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DESIGN AND AIRWORTHINESS REQUIREMENTS FOR MILITARY UNMANNED AIR VEHICLE SYSTEMS

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Bernard C Rogers (MRAeS AMAPM)
ADRP2c, MoD UK, Defence Procurement Agency (DPA)
Walnut 2b
Abbey Wood #68
Bristol BS34 8JH
England
e-mail: adrp-2c@dpa.mod.uk

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ABSTRACT

This paper examines the safety implications and factors to be considered for the procurement of a UAV and identifies the design requirements to be used as a guide to produce an air vehicle specification. It will touch on matters covered in more detail by other presenters because of the need to reflect the information they provide within the new standard. It should be noted that while appreciating that dirigibles and micro UAV's will be introduced in the future, it was agreed that the current UK Defence Standard 00-970 should comply with current policy agreed within the United Kingdom (UK) Ministry of Defence (MoD), and that by the Civil Aviation Authority (CAA), which is, that UAV Systems under 20kgs should be treated as models and as such do not need to comply with the regulations governing aircraft. This paper also identifies the role of the "Airworthiness, Design Requirements and Procedures (ADRP) organisation" of the UK MoD Defence Procurement Agency (DPA) and details the work being carried out in developing a set of general design and airworthiness requirements for UAV systems. ADRP are part of the new Defence Procurement Agency (DPA), which was formed on the 1st of April 1999, to take forward the "SMART" Procurement initiative, which aims to use faster, cheaper and better ways of equipping the UK armed forces. This involves Integrated Project Teams (IPT) managing the programmes throughout the life of the equipment. This paper discusses the current and future UAV Systems requirements and gives a brief insight into the strategy adopted to produce a set of regulatory documents and procedures for the guidance of the MoD Integrated Project Team leader (IPT/L). This is done by ensuring adequate procedures are in place for the safe and airworthy operation of such aircraft. These procedures set the minimum standard required to accommodate the safe operation of all UAV systems in all airspace conditions subject to any limitations and constraints imposed by the design.

INTRODUCTION

This paper discusses airworthiness activities and the set of procedures which are being produced by ADRP. It is not intended that these procedures should solve all the problems relating to the introduction of UAV Systems (UAVS) however, the documentation being produced should form the basic building blocks from which future UAV's will develop. This paper will also identify and describe some of the activities being undertaken by ADRP and the Unmanned Air Vehicle System Subcommittee (UAVSSC) relating to airworthiness and design, and to identify those areas of concern that need to be addressed to ensure safety in the air and on the ground. The paper, although generally based on my own thoughts and opinions also reflect the policies and procedures agreed within MoD.

SAFETY CONSIDERATIONS

The requirement to fly military UAV Systems (UAVS) in civil airspace is being addressed but I understand that it may be some time before a comprehensive policy is formulated and is incorporated into Air Navigation Orders. From my own point of view I would like to see four levels of operation, these should be:

- a. Military controlled ranges - where civil aircraft are generally excluded from flying;
- b. Civil airspace below 3000ft/10000ft (depending on area) where see and be seen is of the utmost importance.
- c. Civil airspace 10000ft-24500ft Used by most commercial airlines and under Air Traffic Control

- d. Civil airspace above 24500ft - Although some commercial aircraft fly at these heights this is considered uncontrolled airspace.

From the above levels of operation can be identified three distinct types of UAV. Figure 4 (attached as an Annex) identifies three levels of sophistication depending on application. Area of operation, size, and endurance of the system need to be considered as this will effect cost, why use a complex system if durability and safety of personnel are not a issue?!

If we first look at the problems associated with flying military UAVS on ranges for training or as targets, in general suitable regulations can be produced. The solution adopted is to have a set of regulatory procedures which include extensive testing, restricting the spread of personnel on the training area under the flight path and the introduction of cut down mechanisms and other fail safe devices, however if you are flying over the civilian population the solution becomes far more complex. The types of UAV likely to be used will be varied in size, weight, range and complexity. As I see it there will be an on going need to interface and interact with other organizations such as the Civil(CAA) and Federal(FAA) Aviation Authorities, local Air Traffic control and possibly the civic authorities over whose area the UAV is being over flown if emergency landing areas are to be identified.

Under the general heading of Safety I have addressed those aspects which I feel need to be considered. This list however is not exhaustive and I am sure will be added too. For this presentation the term **Safety** includes the following elements.

a. **Airworthiness.** - Embraces such factors as: Reliability, System Maintainability, The use of approved designers and manufacturers, crew training, Controllability, Recovery, Commands and control links. If we look at these areas in more detail, taking into account the future need for UAV's to fly in civil airspace in peace time, the designer will need to consider:

(1) **System Reliability** - comply with the requirements for manned aircraft as far as system reliability and maintainability is concerned. Where possible critical systems should be duplicated. The use of redundant systems will only be possible on the larger UAV's where the weight factor will be less of a problem.

(2). **Structural Failure** - To prevent structural failure all components forming the airframe (whether modular or not) should if possible be dynamically tested, this testing

should be commensurate with the size and type of UAV.

(3) **Manufacturers** - In the UK there are few dedicated UAV manufacturers, however most of the big companies have been involved with control systems, Guided Missile production, test and evaluation procedures which should be similar for UAV systems taking into account the need for durability and reusability.

(4) **Controllability** - is a major area of concern, the interruption or corruption of signal commands and data links to and from the UAV is an area which further work is required and STANAGS are being produced. The loss of signal during conflict can be embarrassing as well as costly especially if the result is the loss of a number of UAV's. In parallel to this, in the model aircraft world, cases have been reported of interference by high powered electronic equipment operation causing models to fly erratically and in some cases causing injury and death.

