Introduction

These design requirements apply to large model aircraft being designed, constructed and flown under the LMA Ove 25kg Scheme.

Throughout this document, the requirements are in GREEN and the guidance / acceptable means of compliance are in PURPLE

Although this document may appear at first to be impenetrable and excessive, the intent of these requirements is to

- not to deter anyone from building large model aircraft, but to help and encourage with clear guidance on what needs to be done to have a successful project
- provide a level of detail that should be considered when building and operating a large model aircraft to ensure that it is safe and reliable
- provide inspectors and flight test witnesses with criteria and guidance on what needs to be shown and demonstrated to make an acceptably safe aircraft

These requirements also include guidance / acceptable means of compliance to help both the builder of an over 25kg aircraft know what is required, and to help the inspector capture the required evidence.

The inspection record form and the flight test record form record how the aircraft complies with this set of requirements during the design, build and test phases.

Major modifications or repairs that are carried out once the aircraft is in service, will also need to be carried out in accordance with the relevant parts of these requirements and recorded / demonstrated in the same way as a new build.

The range of aircraft that have and can be built under these requirements encompasses the full history of aviation, from the pioneers of flight, to modern jet fighters via WW1, WW2, jet airliners and helicopters. Specific performance requirements will not encompass all these aircraft, so it is only required that the pilot knows what the performance limits for the aircraft are, can fly the aircraft within those limits and only operates the aircraft from locations that the aircraft can safely support.

Because of that range of possible aircraft, there are deliberately the bare minimum of absolute limits to an upper mass limit and an upper speed limit.

Applicability

All of these requirements apply to all over 25kg model aircraft, but the way the aircraft and the builder will satisfy the requirements will depend on the type of aircraft build project:

1) A build of a new design or a build of a scale-up of an existing design
   a) The builder needs to show, and the inspector needs to be satisfied, that all relevant* requirements have been met

2) A build of an existing design (either from plans or a kit)
    a) The builder needs to show, and the inspector needs to be satisfied that, all construction work, modifications to the design, system design decisions and system installations have been carried out properly and satisfy the relevant* requirements
3) A build of a moulded airframe / pre-built ARTF
    a) The builder needs to show, and the inspector needs to be satisfied that, all construction work, modifications to the design, system design decisions and system installations have been carried out properly and satisfy the relevant* requirements
4) A modification / repair
    a) The builder needs to show, and the inspector needs to be satisfied that all repairs / changes have been carried out properly and satisfy the requirements pertinent to the scope of change or repair
5) A change of ownership
    a) The builder needs to show, and the inspector needs to be satisfied that any changes have been carried out properly and satisfy the requirements pertinent to the scope of change

*some requirements are not relevant to all aircraft, such as buoyancy for landplanes or powerplant for gliders.

Once built, all aircraft and all remote pilots will need to demonstrate that they meet the flight testing requirements.

SUBPART A – GENERAL

DR-LMA-1000 Definitions

UA – Unmanned aircraft, including all parts required to be fitted to the aircraft for flight

UAS – Unmanned aircraft system, including all equipment required to fly the aircraft.

MTOM – Maximum Take Off Mass

Engine and Powerplant-

The powerplant is used in this design specification to encompass turbine engines, reciprocating (piston) engines, electrical motors/engines or any other type of powerplant.

The UA powerplant installation includes each component that is necessary for propulsion, affects propulsion safety, or provides auxiliary power to the UA.

The system includes the radio transmitter.

DR-LMA-1100 Applicability

This Design Specification provides requirements for the issuance of permissions and authorisations to operate, and changes to those permissions and authorisations, for UAS under the conditions below:

1) MTOM exceeding 25kg but not exceeding 150kg
2) Maximum speed not exceeding 200mph
3) Human transportation is excluded

SUBPART B – PERFORMANCE

DR-LMA-2000 Approved Operating Limitations

1) The UA may only be operated in day visual line of sight (VLOS) conditions at a maximum of 500m from the remote pilot
2) The applicant must define any additional limitations of the operation within which safe flight will be demonstrated
3) In defining these limitations, environmental conditions must be considered

It is up to the applicant to define any additional limits that the aircraft can be flown under. If a maximum windspeed or crosswind limit is declared, or flight in the rain is to be permitted, the flight testing will need to demonstrate flight in the closest conditions to the limits that can be achieved.

DR-LMA-2100 Mass and centre of gravity

1) The applicant must determine limits for mass and centre of gravity that provide for the safe operationof the UA
2) The condition and configuration of the UA at the time of determining its mass and centre of gravity must be well defined and easily repeatable

All aircraft have a centre of gravity range, and the flight test programme will need to demonstrate the range. It is the decision of the builder what level of calculation to carry out to determine the centre of gravity before beginning flight testing.

The state of the aircraft when it is weighed needs to be defined. As aircraft get larger, where they can be safely picked up becomes important.

Measuring the weight on each wheel with the aircraft level is the most reliable way to both get the maximum weight and also the centre of gravity of the aircraft without risking damage to the aircraft or the people trying to pick it up.

DR-LMA-2200 Approved Flight Envelope

The applicant must demonstrate during flight test the complete flight envelope within which the aircraft may safely operate up to the applicable maximum speed and mass.

The Flight test programme will require the full flight envelope to be explored and demonstrated, within the categories of 'non-aerobatic', 'scale aerobatic' or 'fully aerobatic / unlimited'.

DR-LMA-2300 Takeoff and Landing Performance

The applicant must determine, within the operating limits:

1) The runway and clear distance required for take off and initial climb
2) The clear distance and runway required to land and come to a stop

There are no minimum performance requirements for aircraft, other than determining the clear distance required to take off, climb to circuit height and then descend from circuit height and land.

During flight testing the minimum required space for take off and landing will be determined, and the type of runway (if any) required.

e.g. takeoff - 50m grass runway & no trees for 50m, landing no trees for 75 m & 50m grass runway approximate minimum

Some aircraft may require 100m of smooth swept tarmac with no shrubs taller than a meter within 300m of the pilot, where others may only need 5m of long grass and be able to clear a 20 metre high tree within 20 metres on both take off and landing.

DR-LMA-2400 Controllability and stability

The UA must be controllable and manoeuvrable, within the demonstrated flight envelope:

1) At all loading conditions up to MTOM
2) During all phases of flight, including ground phases
3) During configuration changes
4) The UA must not exhibit any unrecoverable divergent stability characteristic in all phases of flight, including ground phases

The aircraft needs to be flown in all configurations during the flight test programme to make sure it doesn't have any dangerous flight characteristics including when stalled. If the aircraft has any unpleasant but not dangerous flight characteristics, the pilot knows by experiencing what the characteristics are and how to safely handle the aircraft in those conditions.

If the aircraft is 'unrecoverably divergent' it will be obvious as pretty much unflyable, such as a C of G too far aft or a landing gear geometry that causes a ground loop at the slightest provocation.

It is understood that some scale models of full-size aircraft that had 'interesting' handling characteristics will potentially replicate those handling characteristics. In such cases, it may be wise during the design phase to make tail areas slightly larger than scale and apply 'washout' to the wing (either by a twist in the wing or a change in aerofoil along the wing to reduce angle of attack at the tip versus the root).

