

First Flight of an Amateur Built Airplane

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Abstract

An amateur built airplane is considered as a light airplane below 2000 kg which is built by the owner for its own recreation and purpose.

Flying with and flight testing of an amateur built airplane is one of the most interesting and one of the best training activities for an FTP - flight test pilot.

He will find a lot of characteristics normally not found in a certified airplane. It is important that he recognizes items that should normally not be certified and he can compare this experience a life long as a test pilot.

In addition all interfaces and problematic factors around flight testing are present in the same matter as on flight testing within large and complex companies.

To make these flights safe it is important to know a number of facts around, which must be considered during the flight test activities.

Objective-Target-Focus

The main subject of this article is to provide additional information and finally additional safety for pilots involved into flight testing of amateur built airplanes. It is especially dedicated to young FTP first time involved into testing of an amateur built airplane and for the builder if he wants to flight-test his own airplane.

Practical Guide for FTP

It is not the aim to guide through a detailed planning of a test flight for an amateur built airplane; this depends too much on the situation itself. But this article will give practical tips and informations for the planning of a safe flight with a unique airplane.

Hazard Analysis

Hazard Analysis is the basis for a safe test flight. You may need a lot of additional informations around amateur built airplanes to conduct an effective analysis.

This article cannot replace a hazard analysis but shall be an advice and a guidance to carry out the analysis.

A Typical Situation

Would you fly my airplane?

It is a nice evening talk under pilots - builders, about the experience during the first flights. Some small events which happened during the flights are now a "big issue". One guy was calm and he is calling you the next day. A discussion started with him about the minimum qualification of a pilot and than the very weak the question "would you fly my plane?" - Now it is up to you!

The reflight pilot

On the other hand, some national systems require that an amateur built airplane must be flown by a professional test pilot to confirm the results of the test flight program and to ensure that the plane is safe. This might be your task, but it is different than a "First Flight". You may get a completed flight program with results and the airplane already logged a number of fine flight hours.

But could you believe the results? Do you think that this builder has the engineering background to recognize unsafe features and take some action to change the design? Often I have recognized that I have opened the flight envelope during this flight, typical areas are high speed or stalling characteristics.

Be careful and handle it as a first flight to be safe!

Key Safety Factors:

The following factors are some of the key safety factors which should be considered during test flights with amateur built airplanes.

HUMAN FACTORS:

Done several times

It is a phenomenon that happens often during production test flights: a test flight is going to be your daily business; it will be more and more a normal flight. But it is not a normal flight, thousands of parts have been manufactured and set to the right place, be ready for the first functional test, the first flight. The natural human reaction for such a situation is special care, but this can be pushed away. It is the same situation as for sporting actors such as racing or Formula One pilots. They are often involved into accidents during normal life, the stop sign is gone!

Especially experienced flight test pilots should try to avoid these situations by strictly following the good flight test procedures and plans. It is important that a first flight of an amateur built airplane is not a production test flight.

Commercial Pressure

It should not happen in an amateur built project but the builder may put himself too much under pressure during work. Some surrounding factors like available hangar space or the coming winter season may put pressure on the builder to complete his project within a too short time.

This must not lead to any safety reduction by cutting necessary quality steps.

The First Flight, an Event

It is seldom at the pure amateur built scene, but it happens very often in the commercial design world. The first flight is going to be planned, it is advertised, with cameras, media and press. And this is going to be the prime focus, the target that has to be reached. Safety is going to be out of focus, technical compromises as a solution to reach the target have been filed in most cases.

This is not professional and should be avoided, anyhow, if something is going wrong it is not a good press. The First Flight is a "Non-Event".

The Owner/builder is the pilot

This is definitely the best solution. The builder knows his airplane best and he takes the risk.



But most builders forget to practice flying during building or don't have the budget at that time to practice it frequently. Training provided by the builders-community for that special case is often not available. The remaining solution is to hire another pilot.