(5). **Approved training schemes** for personnel are being implemented. With the operator/pilot being remote from the UAV, as well as the need to operate the system correctly there is also the need to ensure that personnel have instilled in them the fact that their actions could directly affect the health and safety of third parties on the ground and in the air .

(6) **Recovery, planned or emergency.** When, in future, we start to fly UAV's in civil airspace on a regular basis the problems of landing safely will be of paramount importance. By this, I don't mean the need to land the UAV at the end of a mission. If a problem develops with a major sub system such as the engine or receiver/transmitter when flying over a populated area, the last thing that you want to happen is for the UAV to cut down immediately. It would seem therefore that either emergency landing areas along the route should be identified or diversions around high density areas must be programmed into the onboard computer. Steerable parachutes controlled by GPS could be one way of getting around the problem of where to land. The use of specified areas such as Parks or reservoirs as possible emergency landing ground along the route should be considered and this information programmed into the onboard computer.

b. **Airspace Management** - The UK Airspace Steering Committee has working groups looking at the

problems of flying UAVS to the current Air Navigation Orders (ANO) such as **See and be Seen** and **See and Avoid**. Conspicuity is another matter, is camouflage really necessary in peace time? Should the UAV be controlled or autonomous (how involved should the man in the loop be?) And finally should there be timed exclusion zones along the flight path of the UAV? All these questions have an impact on airworthiness and the design requirement.

(1) I see the flying of UAV's below 10,000ft, as being the major problem area as this is used by general aviation and low flying military aircraft. Helicopters and other light civil aircraft may even be below 500ft in certain areas. Most UAV's will be flying between Zero to 2000ft. The ANO requires a minimum separation of 500ft between aircraft, the ground, any obstacle or person, this could create a problem when in VFR(see 3 below).

(2) There is a need for the UAV to communicate with ATC especially when "operating in" or "transiting through" controlled airspace. There is also a need to recognise other airspace users. A dedicated UAV controller (possibly retired aircrew) to act as liaison with the ATC may be the answer.

(3) The ability to **see and be seen**, or **see and avoid** is the major problem. Most military UAV's will be camouflaged and designed for low visibility (possibly visual and radar signature), essential for operational purposes. In addition unless they are like Predator or Global-hawk they will be smaller than a manned aircraft and likely slower. If other small manned aircraft are operating in VFR it will be difficult for these pilots to identify the approaching aircraft as a UAV, and assess the separation distance. The fact that it cannot comply with the rules of the air to avoid a collision means that it will be necessary to indicate to other airspace users that the aircraft is a UAV. Some UAV systems use cameras for flying, the operator having direct control of manoeuvres, however there will always be blind spots which will affect safety. The fitting of Transponders to all UAV's will not alleviate the problem as not all civil owned aircraft have them fitted, or switched on, or have the means to pick up external signals. The use of timed exclusion zones for other traffic may be worth considering as a method of reducing the risk of collision.

(4) For Visibility/Conspicuity - high intensity strobe lights have been suggested however as well as the weight penalty, you may

need more than one to ensure that all angles of visibility are covered. This solution is impractical for the smaller UAV Systems for several reasons including, weight and power consumption I suggest that anything smaller than the UK Phoenix would be impractical. To have separate aircraft for peacetime could be one solution (forgetting the strobes), discussions into the colour to be used, are taking place in the UK. The colour scheme to be used should take account the heating effect of solar energy. It is suggested that painting any UAV's "Black", like current training aircraft could affect electronics and mechanical actuators close to the external skin.

(5) Man or Machine Operation - For flight safety purposes I cannot see that there is much to gain by having a man in the loop flying the UAV during transit from the launch area to the target location. His visibility will only be that shown on the screen by the selected camera, I can see a certain amount of disorientation if more than one camera is fitted, and the controller is constantly switching between cameras (see and be seen aspect), especially with the medium to long range UAV systems.

c. Health and Safety In the United Kingdom legislation is in place on health and safety. The Secretary of State for Defence has stated that the MoD will be subject to the requirements of the current legislation, therefore personnel, and equipment (throughout its life cycle), provided for and/or operated by the Services must comply with current health and safety. The equipment life cycle will include all elements of: design, supply, manufacture, operation, maintenance, testing, storage and disposal.

Operational - This is very much a chicken and egg situation, what comes first? Should we be looking at our needs/requirements or should we be looking at what's on offer and adapting it to our needs. What is the most cost effective method? Some of the criteria to be considered are:

(1) Tasking - the questions to be asked does the task require the UAV be flying, low, medium or high level and is it required for short, medium or long range use. The type of sensors to be fitted will also have an impact on how the UAV is treated. In case of failure during operations, does it need to be destroyed or can it be recovered?. Another factor which will have an impact on design is will it accompany manned aircraft, fly solo or be part of a group of UAV each having different functions.

(2) Environment. - Will the UAV need to be operational in all climates or can it be tailored to suit specific areas?

(3) User - whether the UAV is ship launched, ground launched or dropped or ejected from an aircraft needs to be determined and the design of the UAV and its system adjusted accordingly.

(4) Interruption or corruption of signal commands. - I have already iterated this point once, however the hardening of the system although a costly exercise maybe necessary.

THE ROLE OF ADRP

The role of ADRP is to:

- Provide airworthiness and safety services to all involved in the procurement and operation of UK military aircraft.