SUBPART C – DESIGN AND CONSTRUCTION

DR-LMA-3000 Structural design loads

The applicant must design the structure to take into account the loads arising from:

1) flight and ground load conditions to be expected in service
    a) Critical flight loads for symmetrical and asymmetrical loading from all combinations of speeds and load factors up to maximum speed and MTOM
    b) structural ground loads resulting from taxi, take-off, landing, handling and transportation conditions in all attitudes, configurations and conditions
2) mass variations and distributions over the applicable mass and centre of gravity envelope
3) loads in response to all designed control inputs
4) powerplant load at all rotor/fan/propeller rpm ranges for power-on and power-off
5) interaction of systems and structures

Before starting to design the structure, think about what the aircraft is and what it is being designed to do.

Grounds loads must be considered. As well as the loads passed into the airframe from the landing gear, it is no use having an aircraft that is strong enough for flight, but any handling on the grounds results in damage such as fingers through wing / fuselage skins.

All the loads on the control surfaces are passed into the airframe at the mountings of the actuating servos. The loads on the servo mounts must be taken into account

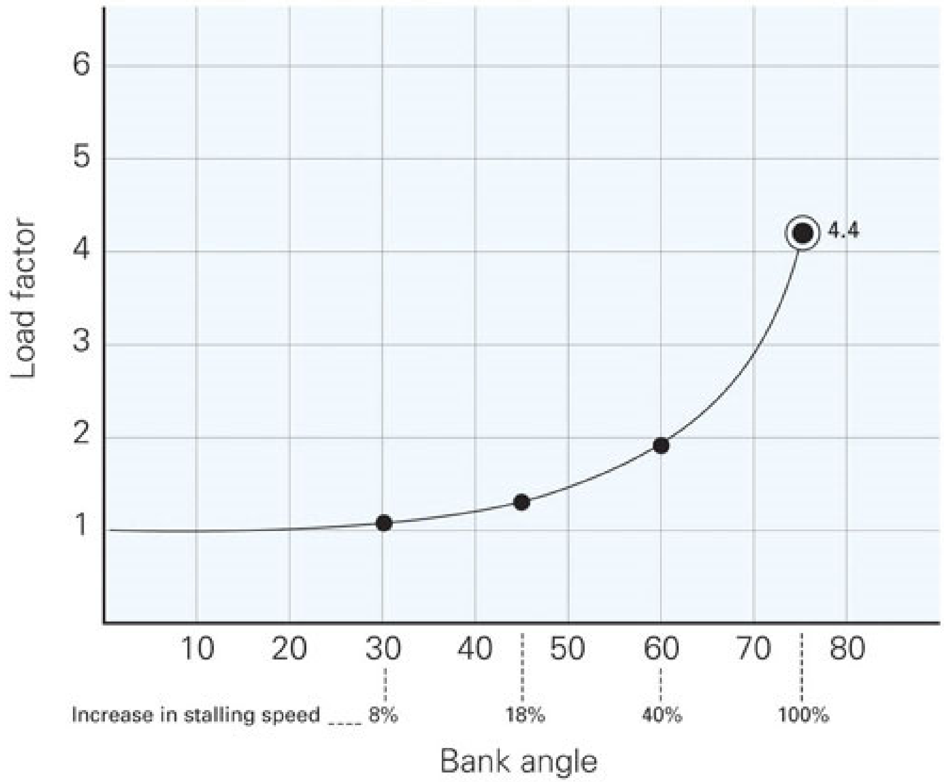
One of the significant differences between a manned aircraft and a model aircraft is the 'feel' of the loads that are being applied by the pilot to the aircraft.

When you are sat in the aircraft, you can feel how much load is being applied (the 'g force') and, provided the aircraft has been designed properly, you can feel through the controls how much control input you are applying.

With a model aircraft you have no such 'feel'. The springs in the sticks give exactly the same resistance no matter how fast the aircraft is flying, and unless there's seismic activity, your body feels the same load during the flight, no matter what the aircraft is doing.

Even in non-aerobatic aircraft, a steep turn can significantly increase the loads on the airframe as shown below. A 60 degree banked turn doubles the load (2g) and another 10 degrees of bank to 70 degrees triples the load (3g).

It is reasonable to expect that non-aerobatic aircraft should be designed to a limit load spectrum of -1g to +3g



If the aircraft is being built from existing plans or a kit or is a moulded / ARTF airframe. It is assumed that the design takes all loads into account and complies with this requirement.

Several reference guides on the design of aircraft and defining applicable loads are available for download on the LMA website at XXXX.

DR-LMA-3010 Structural strength

The structure must be designed and constructed to be able to support:

1) limit loads which are equal to the structural design loads without:
   a) interference with the safe operation of the UA; and
   b) detrimental permanent deformation
2) ultimate loads which are equal to the limit loads multiplied by a 1.5 factor of safety without failure

Having thought about the loads that the aircraft will see in service, the aircraft should have a structure designed to support those loads with a margin of safety.

Limit load is the maximum load that the aircraft will ever see in flight.

Ultimate load is the load when the structure of the aircraft fails.

The structure must be strong enough to survive all normal flight loads without breaking, bending so that control surfaces do not work or permanently bending the structure.

There is no requirement to actually prove the strength of the structure with a destructive physical test, but when designing the structure this is the strength you should be aiming for.

Examples of limit and ultimate load capability are-

1) A manned non-aerobatic aircraft can in a steep turn reach +3g and in a hard landing -3g
    a) A model of a non-aerobatic type should be designed and built to a limit load capability of -3g to +3g and an ultimate load capability of -4.5g to + 4.5g
2) A manned WW2 fighter such as the P51 Mustang has limit load spectrum of -4g to +8g
    a) A model of an WW2 fighter that will be flown in a scale manner should therefore be designed and built to a limit load capability of -4g to +8g and an ultimate load of -6g to +12g
3) A modern manned aerobatic aircraft such as the Extra 300SC is certified for +/-10g limit load.
    a) A model of an aerobatic aircraft should therefore be designed and built to a limit load capability of +/-10g and an ultimate load of +/-15g
4) A modern manned jet fighter aircraft such as the Eurofighter is limited to -3g to + 9g to protect the pilot, it is safe to assume a structural +/-10g limit load.
    a) A model of a jet fighter aircraft should therefore be designed and built to a limit load capability of +/-10g and an ultimate load of +/-15g

How can this strength be achieved?

There is no shame at all in copying an existing design. If you are designing an aircraft that is similar in size, weight and performance to an existing proven model, the primary structure can be copied from that aircraft.

If the aircraft is being built from existing plans or a kit, the plans themselves meet this requirement (unless experience has highlighted areas where changes are necessary) provided the construction follows the plans / instructions, and any changes to the design are appropriately recorded and designed.

A moulded / ARTF airframe has already been designed and constructed. Previous experience of the performance of the type can give confidence that the design is good and complies with this requirement. For the first example of a moulded / ARTF type, a thorough inspection should be made to ensure that the design is appropriate to the type of aircraft. If there is any doubt about the design of the aircraft, the inspector is not obliged to approve the aircraft and can contact the LMA Safety Panel for advice.

Several reference guides on the design of aircraft structures are available for download on the LMA website at XXXX.