But the combination builder-pilot raises other questions. Is this man/woman mentally the right one or is there a special ego behind?

Is he/she able to say No if the facts call for it?

A qualified builder's community or an assistant pilot may give the builder some advice to take the right decision.

Good Relation and Communication

Someone may call it also good "vibrations" but it is the essential basis for a successful first flight. A positive relationship and open communication between the builder and

the FTP should be established. If you feel that this cannot be achieved, let it be. It is an unsolvable human factor. If it is achieved, than you may not need a contract between the builder and the pilot. It may be an unbeatable team for any situation.

The Builders Progress Chart

About 50% of the builders have fun with building, that's their main task. I recognized very often that at the end of a project the progress to complete the airplane is getting slower and slower. The builder tries to reach a 100% completeness level which he will never achieve. There is a trend to change a lot of details at the program's end, with an airplane that is nearly ready to fly. That would be a clear indicator that the first flight is a wall in front of the builder and he cannot see behind. It is a good time for the FTP to step in; you do not need a 100% perfect airplane before the first flight, just technically fit and safe. It is normal during the first flights that something needs to be changed, but you have to fly to know it.

Jump over the mystery wall and you will see the light again!

This airplane is a part of my life

The FTP has to understand the relationship between the builder and his airplane. You will find cases where any part of the plane has been made by the builder's hands. I remember wooden airplanes that have been built out of one single tree, carefully selected and cut during a moon-night, or airplanes where any screw had been made out of raw materials in the exact length and fit perfectly.



It is a kind of love, and the emotions behind are understandable if the "baby" should be flown by someone different. This must be understood and accepted. The FTP must handle it as his own, with care and respect. And the builder must feel that emotion, otherwise let it be.

If possible try to bring the builder in the boat, keep close distance. Make the first flight, solo. Open the basic envelope. On the same day the builder should make the second one, instructed, guided within that envelope. Step by step.

Even No call for assistance - the pilot's ego

Over the years I experienced a number of cases where the builder failed to communicate its flying qualities. Legally they had a valid pilot license for that category and that's the problem. Only a small number of legal systems require a minimum pilot qualification for a first flight. And even then, is the builder mentally in a position to make the right decisions? To say no, is something against the personal ego, driven by some stupid questions like "Are you frightened?"



This needs definitely assistance by a trained FTP. The builder might be a good pilot but not qualified for this task. I remember a number of fine built airplanes accidently damaged by missing this important fact.

TECHNICAL FACTORS:

Only some minor Modifications

During the first contact with the builder you got the impression that only minor modifications have been done to a proven well known design.

This should be carefully reviewed. Most of the builders want to give their airplane a personal touch. A new wingtip or an additional fin, an electric flap instead of a hand flap, a new cowling with a nice spinner, The list is long.

One point alone or in combination with others may have some significant impact to the handling qualities or the safety of an airplane.

Very professional summaries of flight test results⁴are available for common types of amateur built airplanes.

Replica of Old Design

This can really be a challenge! Replicas of the first generation in aviation such as Bleriot's, Antonett's, Tauben or Wrights designed around 1910 may have features you never imagine. Nature of a replica is, to build an airplane most identical to the original. It starts from building techniques over materials, shape and sound.

The most important question is the final flight profile for this airplane.

Should it be flown only by very experienced pilots on very rare events or should it be flown more public or even cross-country by a good trained pilot?

What is the FTP's order? What compromise should be found?

Flight Safety gets a new definition!



The best starting point is to forget everything you expected from modern designs.

If you read some historic publications from the age of design, you will find some articles about the nice flying qualities of that type. But be careful. It is written with the knowledge of that time and this might have been true at that time, but today the flight qualities might be miserable. Basically instable constructions with a CofG aft of the aerodynamic center, spiral tendency or very limited performance are typical. In addition the replica itself need not be identical to the original. Airplanes at that time are built and adjusted by practical mechanics and engineers. Flying wires are the main structural elements, elastic wings and controls are typical. You will find only a very limited number of qualified informations for rigging and adjusting, both have been changed from flight to flight. Most airplanes are quiet unique. If you study details using existing photos of one same type, than you will know what I mean.