To achieve this we:

- Assist those with responsibility for military aviation safety to establish and maintain the high standard of safety demanded of the aviation business by:

- * providing effective support to the Defence Aviation Safety Board (DASB) and the Joint Airworthiness Committee (JAC).

- Assist DPA, the Chief of Defence Logistics (CDL) and operational staff to achieve their mission in a better way, consistent with achieving high safety standards, by promulgating and advising on:

- * DASB policy
- * airworthiness standards and procedures,
- * Best safety management practices.

ADRP organisation chart (see Fig 2).

With increased interest from the three Services to operate UAV Systems and the need to fly UAVS outside of military controlled ranges it is of the utmost importance that high integrity proven systems are used and operated correctly. This is best achieved by providing a set of regulatory documents for all to use. It is in the design area that the Airworthiness Design Requirements and Procedures (ADRP) Branch of MoD Defence Procurement Agency (DPA) has a major role to play.

The Branch is split into three sections under the Assistant Director (AD)/ ADRP, these are ADRP1 (Policy), ADRP2 (Procedures) and ADRP3(Weapon Airworthiness). The function of the three sections is as follows:

ADRP1 (Airworthiness Policy and Procedures)

Tasks Include:

- Secretary to the DASB
- Internal Audits of Aircraft Projects
- Controls the register of all UK military aircraft
- Joint Service Publication (JSP) 318B Regulation of Ministry of Defence Aircraft
- Def Stan 05-122 Military Listing of Civil Owned Military Aircraft (COMA)
- Airworthiness Training
- advice on Safety Critical Software and Y2K matters.

ADRP2 (Airworthiness Design and Procedures)

Tasks Include:

- Production of Def Stan 00-970, 00-971, 00-932, 00-933, 05-123 and Airworthiness elements of 08-5.
- Management of the Design Approved Organisation Scheme.
- Secretariat of the JAC
- Focal point for SBAC and Industry
- Focal point on Standardization

ADRP3 (Armament Airworthiness and Safety)

Tasks Include:

- Professional advise to aircraft platform offices/IPT's on Armament Safety, Airworthiness and related subjects.
- Provide advise on the application and amendment of MIL STAN 1760.
- Advise on the safe integration of weapon systems.
- Provide assistance to ADRP1 and 2 on weapon safety policy.
- Assist the Defence Logistics Organisation (DLO) with advise on Armament matters.
- Involvement with the preparation of a new MIL STAN on Miniature Munitions.
- Maintain a Weapon MA Release and COMA data base.
- Review of environmental testing of armament stores.

DEFENCE AVIATION SAFETY BOARD (DASB)

UK military aircraft (including UAVS) operate under the Crown Prerogative that is they are not regulated by an act

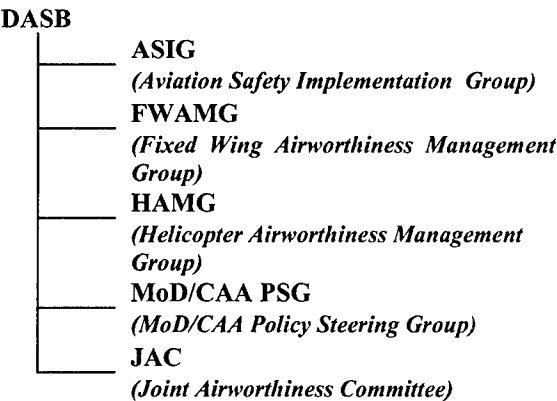
of Parliament. However The Secretary of State (SofS) for Defence has a duty of care to ensure that the procurement, maintenance and the operation of military aircraft is carried out in such a way as to ensure safety. This duty is discharged by employing a regulatory system and supporting procedures, with the intention that they should be no less effective than that required for civil aircraft. The DASB is established to assist the SofS in discharging his airworthiness responsibilities by directing airworthiness policy and providing advice to the SofS, Single Service Chiefs, Chief Executives' (CE) of DPA and DERA. Its members are drawn from all three armed services (both in operational and engineering capacities) and includes senior representatives from DPA and the Defence Evaluation and Research Agency (DERA). AD/ADRP is the group secretariat, and consequently is the air system focal point for the promulgation of airworthiness policy.

DASB Terms Of Reference (TOR)

- **Provide top-level advice on Aviation Safety.**
- **Inform MoD top-level management on Aviation Safety.**
- **Call for and consider reports as appropriate.**
- **Co-ordinate and review MoD Aviation safety policy.**
- **Recommend where appropriate revisions of Airworthiness delegation.**

The DASB has five subordinate committees dealing with the specific tasks identified below and in **Figure 1** (attached - the DASB organizational Chart down to working group level). Depending on the type and the scope of the UAV to be used, it will be discussed at the appropriate committees.

DASB Committee Structure



However for the purpose of this presentation we will only be concerned with the Joint Airworthiness Committee structure, which is chaired by AD/ADRP

The Joint Airworthiness Committee (JAC)

Chaired By AD/ADRP

Membership:

- MoD Project Staff**
- SBAC Members**
- DERA**
- Sub-Committee Chairpersons**
- CAA**
- ADRP Technical Staff**

This committee first established on the 2nd Feb. 1940 allows consultation between Industry (SBAC) and MoD on matters of airworthiness and military aircraft safety (this includes equipment and associated services). In particular the JAC is charged with endorsing technical design and certification standards for military aircraft, and joint MoD/Industry processes and procedures for the procurement and maintenance of military aircraft.