Structural Design Guidance

Wings

With every wing assembly it is necessary to consider exactly what each part of the airframe is expected to do and the forces that will act upon it both in flight and on landing.

Biplane wings should be considered together as a unified structure. This means that the integrity of interplane struts and rigging wires is fundamental and they should be designed to be load bearing. Correspondingly, the spars can be much lighter than those of a cantilever monoplane. The load bearing structure will be a collection of triangles, mostly in tension and compression.

Cantilever monoplane wings have a quite different load bearing structure. The strength of the spar will be crucial. It should be carefully determined at and near the centre section. The upper element of the main spar will be in compression during level flight and the lower component will be in tension. Their cross sections should be adequate, and the materials must be suitable. Shear Webs should be designed with grain vertical. As failure of a spar in flight could be disastrous it is crucial that this component is of adequate design and construction. Experience should determine dimensions and materials, but if there is uncertainty advice must be sought and if necessary, the strength of the spar of the complete wing must be experimentally tested. In many cases, loads will be taken by a second spar or by the skin of the wing either on just the around the area between the leading edge and the spar or on the whole wing chord. The covering may also take some of the load, but care is necessary because damp or temperature changes may cause a fabric covering to slacken and it may be unwise to depend upon it for the integrity of the structure.

Multi engines

Where two or more engines are mounted on the wings, they will alter the loads. For example, when there is a positive force in flight, the weight of the engines will tend to balance part of the lift. On landing the engines will contribute a large additional (negative) down force on the wings. In addition, especially where the engines are attached with substantial forward overhang, a heavy landing will cause considerable torsion forces load on the wing which and these will need to be neutralised by internal cross bracing or sufficient skinning of the wing centre section.

Struts and rigging wires

These should be fully load bearing, which is not always the case with small models. Struts have to perform in compression as well as tension (interplane struts should always be in compression) and they should therefore not bow in compression. For this, bracing may be needed. End fittings of both struts and wires must be strong and proof against vibration in addition to being of adequate strength.

The points of attachment at each end must be designed into the structure so that loads are suitably spread.

Landing Gear

If the gear is attached to the wing either direct or through engine nacelles, it will change the downward force of the wing on landing to an upward force, which will be severe in a heavy landing. This should be considered for strength, shock absorbing capability and attachment to the rest of the structure. If retracting, accessibility and repair should be considered. Remember the wheels. There are now a number of types that can withstand the loads to be expected. A sprung undercarriage will reduce landing forces and should bottom out at approximately 3g.

Wing joiners and attachment to fuselage

Most commonly employed methods of joining wings: large diameter tubes, tongue and box, straps attached top and bottom to spars. Suitable materials include aluminium alloy, steel and glass or carbon fibre reinforced plastic sheet. Plywood tongues should be viewed with suspicion because the inexperienced often forget that the alternate laminations, with grain vertical, add little to the strength. The thickness and hence weight has to be increased to counter this.

Tail surfaces

The most likely problem is flutter. Construction can be light but should be stiff if not braced. Both rudder and elevator flutter can quickly destroy the aircraft in flight.

Some full-size aircraft can suffer pitch instability due to loss of engine slipstream or of the shielding of air flow by the wing or fuselage at high angles of attack. The possibility of scale effects should be considered.

Aircraft with a T-tail can be particularly prone to this phenomenon, especially jet airliners. All full-size jet airliners since the 1960’s have complex systems to prevent an excessive angle of attack and stall where their basic aerodynamics needs it.

Control surfaces

These should be light but rigid. Gaps should be minimal, the hinges strong and positively locked in place. Control horns should be made of strong, stiff material and securely anchored. 1.5 to 2mm or even 3mm glass GRP has been employed satisfactorily. Consider static or dynamic balance for the control surface. Consider also the full size practice of balance weights.

Fuselage

It is rare for a structural failure of the fuselage to take place. It has been seen that where a big, heavy engine has been fitted to a light airframe that was designed for a smaller engine, the fuselage has failed in flight, due to vibration. Check that the rear fuselage has sufficient torsional stiffness to support the tail plane and that the fin is sufficiently strong, if it is used for ground handling.

If the fuselage is to be split for transport & storage, the join needs to be strong enough for the loads the fuselage will see both in flight and on the ground.

DR-LMA-3020 Structural durability

1) The applicant must define inspections or other procedures to prevent structural failures due to foreseeable causes of strength degradation, which could result in fatal injuries, or extended periods of operation with reduced safety margins.
2) Unless it is not practical, the procedures developed must be capable of detecting structural damage or partial failure before the damage could result in a catastrophic structural failure

Nothing lasts forever, so the aircraft will need inspecting periodically to check for any damage or deterioration.

An annual inspection for aircraft in service will be needed as a minimum, and a return to service inspection of aircraft being returned to use after a period of storage will be needed.

Generic maintenance schedules are provided for wooden and composite airframes, that specify the generic inspections that need to be performed on those types of structure. If any additional or specific inspections are needed they should be added to the generic maintenance schedule.

DR-LMA-3100 Aeroelasticity

The UA must be free from flutter or control reversal:

1) at all speeds within the structural design envelope
2) for any configuration and condition of operation

Flutter is very destructive. The aircraft must be designed and constructed to minimise the chances of flutter occurring.

If the aircraft is of ‘conventional’ layout, Compliance with the rigidity and mass balance criteria (pages 4-12), in Airframe and Equipment Engineering Report No. 45 (as corrected) ‘Simplified Flutter Prevention Criteria’ (published by the Federal Aviation Administration) may be accomplished to show that the aeroplane is free from flutter or control reversal.

Report No. 45 is available for download on the LMA website at XXXXXXXX

All control surface actuation arrangements must be as rigid and slop-free as possible, from the servo mounting to the control surface horn / attachment.

Where possible, ensure that all control surfaces are statically mass balanced.

For a scale model ,if the full-size did not have balanced surfaces (WW1 types for example) mass balancing is not needed, but where the full size has balance weights, the model controls should be balanced also.

DR-LMA-3200 Design and construction principles

1) Each part, article, and assembly must be designed and constructed to be suitable for the expected operating conditions of the UA
2) Sufficient design data must be created to adequately define structurally significant parts, articles, or assemblies and allow their proper construction
3) Doors, access panels and canopies must be designed to not open in flight, unless shown to create no hazard, when opened in flight

Taking into account the operating conditions and loads that the aircraft will experience, the aircraft can be designed in detail. The design should be sufficiently strong and robust, and capable of being constructed properly with the facilities available.

The design of the aircraft must be in sufficient detail that the aircraft can be constructed properly to the design. A full set of drawings does not need to be produced, an outline and a few sketch drawings of critical structural sections can be enough to define the structure of the aircraft.

If any parts need to be made using a specific process (such as composite layup), the process should be properly planned and written down, both to be able to say what has been done during the build process, but also to prevent the possibility of an incorrect process being followed and materials / time wasted.

If the aircraft is being built from existing plans or a kit, the plans themselves meet this requirement provided the construction is carried out to the appropriate standard and any changes to the design are appropriate.

A moulded / ARTF airframe has already been designed and constructed, but a thorough inspection should be made to ensure that appropriate materials have been used and that the construction has been carried out properly. If there is any doubt about the construction of the aircraft, the inspector is not obliged to approve the aircraft and can contact the LMA Safety Panel for advice.