And if it flies acceptable, be careful, it might be quickly the "fleet leader" and some other problems may arise.

Production Quality

Industrial aircraft production must have a very controlled production quality and all is within a very close tolerance with only small differences between each SNo. In amateur built airplanes you will find a wide variation in production quality, from very fine and exact, better than industry ever can achieve (they do not have so much time) to very poor or almost unacceptable. It is important to know the relative quality of the specific airplane to be tested by the FTP. Sometimes it is hard to determine but a detailed inspection of parts and installation or just a look into the condition of the workshop (cleanness, tools) can give a picture. I remember airplanes with twisted wings, bonding failures, missing bolts and nuts, non fitting parts and so on. Be careful and avoid uncertain quality.

A brand new design

It does not happen so often, but you can find completely new airplane designs built and designed by an amateur. New shapes, new airfoils, new production methods and so on, everything is possible in an amateur built airplane.



Such a new airplane needs engineering capability by the builder or engineering assistance. A standard flight test program might be not appropriate for that airplane and it is highly recommended to discuss the engineering and the results from a flight test perspective.

It is a Kit and ...

It is frequently misunderstood, but the Kit-Manufacturer has no responsible function in the system. He supplies parts and the

builder is making an airplane out of it. That does not mean it is a good design with nice flying qualities. It does also not mean that the parts built meet certain quality standards. The builder receives no paper and the kit manufacturer has in fact no responsibility. "Certified" Kit means that this Kit meets the 51% major portion rule - 51% built by the amateur.



Well, in practice you will find a number of very good kits providing a good safety standard.

An Electronic world

Electronics and Avionics do not stop on amateur built airplanes, but there is a major difference. Certified airplanes have to use certified parts. That means parts have to comply with a standard such as FAR, JAR, CS, TSO, ETSO or RTCA, this is not a must in an amateur built installation. That does not automatically mean that the quality is not sufficient. To prove this kind of equipment it needs much more testing on ground and in flight. Special care should be taken for primary flight instruments and airplanes which should be qualified for night and instrument flying. Precaution is necessary for Autopilot installations and full EFIS cockpits. The reliability and suitability of the electric system should be proven by analysis and tests, it is highly recommended to have a simple mechanical backup installed.

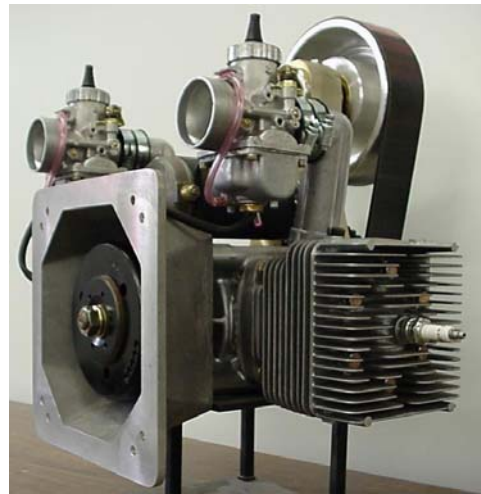


Modern Avionic and Electronic systems can, if properly installed, provide additional situational awareness, easier navigation and additional safety. Good examples are AOA indicator, stall warnings, flight displays, GPS and collision warning systems.

Engine and Propeller built by my own

There are a number of proven and reliable engines available on the market and in most cases they have been used.

Some builders have made their own propeller; this is in general OK for a simple wooden fix pitch propeller, but it can be complex for a variable pitch prop. The minimum test is a blade pullout test at operating temperature with a good safety margin to the ultimate load. Vibrations are an issue for metal or carbon props. There is a wide range of custom built uncertified propellers available. The questions to be asked are the same, if you cannot get data from the manufacturer or any other reliability data are available, let it be.