Airworthiness and safety tasks of the JAC include:

- **Reviewing the impact on military aircraft of new revised MoD policies and practices, recommending changes to improve airworthiness or safety.**
- **Examines, reviews and recommends where appropriate the application of emerging civil aviation and central Government policies and practices and requirements to military aircraft.**
- **Considers and recommends where possible, the application of best practice in assuring airworthiness and safety to military aircraft.**
- **Ensures a common and co-ordinated approach to the use of European, International and National standards for MoD procurement in the aerospace sector.**
- **It will initiate and progress changes to MoD Technical Documentation arising from emerging technology or aircraft incidents/ accidents to assure the airworthiness and safety of military aircraft**
- **Once the JAC has ratified papers produced by its sub-committees or consultants, ADRP carry out all necessary action to ensure that the papers produced are inserted into the relevant Defence standards 00-970 or 05-123 (Procurement Procedures for Aircraft) .**

It is appropriate at this stage to define airworthiness, especially as airworthiness appears to have a slightly different meaning depending on who you talk to. The UK MoD definition of Airworthiness is as follows.

Definition of Airworthiness (from Joint Service Publication (JSP) 318b)

Airworthiness is the ability of an aircraft or other airborne equipment or system to operate without significant risk to aircrew, ground crew, passengers (where relevant), or to the general public over which such airborne systems are flown.

For an Unmanned Air Vehicle (UAV), airworthiness embraces a number of elements or sub-systems not normally associated with flying aircraft. I refer of course to the ground/sea/air "Support Facilities" which may consist of the control station, launch mechanism and the transmission systems for the control link. The complexity of the system and the theatre of operation in which the UAV is going to be used will have an impact on the design factors necessary to achieve airworthiness. It should be noted that the design, build and maintenance elements are implicit in this definition of airworthiness.

While on the subject of definitions, throughout this paper I have used the term "Services" with a capital "S" this refers to the Navy, Army and Airforce of the United Kingdom

MILITARY AIRCRAFT RELEASE

7.1 Before any aircraft can be released to any of the three Services it has to receive a Military Aircraft Release (MA Release). The MA Release identifies the flight envelope in which the UAV is safe to fly. The procedures to be adopted are set out in the Joint Service Publication JSP318B, Regulation of Ministry of Defence Aircraft.

The M A Release covers:

- **Airworthiness and Document Management.**
- **Aircraft Design and Handling Limitations.**
- **System Limitations and Constraints.**
- **Audit Trail.**

The MA Release is the military equivalent of the CAA "TYPE" Certification. The initial **MA Release** is issued under the authority of the Chief Executive (CE)/DPA, who delegates responsibility to the MoD Integrated Project Team Leader (IPT/L)/Aircraft Project Director (APD). The IPT/L will only recommend issuing the MA Release once he/she is satisfied that sufficient evidence exists to establish the airworthiness of the aircraft. Such evidence would include: a Certificate of design signed by an approved signatory for the Contractors; all supporting documentation and procedures for the design and construction of that the aircraft /Equipment, comply with the requirements of the specification and all

standards identified therein; The IPT/L(APD) will request an assessment independent of the designer to establish confidence in the airworthiness of the design. This may be carried out by DERA Boscombe Down or any other approved aircraft assessment organisation. All activities are documented and the design, handling, role, system limitations and constraints are set out so that a comprehensive audit trail can be maintained.

The MA Release is then passed to the Service Operational Branch who issue the **Release to Service (RTS)**. Initially this is normally a copy of the MA Release with a new cover. The RTS authorises flying under the control of the Chief of Staff (COS) for that Service. At some point after entry into Service, the Service may wish to change the operating limits either to save on fatigue life or to extend the limits to cover some specific short term mission capability or because they wish to embody a **Service Engineering Modification** - such alterations are covered by Service Deviation and the parent Service accepts full responsibility for the airworthiness of these deviations.

HISTORY OF UAV's IN SERVICE

The early pioneers of manned flight had their problems, especially with structural integrity. The materials used, the methods of construction, and the design concepts that were applied resulted in several incidents involving the pilot and also innocent bystanders. In the early years the UK National Physical Laboratory were concerned with aerodynamics and structural strength for military aircraft, as a result of this and other activities, the Handbook of Strength Calculations (HB 806) was produced and further developed during the 1914-18 war. This document has evolved over the years through Air Publication 970 to the current Defence Standard (Def Stan) 00-970 (discussed later). However even with the best design techniques and maintenance procedures, mechanical failures still occur, and some of the more dramatic modern failures are those associated with electronic control systems. The introduction of new technology to control aircraft, such as fly by wire/light and computerised operating systems with no mechanical backup, has brought about its own problems.

The need to consider the control of Software and other factors such as Electro-Magnetic Interference (EMI) and for equipment to be hardened against this effect, whether it is natural or induced by man has to be considered. Aircraft system failures can lead to spectacular results as well as being both costly in life and equipment as shown in the video. Although these incidents relate to manned aircraft similar situations could arise with a UAV's. The risk to life in populated areas must be taken into account whether training or operating as part of a peace keeping force.

When you consider that the first unmanned Aircraft flew in the UK around 1913, it has taken the UAV a long time to progress especially when you compare with manned flight. However the UK has flown a limited number of UAV Systems over the years mostly as targets or target towing aircraft, the exception being the "Midge Drone" (CL 39) Reconnaissance UAV, the Army's predecessor of Phoenix.