DR-LMA-3210 Protection of structure

1) Each part of the UA, including structurally significant small parts such as fasteners, must be protected against deterioration or loss of strength due to any cause likely to occur in the expected operating environment
2) For each part that requires maintenance, preventive maintenance, or servicing, a means must be incorporated into the UA design to allow such actions to be accomplished
3) There must be enough clearance between movable or rotating parts (such as propellers or rotor blades) and other parts of the structure to prevent the movable or rotating parts from striking any part of the structure during any operating condition

If it is likely that the aircraft will go rusty or mouldy in its life (either where it is flown or where it is stored) then all the structural parts of the aircraft that could be weakened by rust / mound need to be protected, either by paint, varnish or being corrosion resistant materials.

DR-LMA-3220 Materials and processes

1) The applicant must determine the suitability and durability of materials used for parts, articles, and assemblies, the failure of which could prevent continued safe flight and landing, accounting for the effects of likely environmental conditions expected in service
2) The methods and processes of fabrication and assembly used must produce consistently sound structures. If a fabrication process requires close control to reach this objective, the applicant must define the process as part of the design data
3) Designs must account for the probability of structural failure due to material variability
4) If thermal or humidity effects are significant on a critical component or structure under normal operating conditions, the applicant must take those effects into account

You can make the aircraft out of anything you like, as long as you can justify its suitability. There is also no need to use 'aircraft' materials. If using metal for primary structure, it may be worth acquiring metal of a known specification (such as 2024 T3), as the metal sold in B&Q and similar could be pretty much anything, and of unknown quality / specification.

Wood structures

If the aircraft is made from wood, allowance will need to be made for the natural variability of even the best timber.

Ensure that the timber chosen is appropriate for the parts being made

Spruce / Douglas fir / Cyparis are suitable for spars and load bearing structures

Birch plywood is suitable for parts of spars and load bearing structures, but the alignment of the grain must be considered. If plywood shear webs are used, the grain should be at 45 degrees to use all laminations of the wood.

Lite (poplar) plywood is suitable for lightly-loaded structure.

Balsa is suitable for skinning structures, falsework (leading and trailing edges) that need carving to shape

Composite structures

If designing and manufacturing a composite structure (or composite parts), allowance will need to be made for any areas where less than perfect layup, resin transfer or bond strength are present.

Composite structures are particularly applicable to jets and some large WW2 aircraft where formers are used to supplement the strength of the structure. In such cases a careful inspection of the secure lamination of the formers to the composite structure should be carried out.

Adhesives

There are a large number of very good adhesives for various applications. The builder should discuss what he intends to use for the different joints. Just as important as the choice of glue is the way it is employed. For example, where a large surface has to be glued, it probably needs to be clamped to ensure good contact and adhesion throughout.

Adhesives have a shelf life, and should not be used beyond their shelf life unless satisfied that the adhesive cures correctly and is still sufficiently strong.

Although cyanoacrylates are very strong when properly employed, but the strength of a join that seems to be satisfactory can actually be very low, especially if the area is large, because the adhesive can cure before proper contact has been made.

As a general rule, tension should not be placed on an adhesive and where necessary this should be avoided by screws, bolts or gussets to give additional support to the joint.

In particular the engine bulkhead (firewall) must be properly attached employing screws or well-engineered joints.

General Design and Assembly Principles

Bulkheads and firewalls normally use birch ply, 6mm thickness and larger. Where boxes are constructed from light ply and poplar ply, doublers should be considered to increase strength. If possible, tongue and slot construction can aid with assembly. Ply tends to be brittle on loads applied to its surface and large areas may need stringers to prevent bending. Where there is tension that would tend to delaminate the ply, there should be adequate bolts that go through the whole thickness.

The use of 'Thread lock' on all nuts or 'Nyloc' shake proof nuts is necessary in areas of vibration. On engines where metal to metal fixings are used, shake proof washers are an option. Don't replace used Nyloc nuts; use new. The inspector should ensure that the builder fully understands the importance of locking all screws or nuts.

Care should also be taken with wood screws, which should be of adequate length and it is probably advisable to run thin cyano into the hole to strengthen the wood and lock the screw. Where metal fittings are attached to wood with screws or bolts the metal should be glued to the wood.

Remember that nuts and bolts can compress wood, and vibration, especially on engine mounting bolts, can exacerbate this. It is important that in these areas there is an adequate washer or plate on each side of the wood.

DR-LMA-3330 Transportation, reconfiguration and storage

Where the UAS or part of the System is designed to be assembled & disassembled or reconfigured for transportation, the following applies:

1) The conditions defined for transportation and storage must not adversely affect the airworthiness of the UAS
2) Incorrect assembly must be avoided by design

3) Sufficient instructions for transportation, disassembling/assembling, reconfiguration and storage and the respective handling must be appropriately documented

Unless the aircraft will be stored in a hangar, some disassembly will be required for storage and transportation to the flying site.

It must not be possible to assemble the aircraft incorrectly, either by marking which parts fit where or by making mating parts physically impossible to put together incorrectly.

If the aircraft is complex to assemble with many and different fasteners, the number and location of the fasteners should be recorded to ensure that none are missed during assembly.

DR-LMA-3400 Landing Gear systems

1) The landing gear if installed must be designed to provide stable support and control to the UA during ground operation
2) The UA must be designed to absorb the kinetic energy of takeoff and landing at MTOM. Landing at MTOM must not cause damage to the essential systems or structure of the UA, which could lead to a hazardous or catastrophic event if not detected
3) For UA that have a system that actuates the landing gear, there must be a positive means to keep the landing devices in the takeoff / landing position

The landing gear and brakes (if fitted) must be capable of stopping the aircraft in case of a rejected takeoff and prevent the aircraft from exiting the defined takeoff area at a speed likely to cause harm.

The landing gear should not collapse either during takeoff or landing

DR-LMA-3410 Buoyancy for UA for take-off and landing on water

UA intended for operations on water must provide buoyancy to support take-off and landing in water conditions

If the UA is a waterplane intended to be operated from water, it must not sink when put in the water.

DR-LMA-3500 Protection Against High Energy Electrical Sources

If the UA is fitted with high energy electrical sources, information and protection against serious injury must be provided by:

1) Adequate warning of the presence of high energy sources
2) Adequate shielding or insulation of the high energy sources

If the model has electric power sources in excess of 12S lipo equivalent (50volts DC), warning and protection must be incorporated to prevent possible injury to the pilot / operator, helpers or anyone who may need to recover the aircraft.

Properly made electrical wiring with shielded commercial connectors (e.g. XT90) and no bare / uninsulated wiring will comply with this requirement. Shielding of the battery balance connector is not needed.

DR-LMA-3600 Fire protection

1) The UA must be designed to minimise the risk of fire initiation due to:
   a) anticipated heat or energy dissipation, system failures or overheat that are expected to generate heat sufficient to ignite a fire
   b) ignition of flammable fluids, gases or vapours; and
   c) fire-propagating or fire-initiating system characteristics
2) The UA must be designed to minimise the risk of fire propagation by the appropriate use of self-extinguishing, flame-resistant, or fireproof materials that are adequate to the application and location.

The aircraft should not catch fire in use. If gas turbine engine(s) are used, the design should ensure that hot exhaust gasses are kept sufficiently clear from the structure.