This is different with homebuilt engines. Only well informed engineers should enter this area. Most of the designs are derivatives from car or motorcycle engines. Modern car engines using full electronic engine controls. Car installations are using only single path systems, this is enough for cars on street but questionable in airborne systems.

A similar problem is the vibration dampening in geared engines. It is in fact a very complex area and I remember a number of cases where an engine failed due to fatigue. Even modern engine designers are fighting with that problem. Finally most of engine experiments ended in a modification back to a proven aviation design.

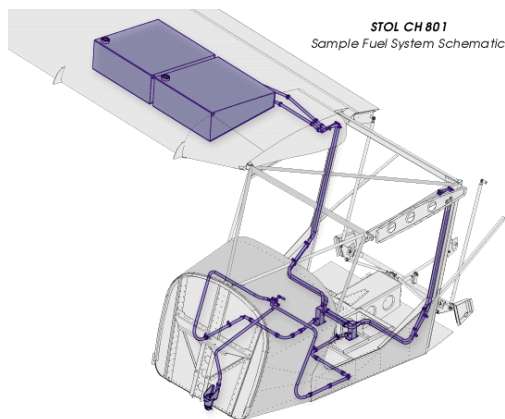
Ground tests

Between the last screws that have been torqued and the first flight there is a very important area, the ground tests. These tests should be setup individually. It should start with an individual quality check; independently carried out, as well as detailed system analysis.

Rudder travel and balancing, this may be tricky because limit data are missing in most cases.

The fuel system should be tested functionally with the engine running under all conditions including the maximum angle of attack and minimum fuel level. The fuel quantity indicator must be calibrated. The unusable fuel at the critical

attitude shall be determined. The fuel system on amateur built airplanes is simpler in most cases and fuel supply is not guaranteed in all flight attitudes. Engine indications shall be calibrated or sample checked in critical areas.



The length of the engine ground runs depends very much on the engine and propeller installed. 5 hours are always recommended but for a new engine design it may be much more.

The cooling design is fine if normal taxiing and a full engine run-up is possible without overheating. This may be very tricky and hardly to achieve on pusher type airplanes.

The electrical system shall be checked during the ground runs and should include basic system failure modes and the proper indications for the pilot.

What can be tolerated - accepted?

An amateur built airplane must not meet a certification specification. The proximity to the specification is depending on the national regulatory system. But what technical deviation can be tolerated? Control Knob shapes and instrument arrangements that might be easy to decide. Also on a Stability issue you might find a decision if it is still safe to fly. But what is with more complex issues such as spinning or flutter?

Finally it must be operationally safe; there is a great spectrum of technical deviations which can be compensated by operational restrictions. A number of items can be closed with a simply day-VFR restriction.

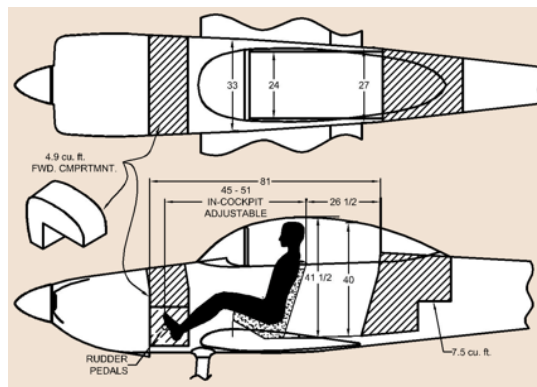
Others, such as flutter and spin, can be closed only with the lower airworthiness standard. This must end in a clear and unmistakable pilot and passenger warning as part of a special or restricted Certificate of Airworthiness.



Anyhow, it is important that the operator is aware of the flight test results and a detailed description of the airplane character is part of the Operating or Flight Manual. We must recognize that in most cases the airplane will survive the builder and any following owner-pilot should be aware of the airplane characteristics for a safe flight.

