, the toggle should move forward to on. If the same switch is located on an overhead console, facing down, the toggle should still move forward to on.

Engine

The biggest enemy of your engine is heat. The best way of measuring engine temperature is through cylinder head temperature for an air-cooled engine or coolant temperature if you have a liquid-cooled engine. Oil temperature is useful but is not a direct measure of the thermal stress on the hottest part of the engine. Cylinder head or coolant temperature is the more accurate and responds more rapidly.

Traditionally cylinder head temperature is measured with thermocouples which are normally bimetallic washers that replace the sparkplug washers on the cylinders you wish to measure. These would be wired to a mechanical instrument in the panel. If you wanted to monitor more than one cylinder you would need a gage for each cylinder or a selector switch to allow you to look at a number of thermocouples. This system works but it is clumsy and requires a lot of pilot attentions.