Petrol engine installations should ensure that fuel lines and fuel tanks are kept sufficiently clear of hot exhausts.

Heat resisting paints or coatings can be used if necessary.

Especial care should be taken with composite airframes, as they can be significantly weakened by excessive temperatures.

DR-LMA-3700 Design and construction information

The following design and construction information must be provided:

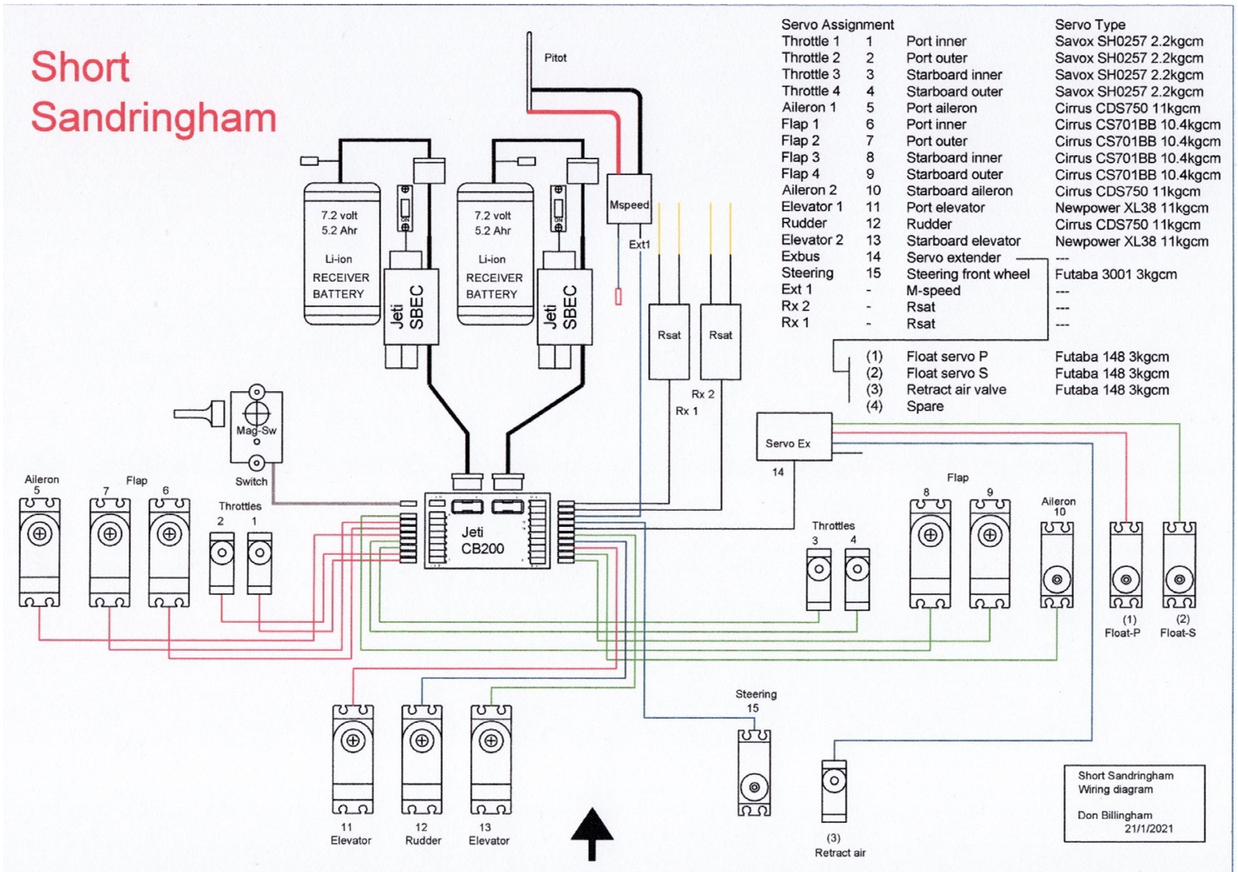
1) a general arrangement drawing of the UA showing the principal dimensions
2) a schematic diagram of the flight control system showing all equipment
3) a schematic diagram of the powerplant and energy storage systems

To help with the design process, and to show that the requirements are being met, there needs to be a definition of what the aircraft, the airframe and its systems actually are.

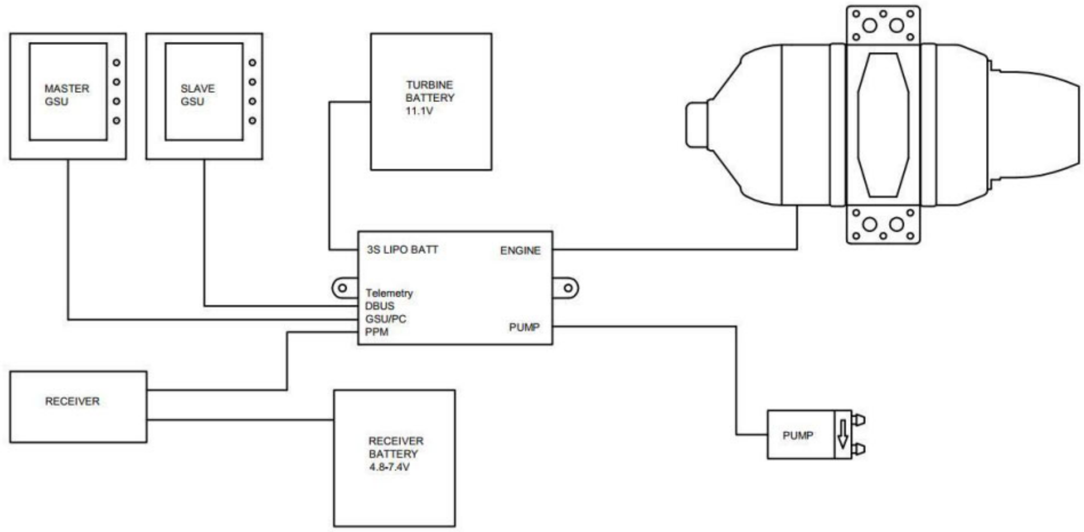
The system diagrams will also allow the system design to be properly considered and the correct level(s) of redundancy in the radio system and power supply identified.