Customized but not for me

Most of the airplanes are customized for the builder and that is fine but it can create some unexpected difficulties for a FTP with a different size. Some of the airplanes are really small and a pilot with a size of more than 60kg/1,6m will not fit. In a lot of airplanes you will find problems to fit with helmet or parachute.

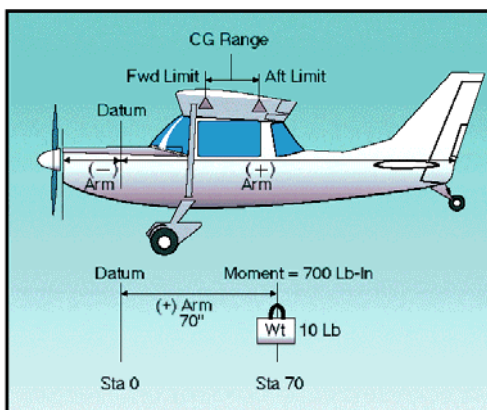


It may need some compromises or a technical solution by the builder, a different seat cushion may help in some cases, sometimes it needs a repositioning of the rudder pedals, and sometimes it is simply not possible to fly this airplane.

Flight Envelope - CofG

It is important that the usable flight envelope is completely tested. Any untested grey area shall be clearly indicated in the resulting report and the flight manual for that airplane.

Weight and balance is not only the determination of the empty weight and CofG. It should also contain a determination of the pilot arm because most seats are customized by the builder. This can be done with a flight condition weighting and subsequent calculation. The fuel arm shall be calculated for all tanks and conditions.



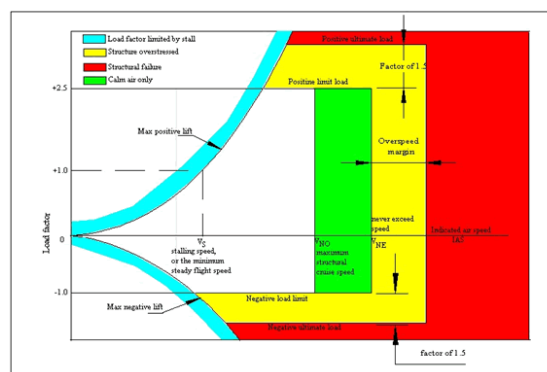
A detailed calculation of the flight CofG envelope is required. Some types have an unusual wide flight CofG in their building manuals.

The Ideal Case

The ideal case for a first flight in an amateur built airplane is, that the design itself is not questionable. That means the design is certified and the first flight is nothing more than a production test flight within a well known envelope. Sometimes it happens like that, but not very often. Examples are the Italian Falco F8L, Bucker Replicas, the French Jodel or the Legend Cup.

Outside of the Known Envelope

The certified airplanes are within a well known and given envelope of the certification specification. That's what pilots have learned to handle in all the lessons. Amateur built airplanes must not meet this specification and may have characteristics outside this envelope or have even unknown areas within the envelope. Typical unknown areas are flutter, vibrations, spinning and stability or even structure.



Spin and flutter is a "grey" area on most amateur build airplanes. Some of the types have very nice handling qualities and are very popular, but looking at the Plainview of the tail it very quickly determines that spin recovery might be a problem.

The reason is very simple: effective spin recovery testing is very cost-intensive, needs special equipment such as a spin recovery chute and is not required to be demonstrated in most countries. Due to the fact that a Kit manufacturer has no responsibility it was often left open.

Do not enter these hazardous tests unless required, the proper safety equipment (e.g. spin chute) is installed, the pilot is properly trained for, and the airplane is designed for. And even than, expect difficulties and design changes.

Resulting from this situation, a gentle stall behavior, a clear indication of an approaching stall and a stall warning under all CofG conditions is highly recommended.