Falconet, Chuker and Jindivik to name but a few have been used by the three Services, however all these systems were and are still restricted to cleared ranges. Jindivik, which is primarily used to tow targets, is the one exemption to the rule as this has to travel for a very short period of time in an air traffic zone when in transit between the airfield and the range. To do this it is accompanied by a manned shepherd aircraft, usually a Hawk. The shepherd aircraft accompanies Jindivik throughout its flight into the range but withdraws when the missiles are being fired at the towed targets. On the completion of firing the shepherd aircraft rejoins the Jindivik and carries out an airborne inspection of the airframe to ensure that the air vehicle has not been damaged during the firing, and is recoverable. It should be noted that this inspection is carried out prior to leaving the range.

The Directorate of Flying is responsible for regulating all non service flying of UK military registered aircraft, including UAV Systems this includes private ventures using MoD ranges.

DESIGN APPROVED ORGANISATION SCHEME (DAOS)

To ensure that safety and airworthiness are addressed at the design stage, the UK MoD have a set of procedures which are employed to select companies that are capable of carrying out the tasks required. The competence



of design of the potential UAV contractor will be assessed, under the Design Approved Organisation Scheme (DAOS). Information on this scheme is contained in Def Stan 05-123. Briefly, companies under contract for design functions for the UK MoD have their company structure and key personnel assessed for the acceptable level of design competence for the scope of the specific contract. The assessment is carried out by the Integrated Project Team responsible for placing the contract assisted by ADRP staff. If the company is acceptable they are then put on the register of Approved MoD Companies. If the company has a change of personnel, location or management structure it will need re-assessing. Inclusion in this scheme is not an essential pre-requisite for the award of design and development contracts, however an assessment of the company will normally be carried out by the IPT assisted by ADRP.

RESTRUCTURING OF DEFENCE STANDARD 00-970

Design, Airworthiness and Operational procedures for military aircraft are produced by the MoD. Considerable work has already been done to revise and produce a set of Design Requirement for aircraft and UAV Systems. Def Stan 00-970 (Design and Airworthiness Requirements for Service Aircraft) has grown in size and complexity since its conception and at present comprises two volumes each of three books covering respectively fixed and rotary wing aircraft. It is now under going revision, the aim being to eliminate duplication and irrelevant material and to present the document in a modular format with the information being presented in a more structured manner. The first tranche of work will be published this year (1999).

New Format of DS00-970

- Part 0 - Guidance and definitions**
- Part 1 - Combat Aircraft (A/C)**
- Part 3 - Small Civil Type A/C**
- Part 5 - Large Civil Type A/C**
- Part 7 - Rotorcraft**
- Part 9 - UAV Systems (was Def Stan 05-127)**
- Part 11 - Engines (was Def Stan 00-971)**
- Part 13 - Military Common Fit Equipment**
 - Includes:**
 - NVG Compatibility
 - Recce Pods
 - Electrical Installations
 - Aircrew Equipment Assembly
 - Launchers
 - Role Equipment e.g. Aero Med.
 - TRD (Towed Radar Decoys)

- Part 15 - Items With No Military Specific Requirement**
 - Auxiliary Power Unit (APU)

Propellers
Very Light Aircraft (VLA)
Gliders
Airships

DS 00-970, will be published in nine Parts. It will be issued in CD ROM (hypertext linked) or "Hard Copy", but the idea is that in the future it could be published on the Internet with linked access to all other Standard references. You will note that only the odd numbers have been allocated this to ensure that any additional new requirement, such as for example, future Spacecraft can be inserted.

DEF STAN 00-970 PART 9 - **DESIGN AND** **AIRWORTHINESS** **REQUIREMENTS** **FOR UAV SYSTEMS**

In the late 1980's it was agreed between Industry and MoD, that there was a need to produce a Defence Standard which would cover elements of unmanned and manned aircraft. A new Defence Standard was drafted. While at the same time SBAC/MoD set up a joint working group to produce a "Guide To The Procurement, Design And Operations Of UAV Systems", however, neither of these documents had sufficient depth. In 1992 MoD decided to produce a more detailed Defence Standard and formed a Sub Committee under the Joint Technical Requirements Committee (responsible for Weapon Systems Design Standard). The sub-committee reviewed the two documents and started producing new draft material as well as extracting relevant information from the previous publications to form the new standard.

In 1996 reorganisation of ADRP took place, this resulted in responsibility for the sub committee being passed to the aircraft side under the Joint Airworthiness Committee and the sub -committee was renamed the Unmanned Air Vehicle Systems Sub-Committee (UAVSSC). At this point a decision was made to place the design requirements into Def Stan 00-970. The present Committee Chaired by ADRP2, has members from MoD, CAA, SBAC and other aircraft related Industries. The committee, discusses, drafts and prepare papers to be ratified by the JAC. The committees terms of reference are:

UAVSSC - TOR

- **Establish and prepare new Part 9 covering design and airworthiness requirements for UAVS.**
- **Examine current standards to determine their applicability to UAVS**

- **Recommend insertion of design and procedural clauses into other related Defence standards.**
- **Consider any document generated by other organisations relating to UAVS, which had material relevant for incorporation into the new standard.**
- **Draft paper for submission to the JAC**
- **To advise the JAC and other sub-committees on UAV matters.**
- **Act as a forum to advise UK representative on NATO and other related committees.**
- **To provide advice and comment on draft standards by NATO, BSI, CAA and other organisations.**
- **To maintain an awareness of UAV matters in other areas and countries**
- **Ensure there is no duplication of effort between The UAVSSC and other MoD committees.**

Initially this committee was only concerned with UAV's flown over MoD ranges, and the documentation produced reflected that fact. The possibility of flying "off range" was not even considered. The effective use of UAVS during Desert Storm and later Bosnia has brought about a reversal of thinking and in 1996 the focus of the document was expanded to encompass both targets and reconnaissance and surveillance mode UAVs, that could have off range applications. Clearly to be able to fly off range any UAV system must demonstrate, that the system is safe and reliable. A formal design certificate must then be issued by the contractor with all supporting documentation so that the MoD Integrated Project Team Leader (IPT/L) can be satisfied that the system is viable and can issue the MA Release.