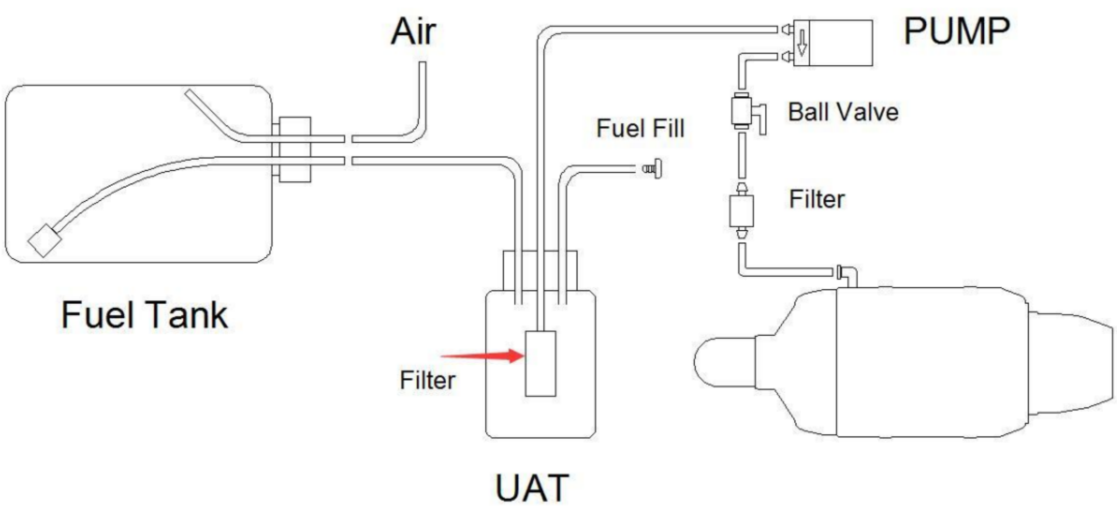
In may cases, the engine manufacturers provide installation drawings in the user documentation. These can be followed and used as-is, or modified for the specific aircraft installation.

An example flight control system is given below (thanks to Don Billingham)

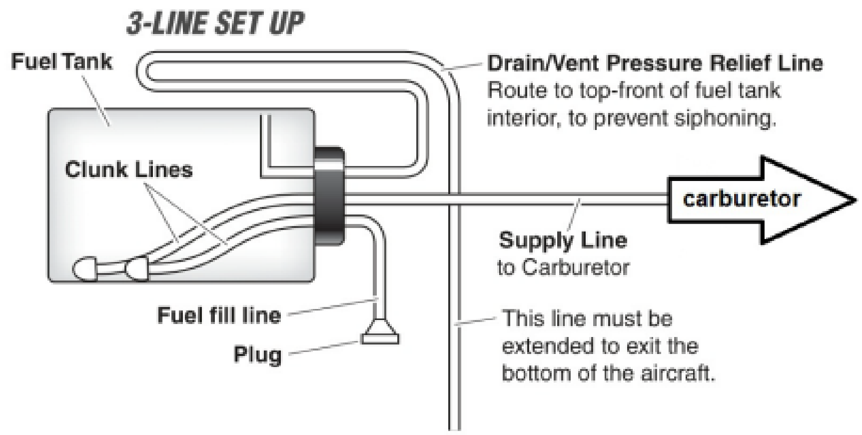


Example turbine powerplant systems are given below (thanks to Swinwin)





Example petrol powerplant system given below (thanks to RCGF)



DR-LMA-3800 UA Marking

The UAS structure must be indelibly marked with the LMA registration number in the format LMA-XXXX (where XXXX is the LMA registration number of the UAS)

As many over 25kg aircraft are now identical moulded airframes, there needs to be a way of telling them apart. Every airframe must be marked (with an engraver or similar) with the LMA registration number somewhere easily visible. Inside an access panel is acceptable, the marking need not be on the outside but the aircraft must be marked on a non-removable part.

SUBPART D – POWER PLANT INSTALLATION

DR-LMA-4000 Powerplant system

For the purpose of this Subpart, the UA powerplant system includes each component that is necessary for propulsion or affects propulsion functionality

The applicant must design, construct and install each powerplant system to account for:

1) all likely operating conditions, including foreign object threats
2) sufficient clearance of moving parts to other UA parts and their surroundings
3) likely hazards in operation, including hazards to ground personnel
4) vibration and fatigue

The engine should be chosen to be appropriate to the aircraft and the operating conditions, to neither significantly under power or over power the aircraft.

As turbine engines have considerable power and a jet efflux considerably in excess of the maximum permitted speed, a turbine engine(s) with sufficient thrust to accelerate the aircraft rapidly to the maximum permitted speed or the safe maximum speed of the aircraft and beyond should be limited to a lower thrust or specifically to fixed periods of high power during flight.

The installation of the engine / motor should be appropriate, and take into account the torque of the engine, vibration and thrust. Electric motors have the potential to apply considerable torque when starting, so should be appropriately mounted.

Installations of petrol engines should consider a secondary method of engine shutdown, either ignition kill or choke control in case of throttle servo / connection failure.

Engine installation

The fuselage or nacelle to which the engine(s) is/are attached should be rigid. Some advocate a rigid mount, and some go for a flexible one. It would seem that a flexible mount can have advantages, if it is properly designed and constructed for the particular engine, propeller and airframe. If in doubt it is probably safer to go for a rigid mount but designed with the possibility of inserting rubber mounts at a later date if they are found to be required.

Check that the firewall is adequate and well-constructed, not relying on butt joints secured by adhesive alone.

It should be properly fixed and of sufficient thickness. Mounting, bolts should be adequate and where they go through wood, protect the wood from compression, for example by the use of large (penny) washers.

Engine cowls

Cowls are subject to vibration and mounts and screws or other attachments should take account of this. Rubber grommets used to isolate the fixing screws may be an option.

The use of ducting and baffles inside the cowl to correctly cool the engine should be carefully considered, especially with multi cylinder engines.

Silencing, fuel tank and plumbing

Consider the use of a larger propeller to reduce the tip speed and engine rpm, significantly reducing the sound level. Excessive noise level can result in the loss of a flying site.

Fuel tanks should have adequate reserve capacity so that at the end of the flight (display) there is sufficient fuel to safely delay the landing so that the landing area can be cleared of any obstruction.

Fuel tank(s) position and type of tubing should be compatible with the fuel. Felt covered clunks are necessary on fuel which easily foams under vibration. A separate fuel clunk may be beneficial for use as a tank draining facility, brought to the outside fuelling position.

Gas turbines

Turbines use significantly more fuel than piston engines and will need correspondingly larger fuel tanks. The mounting structure of turbine fuel tanks needs to be sufficiently strong to support the tank full of fuel at limit load.

Turbine fuel systems are usually more complex than piston engine, and the manufacturer's instructions should be followed to ensure correct and reliable operation.

Due to the lack of vibration, the mounting points for turbines do not have to be as substantial as for piston engines, and the manufacturers mounting instructions should be followed.

DR-LMA-4100 Powerplant operating characteristics

1) Any installed powerplant must operate without any hazardous characteristics
2) If required for continued safe flight and landing, the design must allow in flight shutdown of any powerplant or groups of powerplants

Accepting that the powerplants will either have a rotating knife attached to them, flames coming out of them or a combination of both, they must not do anything unexpected, such as start unexpectedly.

Electric powerplants especially must have means of preventing inadvertent operation, ideally through the use of physical arming plug(s) and arming procedures in the flight control system.

DR-LMA-4200 Powerplant energy storage and distribution systems

For the purposes of this Subpart, 'energy' means any type of energy source for the powerplant, including liquid fuels of any kind or electric current

1) Each system must:
    a) Provide energy to the powerplant with adequate margins to ensure safe functioning under all permitted and likely operating conditions
    b) Provide uninterrupted supply of that energy when the system is correctly operated, accounting for likely energy fluctuations
    c) Provide a means to safely remove or isolate the energy stored within the system
    d) Be designed to retain the energy under all likely operating conditions
    e) Prevent hazardous contamination of the energy supplied to each powerplant installation
2) Each storage system must:
    a) withstand the loads under likely operating conditions without failure, accounting for installation
    b) be designed to prevent significant loss of stored energy under likely operating conditions
    c) prevent significant changes in the centre of gravity of the UA during likely operating conditions

3) Each energy-storage-refilling or -recharging system must be designed to:
    a) prevent improper refilling or recharging
    b) prevent contamination of the stored energy during likely operating conditions; and
    c) prevent the occurrence of hazardous events during refilling or recharging
4) Likely errors during ground handling of the UA must not lead to a hazardous loss of stored energy

The job of the fuel / energy storage and distribution system is to store the energy the aircraft needs for flight, and only release it to the powerplant when needed.