A simple solution is a design with a CofG always in the forward range.

A comparable situation is present in the high speed range. Flutter is a very complex technical issue. Effective flutter prevention needs ground vibration testing, determination of the natural frequencies and complex computer analysis. In addition a flight test campaign is required to prove the theoretical model analysis, and even than flutter happened.

Build light and stiff and use mass balancing is a very simplified method used in most amateur built airplanes.

The only resulting method for the FTP is a step by step speed change in calm air and carefully watching the damping characteristics after implementation of a control disturbance.

OPERATIONAL FACTORS:

Flight Test Area

It starts with the selection of the right airfield for the first flight. A straight in landing after engine failure before reaching a safe altitude should be possible. Suitable landing areas around should be available.



The flight test area normally is a part of the official flight permit. But the intent of the regulator is the safety of the public. The areas are outside of populated areas. But is this the best area for your flights? Is it within the glide range of a suitable landing area? Is it accessible for emergency rescue?

The First is done, the next is easy and safe.

This is definitely not true!

The first flight is normally within a small envelope and hopefully under optimal conditions. The hazard is medium. Much more critical flight tests such as high speed and low speed with extreme CofG positions will follow. It is therefore recommended that the FTP follow the FT phases and step in as necessary.

A Safety Team around

Murphy is always there and an accident can happen, it is only a question of time. Even in simple accident cases you may need some assistance. A small rescue team, well equipped, can provide an additional safety margin.



I remember cases where the pilot made an out landing after engine failure; he made a perfect landing but the soft ground lead to an turnover. It took a long time until someone found him uninjured hanging upside down.

Equipment

Additional equipment is common practice for a professional FTP and it should also use in test flights of an amateur built airplane. Some cost intensive equipment such as spin chute or data acquisition units may not be available.

Safety equipment such as parachute, helmet, flight suite and crash axe should be standard. Using a parachute may be tricky, most canopies are not designed for opening in flight and it is highly recommended to install an emergency opening.



Test equipment to measure stick force and distance should be standard. The builders community may also provide additional equipment such as a swivel head boom for more quantitative measurements and results.

Very useful are small cameras mounted in the cockpit with a plan view to the instrument panel and the pilot. Pilot action as well as instrument indication can be analyzed later together with the builder.

Flight Test Program

Make a plan and fly the plan; to follow this principle it needs a good flight test program³. There are various programs² available and each has its pros and cons. Important is to have one and follow this one. The first flight is only one step in the program. The FTP should guide and advise the builder as a pilot about the program, the content, the intent and the required steps to be done. A constructive discussion between the builder and the FTP may result in some flight tests better to be done by the FTP as the pilot.

SURROUNDING FACTORS:

The National Regulatory System

The relevant National Aviation Authority of the builder or registration is responsible to issue a flight permit for the first flight. There are very different systems¹ in place: from completely relaxed systems up to very detailed regulated systems. It is important for the pilot to know the system behind. Regulated systems require a

Conclusion:

Building a small airplane in private structures could be and was often the basis for a future production design and offers the ability of creative ideas with less bureaucracy. This should not be limited or even stopped by a significant reduction of the safety record due to unqualified flight testing.

If balanced done, it is a win-win situation for both - builder and a hired Flight Test Pilot.

minimum number of inspections and tests. Unregulated systems leave it open.

The pilot requirements may also differ and must be considered in flight planning.

Multiple Builders

To build an airplane needs a long time, 5 to 10 years or more are not unusual. A lot can happen during that time and some projects must be completed by another builder. It must be ensured that the building data are properly transferred.

It is important for the FTP to know the building history of the airplane.

The Financial Side

Flight testing is a higher risk and we quoting the healthy of the pilot with money. A flight test pilot is expensive.

If you are using this principle, than most of the builders will not accept it.

In most cases the builder has spent a lot of money and time to build his airplane, with consequences to the rest of this family. Think only about 2000 to 6000 hrs of building time. Building his own airplane is the only chance to have a new airplane for a reasonable price; in addition it is fun to build.