Once in Service, the MoD IPT/L is responsible for monitoring the configuration control of the system to ensure that the design and agreed operating procedures always meet the required standard of airworthiness and safety.

If we look at the Criteria for UAV Safety, the aim is that it should be no less safe than other military aircraft. The probability that the operation of the system would cause serious injury or fatality to personnel or the general public due to catastrophic technical failure, should be in the order of 1×10^{-6} per flying hour during normal peace time operations. Risk reduction techniques can be considered and put into force if the UAV is to be operated in a controlled environment such as on a range. This can be achieved by operating procedures and by having installed other risk reducing systems such as; flight termination or a limited flight fuel load.

Safety Assessment of the system should take into account the following factors:

The Safety Assessment covers Reliability of the: Structure.

Engine.
Avionics.
Command and Control System and Links.
Software.
Flight Termination System.
Mode of Operation.
Risk of collision with other aircraft.
Population density and exposure time over area over flown.
Risk reduction techniques and procedures implemented.
Political situations such as tension, Threat, TTW.

Operational need and advances in technology and miniaturisation of components, coupled with improved reliability of components mean that off range flying of UAV Systems is being considered in the United Kingdom. This expansion of capability gives rise to increasing challenges in establishing a satisfactory level of airworthiness. It is with this in mind that the JAC are producing Part 9 of the Defence Standard on Design and Airworthiness Requirements for UAV Systems.

Defence Standard 00-970 Part 9 will be a living document, the intention is that it should identify the minimum standard of airworthiness and safety which will give the required system integrity for any UAV Design. It will form the initial building blocks for the more sophisticated future systems vehicles.

Part 9 of the Defence Standard is divided into five Sections, they are:

Sect 1	General Requirements
Sect 2	System Characteristics
Sect 3	Support Facilities/Control Station
Sect 4	Air Vehicle
Sect 5	Design Qualification

We will now look at each section, in more detail:

Section 1 General Requirements

Clause 1.1	Introduction and Purpose
Clause 1.2	Applicability and Scope
Clause 1.3	Definitions
Clause 1.4	Referenced Documents
Clause 1.5	Operational colouring and Marking
Clause 1.6	General Operational Environmental Conditions

Section 2 System Characteristics

Clause 2.1	Reliability and Maintainability
Clause 2.2	Hazard Analysis and Safety
Clause 2.3	Software
Clause 2.4	System Environmental Requirements
Clause 2.5	EMC

Clause 2.6	ECCM
Clause 2.7	Electronics
Clause 2.8	Range Interfacing
Clause 2.9	Guidance on Design and Assembly

Section 3 Support Facilities (Control Station)

Clause 3.1	General
Clause 3.2	Specific Climatic Conditions
Clause 3.3	Launch and Retrieval
Clause 3.4	Ground Control
Clause 3.5	Maintenance

Section 4 - Air Vehicle

Clause 4.1	General
Clause 4.2	Specific Climatic Conditions
Clause 4.3	Flight Performance
Clause 4.4	Structural Strength Requirements
Clause 4.5	Airframe
Clause 4.6	Power Plant
Clause 4.7	Avionics
Clause 4.8	Flight Termination
Clause 4.9	Payloads
Clause 4.10	Electrical Systems and Wiring

Section 5 Design Qualification

Clause 5.1	General Principles of Design Qualification
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Covers the requirement for:

- a. Environmental Testing
- b. Compatibility Testing
- c. Structural Validation
- d. Performance Modelling
- e. Performance Testing
- f. Safety Testing
- g. Reliability
- h. Flight Test Requirements
- j. Demonstration of behaviour on System Failure
- k. Performance Testing of Data Link for:
 - Flight Termination
 - Controllability on the Ground
 - Launch Take Off and Climb
 - Recovery, Approach, Landing and Overshoot
 - Longitudinal Stability and Control
 - Lateral and Directional Stability and Control
 - Rapid Roll/Roll coupling
- l. Demonstration Limits of Flight Envelope
- m. Launch System
- n. Testing of Ground Control System
- o. Controllability on the Ground
- p. Launch Take Off and Climb
- q. Recovery, Approach, Landing and Overshoot
- r. Handling and Performance in Icing

Conditions

s. Testing of Launch System

Each Clause follows the JAR format, however the presentation is set out as a table with the format in landscape. The **Requirements**, **Compliance** and **Advisory** material for each Clause or sub-Clause are set out on the same page. (See **Figure 3**, a representative page from Section 4 of the document).

The new format contains:

- **Requirements** - These are mandatory
- **Compliance** - The suggested means of achieving the requirement which can be mandatory
-
- **Guidance** - Identifies the risk, the requirement addresses plus other salient information

If we look at the philosophy behind the standard, it has been written to put the responsibility for design, on the designer and not the procurer. In this way it eliminates the constraints previously applied and allows for innovative designs to be considered as long as it can be proven that safety is not degraded. To do this is a clear audit trail is required using the information in related Defence Standards such as:

00-35-	Environmental Handbook for Defence Material
00-38	Guidelines for the Evaluation of Micro-processors for avionic application
00-40	} Reliability and Maintainability
00-41	
00-44	
00-55	
00-55	Safety Related Software
00-56	Safety Management of Defence Equipment
00-970	Design and Airworthiness Requirements for Service Aircraft

FUTURE DESIGN AND OPERATING CONSIDERATIONS.