The storage system (usually fuel tanks or batteries) must be adequately installed and supported in the structure of the aircraft during all flight and ground load conditions.

A full 5l fuel tank at 10g is an effective 40kg weight trying to escape from the structure, so needs a support structure that is adequate.

Depending on the size of individual tank(s), internal baffles should be fitted to stop the fuel 'sloshing' around the tank and rapidly changing the aircraft's centre of gravity.

If electric power is used, there must be a simple way to disconnect the battery from the powerplant system, either easily accessible battery connector(s) or a physical arming / disarming connector.

The fuel system should not dump fuel overboard during normal operations, ensure that the vent lines do not allow fuel to syphon out of the tank(s) during flight.

It is strongly recommended that batteries (especially lithium-polymer batteries) are removed from the aircraft for charging. If batteries can be charged while on board the aircraft, the connectors used must not allow incorrect connection, such as reverse-polarity.

SUBPART E – SYSTEMS AND EQUIPMENT

DR-LMA-5000 UAS level system requirements

1) Equipment and systems required for safe flight must be designed and installed so that they perform their intended function throughout the operating and environmental limits for the UAS.
2) Systems and equipment not required for safe flight must be designed and installed so their operation does not have an adverse effect on the UAS throughout the operating and environmental conditions for flight unless the adverse effect does not pose a risk to people on the ground or in the air
3) Each item of equipment must be installed according to the limitations and installation instructions specified for that equipment unless the installation is justified by the applicant.

The flight control radio system must be up to the task, with servos that are sufficiently strong and robust for the controls they are operating.

Extra 'stuff' fitted to the aircraft that is not critical for flight must not cause the aircraft to crash or cause injury. Do not have, for example, the fuel tank supported by opening bomb doors.

The manufacturers instructions should be followed for each piece of equipment, unless the builder justifies the installed use.

DR-LMA-5100 UAS power supply, generation, storage, and distribution

The on-board generation, storage, distribution and supply of power to each system (Except the propulsion system) must be designed and installed to:

1) supply the power required for operation of connected loads during all operating conditions
2) ensure no single failure or malfunction will prevent the system from supplying the essential loads required for continued safe flight and landing
3) have sufficient capacity, if any source fails at any point during a flight, to supply essential loads required for the duration of the flight and landing

The power supply system for the radio control and other systems in the aircraft must be sufficient to supply the power needed for the complete flight, and prevent any single failure from stopping the necessary supply of power to the radio system.

All wiring should be of a good quality and a conducting wire gauge sufficient for the maximum voltage & current that will be seen in service.

DR-LMA-5200 UA Flight Control System

The UA flight control system comprises all those elements of the UAS necessary to allow the remote pilot to control the UA

1) The flight control mechanical systems and mechanical actuation equipment which are installed on the UA must be designed and installed to operate easily, smoothly, and positively enough to allow proper performance of their functions when the UA is subjected to expected limit loads, including autorotation where applicable
2) The flight control system must be designed and installed to ensure that:
    a) no single failure or malfunction of the radio receiving equipment fitted to the aircraft will cause a loss of control or prevent the emergency landing function from operating
    b) no single failure or malfunction of the mechanical actuation equipment fitted to the aircraft will cause a loss of control or prevent the emergency landing function from operating
3) Trim systems, if installed, must be designed to protect against inadvertent, incorrect, or abrupt trim operation
4) The flight control system shall incorporate functionality to land the aircraft in case of loss of the Command & Control radio link to prevent as far as possible:
    a) Fatal injuries to people on the ground
    b) Fatal injuries to people in the air
    c) Damage to critical infrastructure

The aircraft must have, as an absolute minimum a failsafe that will land the aircraft as quickly as possible when the command & control radio connection is lost.

The point of a radio failsafe is to land the aircraft as quickly as possible to prevent the model aircraft from flying beyond visual line of sight of the pilot, leaving the defined flying area or exceeding the height limit in case the radio control link is lost for whatever reason.

the failsafe should if triggered, as a minimum either-

- Return to home and land or loiter (if available and
- Reduce the engine(s) to idle power
- Reduce electric motor(s) 'throttle' to zero
- Gliders, deploy airbrakes, deploy flaps or flight controls to enter a spiral dive

If a flight controller if fitted the aircraft failsafe can be set to return to home (RTH) and either land or loiter in case of loss of control signal. For initial test flights before the flight controller has been tuned, the failsafe should be set to land the aircraft immediately as per a 'traditional' failsafe. There should also be a way to cancel the failsafe action if control is regained.

If using RTH failsafe, ensure before starting the flight that the 'home' position of the aircraft is correctly set and a safe location for the aircraft to land if RTH is engaged. The location of the aircraft immediately before it takes off is generally the most appropriate 'home' position.

The functioning of the failsafe will need to be checked during the inspection process with all engine(s) running to ensure that the minimum failsafe action actually occurs.

In this case 'trim systems' does not mean the usual transmitter trims, it means separate mechanical trim tabs and all moving horizontal tail planes on aircraft like airliners, to prevent an 737 MCAS type situation of the trim system overpowering the elevator authority.

Due to the relatively small speed and mass range of a model airliner compared to the full size, trim systems are usually not needed for normal operation.

Flight Control System Design and Redundancy

Experience has shown that modern solid-state receivers very rarely fail, and 'radio' failures in service are predominantly caused by a fault in the power supply or a loss of radio communication rather than a physical fault with the receiver.

The introduction of serial data bus communication from receivers has also given the potential for the radio reception to be separated from the output to servos which was traditionally all carried out within a 'receiver', and a variety of commercial units are available that provide servo outputs from multiple receivers and multiple power supplies.

Therefore, the requirements have been refined to require duplication of power supply to the receiver, adequate power distribution capability to match the number and type of servos fitted and a minimum level of antenna diversity. This will ensure that the receiver will receive and distribute power correctly and have radio communication at all points during a flight.

Based on this philosophy, the minimum required airborne system should consist

of-

1) A minimum of two independent power supplies (batteries and switches), see Note 1.
2) A minimum of three diverse antennas, arranged and distributed to give signal coverage at all aircraft orientations, see Note 2.
3) A power distribution system matched to the number and size of servos fitted
   a) For slow lightly loaded models using predominantly standard servos, a standard receiver will have sufficient power handling capacity, and one can be used with the minimum number of additional satellite / redundancy receivers.
   b) For faster & heavier models using a significant number of large or high-power servos, either physically separate receivers or preferably a power distribution system should be used to ensure that no part of the control system will be overloaded.

Note 1- If switches are fitted in line, there should be one per battery, so a minimum of two. If a power distribution system has a 'soft' switch that fails safe, one such switch may be used.