Adding the price of a professional FTP, it is not affordable anymore. He will take the own risk as a pilot with an accepted lower safety margin, but with the kick to make the first flight.

The Contract

The best friends can be an enemy if something has been damaged and often the lawyer has the last words. Full insurance for flight testing is very expensive and cannot bring back the building time. To have a clear situation, a contract between the builder and the FTP makes sense.

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The Author

Andreas Winkler, born 1963 working, since 1984 for the Austrian Aviation Authority, pilot since 1979, started as an airworthiness inspector for sailplanes, light airplanes and large airplanes. He carried out production test flights during conformity inspections and holding a national flight test permit for light aircraft. His function within Austro Control, the Austrian Aviation Authority, is the management and certification of national aircraft and project certification manager for Diamond products within the European Aviation Safety Agency. This included the certification of DA40 and DA42 full composite diesel engine powered airplane. He has managed a large number of commercial and non commercial projects from the beginning until final certification and the ongoing continuing airworthiness. He is active pilot and instructor from sailplanes to multiengine airplanes and has built a sailplane for his own recreation and purpose.

Appendix :

Checklist for a Safe First Flight

First Flight Checklist

This checklist should be used by the builder and the FTP for the final preparation of the first flight on an amateur built airplane.

Design

- Modifications identified
- Quality Inspections completed
- Electrical Bonding Engine-Tank checked
- Heating and Ventilation checked
- Taxi Tests completed
- Landing Gear checked up and down, no hang-up probability, no influence to controls
- Control System rigging completed
- Cowling secured and fixed, will hold air loads?

Equipment

- Airspeed and Altimeter calibrated
- Airspeed indicator markings correct conform to design
- COM functional check
- Electric Master switches available when strapped in safety belts
- Brakes tested even when hot
- Compass and Compass System calibrated

Preflight Inspections

- Pitot Static system leak checked
- Airspeed indicator working correct
- All openings closed
- No foreign objects
- All gaps closed, sealed
- Safety belts tight and fit
- Emergency Canopy opening tested
- Headset/Helmet COM ground test
- Fluids checked

Fuel System

- Tanks cleaned
- Drained, no water no dirt
- Indication calibrated
- Fuel shut off valve in range when strapped in safety-belts
- Amount of fuel checked

Controls/Trim

- Free travel controls, pedals, no mismatch with shoes
- Correct direction of movement
- No flexibility, no friction, no free play
- Trim full move test in control positions
- Flap symmetry, alignment

- Flap Hand force test up lh/rh

Engine /Propeller

- Run-ups completed
- CO-Carbon Monoxide, Test carried out
- Variable Propeller Fine pitch checked, on ground run - fine pitch, governor not working
- Check correct ground run pitch for fix pitch prop

Weight and Balance

- Weighting data for that condition
- Arms correct
- CofG in the forward range
- Trim weights fixed
- Shift calculated

Paperwork

- Flight Permit
- Aircraft Insurance valid
- Pilot License and Medical valid
- Aircraft Radio Station License

Flight preparation

- Flight Test Program developed and applied
- Test Cards prepared
- Flight Test Area known, National Airspace Restrictions known
- Hazard Analysis carried out
- Aircraft-Type test reports reviewed
- Runway length checked, takeoff following landing is possible.
- Emergency landing field in front available
- Weather conditions checked
- Emergency plan prepared
- Emergency rescue crew available and instructed
- Medical fit?
- Operating Airspeeds checked and marked
- Need for a chase plane?

Equipment

- Emergency Equipment on board
- Crash Axe on board
- 406 Mhz ELT programmed and filed in National Database
- Mode S Transponder programmed
- Emergency Medical Kit on board
- Parachute packed and fit
- Cameras in and out prepared and tested

Sourround

- Contract builder - pilot completed