Highly manoeuvrable high G capability thrust vectored UAV's are only a short time away. Their high acceleration and manoeuvrability will mean that the human operators reaction times will be too slow, and fully autonomous operation will be required. To achieve the necessary airworthiness and safety, high integrity hardware and software will be required. The failure of the UAV to perform its functions correctly will have, as well as operational, environmental and financial implications, the possibility of causing multiple deaths and/or injury to innocent bystanders. If loss of life is a

possibility, the system can be considered to be **SAFETY CRITICAL**. A Hazard Analysis should be carried out to assess the risk of system failure which could lead to an **Accident**.

Accident:

Event that causes death, injury or damage to equipment.

Hazard:

Situations with potential for causing an accident

The procedure above will not alter if operating micro UAV's. Headlines like:

"BOY KILLED BY MODEL AIRCRAFT AT AIR SHOW" (in a recent newspaper)

do not help when trying to get approval to fly military or commercial UAV Systems. Designers and operators must be aware that any UAV even those weighing 20kg and below still has the potential to cause death, injury or damage and requires therefore a **Safety Assessment** to be carried out and a **Safety Case** and **Hazard Analysis** to be submitted for approval.

CONCLUSIONS

This presentation has been concerned with the factors which affect development of design requirements for operation of UAVS by the UK MoD. It has also provided a brief summary of how the MoD, regulate airworthiness and safety through a series of procedures and Defence Standards. UAVs are a growth industry, with great potential. Several systems are already being considered for civil and military operations and are only being delayed because of airspace issues, it is therefore essential that safety and airworthiness are part of the design process from concept, through life to disposal (cradle to grave).

End

DASB/JAC COMMITTEE STRUCTURE

DASB ORGANIZATIONAL CHART

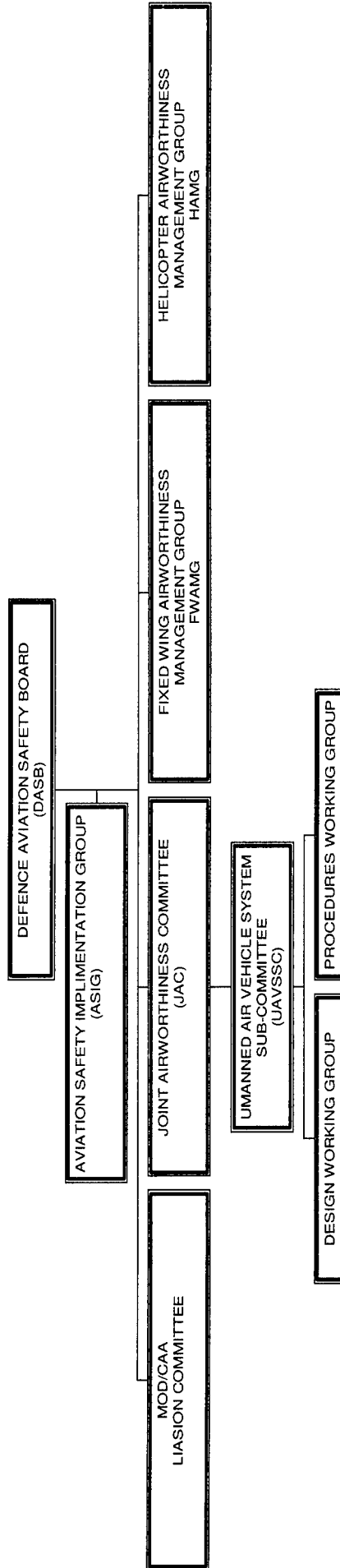
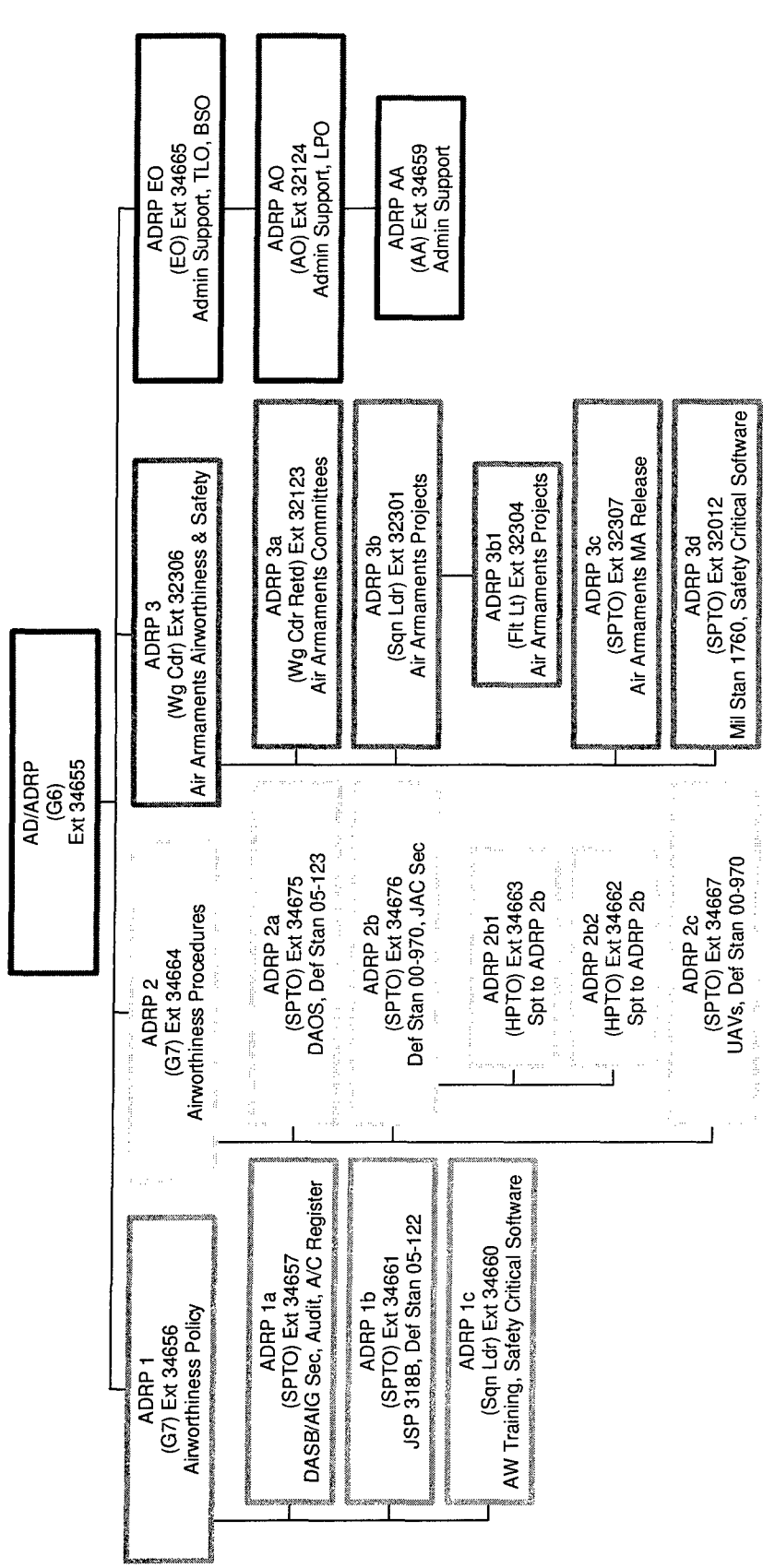