Please make sure that all switches are of good quality and rated for the voltages and currents that will be seen under maximum load.

Note 2 - Careful consideration of the manufacturers' installation instructions should be made when siting and orientating the antennas. As a general rule, antennas which should be installed parallel to each other (in a straight line such as some Spektrum receivers) are one antenna. Antennas that should be installed perpendicular (at 90 degrees to each other such as Futaba or Jeti receivers) are separate antennas.

In practice this means the minimum equipment for a slow lightly loaded model with low power consumption servos would be-

1. one Spektrum Powersafe receiver or similar with at least three satellite receivers
2. one receiver capable of redundancy with a redundancy receiver connected (such as Jeti, Frsky or similar systems)

If the radio control system used is capable of operating simultaneously on two frequencies (normally 2.4GHz and 868MHz), the two receives can be on different frequencies (e.g. one receiver on 2.4GHz and one receiver on 868MHz) provided the transmitter is transmitting simultaneously on both frequencies.

Where satellite / redundancy receivers with a single SBUS / cable connection are installed, great care must be taken to ensure that the cable(s) are securely attached where they plug in and fastened to the aircraft to prevent damage or inadvertent disconnection during operation.

While this guidance is intended as the minimum required standard to give an acceptable minimum level of safety, it is very important that the airborne system is appropriate for the size and performance of the model in question. Additional redundancy can be used if desired to make a model more resilient to potential failures.

Consideration needs to be given to the system planning however, to ensure that additional equipment does not have the unintended consequence of making the model less rather than more reliable. Especial care should be taken with gyro stabilisation systems to ensure they have the desired operation, and the facility should be available on the transmitter to turn the gyro off in flight if needed.

Where gyro stabilisation units or helicopter / multirotor flight control units are installed with a single data bus (SBUS) connection from the receivers, great care must be taken to ensure that the cable(s) are securely attached where they plug in and fastened to the aircraft to prevent damage or inadvertent disconnection during operation.

The performance of the airborne radio system is highly dependent on the quality of the installation, and manufacturer's instructions should be followed when planning the installation.

The location of antennas should also take into account any potential radio blocking features, such as engines or carbon fibre structure, and performance of the whole system verified with a thorough range test in all orientations and with all systems operating before flight.

Many radios feature telemetry capability, which give as a minimum feedback from the airborne receiver of the received signal strength and the battery voltage(s). It is strongly recommended that telemetry and appropriate alarms are used to give a warning of low received signal strength or battery voltage in flight.

The models of all equipment used in the flight control system should be recorded, including receivers, transmitter and the control frequencies and output powers used.

Mechanical Control Linkages

Remember that any free play at all in the control system is the enemy and can lead to flutter.

In all parts of the control system, 'standard' model parts such as plastic clevises, small sprung metal clevises, wholly plastic hinges and moulded plastic control horns should not be used.

Some plastic parts, such as heavy-duty buggy steering parts and glass reinforced nylon may be acceptable depending on the use and loads.

For flying surfaces or equally heavily loaded parts, the hinges used should be sufficiently strong and robust.

A 'sprung' metal clevis with a 1.6mm pin is not considered sufficient. 3mm, 4mm and 5mm metal / appropriate plastic ball joints and links are more appropriate.

Clevises should employ metal pins, bolts or split pins and each must be positively locked. Alternatively, it is possible to obtain heavy duty metal ball and sockets which are also positively locked. Some commercial types are either too small or are liable to come apart.

Some commercially available metal control linkage parts (including some parts supplied with ARTF aircraft) are of low quality with significant free play and should not be used.

Ensure that sufficient thread is engaged from the pushrod into the clevis / ball joint and locking nuts should be used.

Pushrods if employed should be short and stiff. Alternatively, a closed loop system may be used for long runs. The cable runs should have adequate support if the run changes direction and adequate wire swages should be used at each end of the cables.

Check that the amount of free movement is small, with slop free linkages, and check that backlash in the servos is not excessive. Some industrial / robotics servos, while very powerful, have significant backlash. In very large models it is advisable to use twin blade clevises on a single horn or alternatively, a double horn either side of a ball ended coupling, to prevent distortion.

Multiple flaps operated by individual servos can cause a potentially fatal problem if a servo fails. A mechanical linkage through all flaps should be considered or multiple servos per flap. Left and right flaps should not be dual redundancy only be connected to one radio system if 'split' systems are used.

DR-LMA-5300 Pressurised systems elements

Pressurised systems must be capable of withstanding appropriate operational and environmental pressures.

If you use pneumatic power for landing gear or other systems, the whole system must be appropriate for the pressure used. Consideration should be given to fitting a pressure relief valve, as thermal effects (the sun) can lead to a dangerous overpressure & damage to the aircraft & injury to people.

Do not use plastic 'pop' bottles as air tanks, as they are no longer strong enough to safely withstand the required pressure, metal air tanks should be used.

Plastic pneumatic piping is adequate for the pressures used.

DR-LMA-5400 Flight data recorder

The UAS must be fitted with a flight data recording system that must ensure accurate and intelligible recording of the GPS time/ date and the speed and 3-dimensional position of the UA every 2 seconds

The aircraft must be fitted, as a minimum, with a GPS flight data recorder. Ideally, the aircraft should be fitted with full logging of controls and telemetry including GPS data.

SUBPART F – REMOTE PILOT CONTROLS

DR-LMA-6000 Remote Pilot Controls (Performance)

The remote pilot control must:

1) be adequate to support the command and control of the UA by the remote crew for the intended operations
2) be qualified against the environmental conditions expected for the intended operation

The transmitter(s) need to be up to the task of controlling the aircraft, and if it is planned to fly the aircraft in rain or snow, the transmitters(s) need to be sufficiently waterproof.

DR-LMA-6100 Remote Pilot Controls (Human Factors)

The remote pilot control design and arrangement must:

1) allow the remote crew to perform their duties without excessive concentration, skill, alertness, or fatigue
2) minimise remote crew errors, which could result in additional hazards

The transmitter(s) need to be set up so that the aircraft is not tiring to fly, and if there are a considerable number of controls, consider putting secondary functions on a second transmitter so that the pilot can concentrate on flying the aircraft, and a second crew member operate the ancillary controls.

As transmitters have many similar switches, ensure that the 'gear retract' switch is not 3mm from the identical 'snap roll' or 'engine kill' switch.

SUBPART G – UAS INFORMATION

DR-LMA-7000 Aircraft Information

The applicant must prepare operational and maintenance instructions that are appropriate for the intended operations of the UAS

These instructions must define:

1) Operational limitations
2) Recommended replacement or overhaul times
3) system inspections / test intervals
4) structural inspection intervals, and related structural inspection procedures required
5) conditions for safe storage, transportation and appropriate instructions for assembly
6) conditions for long term storage and return to service

An operational and maintenance schedule is needed for the aircraft to define what the limits are and what maintenance needs to be done and when.

The LMA has defined

- Standard operational limitations
- a standard maintenance schedule
- standard storage / transportation conditions
- standard long-term storage / return to service instructions

These will be sufficient for the majority of aircraft of wood / composite construction and petrol / turbine / electric power. If the aircraft is of 'standard' construction and arrangement, these instructions may be used as is. Any specific non-standard features or requirements can be added as needed.