Fig 1

ADRP FAMILY TREE

(17 August 1999)



AIRWORTHINESS POLICY

AIRWORTHINESS PROCEDURES

AIR ARMAMENT AIRWORTHINESS AND POLICY

ADMINISTRATION SUPPORT

Fig 2

SECTION 4 - UNMANNED AIR VEHICLES

4.3 FLIGHT PERFORMANCE

REQUIREMENT		COMPLIANCE	GUIDANCE
4.3.2 DESIGN PROCESS			
a.	The flight performance shall be achieved using proven or acceptable design procedures.	The design of the UAV and all related systems which directly affect flight performance shall be supported by a full Engineering Record, with reference to all source documentation, to ensure traceability. All analytical design processes, and other material generated in the design of each system element, shall be countersigned by an agreed list of approved signatories.	Proven or acceptable design procedures are those that either: (1) have a recognised precedent with a proven record of reliability and integrity, and are supported by accepted technical documentation such as data sheets or theoretical/analytical procedures, or (2) may otherwise be shown to have the required integrity by other methods deemed to be acceptable to the Project Director.
b.	The flight performance and flying characteristics shall not be unacceptably degraded by tolerances associated with the design, manufacture and assembly processes, or by variability in component/sub-system performance.	Consideration shall be given to the cumulative effect of all such tolerances, when applied in a wholly adverse or asymmetric way. This effect shall be quantified by prediction methods, or test.	Variability in the performance of systems, sub-systems or individual components can further arise throughout their service life by environmental and operational factors such as storage conditions, ageing, wear & tear, repair and exposure to moisture or sunlight.
c.	The design of the UAV shall ensure that flight performance is not unacceptably degraded by equipment which is temporarily carried by the UAV for a specific purpose, and which is either jettisoned, or otherwise changes the configuration of the vehicle.	Performance degradation shall be predicted by analysis of the drag and mass properties of the equipment concerned, and simulation of its effect upon the predicted performance of the basic UAV	All supplementary equipment, particularly that carried externally, should be of an equivalent aeronautical standard of design, manufacture and reliability to that of the UAV.
d.	The design shall take into consideration the mass properties of the UAV in order to ensure that flight performance requirements are met.	UAV mass properties shall be estimated by either numerical methods or direct measurement using an accurate mass model for each relevant build standard or flight configuration. Where possible the data should be verified and validated by measurement using actual vehicles.	UAV mass properties have potentially wide-ranging implications on factors such as flight performance, control and handling characteristics, structural loading, launch/recovery characteristics and operating danger areas (safety trace calculations).

DEF STAN 00-970/1 PART 9

SECTION 4

CLAUSE 4.3

DRAFT 0.4 JUNE 1998

Fig 3

		ENVIRONMENT					
		MILITARY	CIVIL AIRSPACE				
		NOTIFIED AIRSPACE	UNCONTROLLED	CONTROLLED			
WEIGHT	ABOVE 300Kg	B	B	A	HIGH	POPULATION DENSITY	
	20-300Kg	C	B	A	MEDIUM		
	BELOW 20Kg	C	B	B	LOW		
		TRAINING	MIXED FLEET & TTW OPS	MIXED FLEET & PEACE-TIME OPS			
		OPERATIONAL REQUIREMENT					

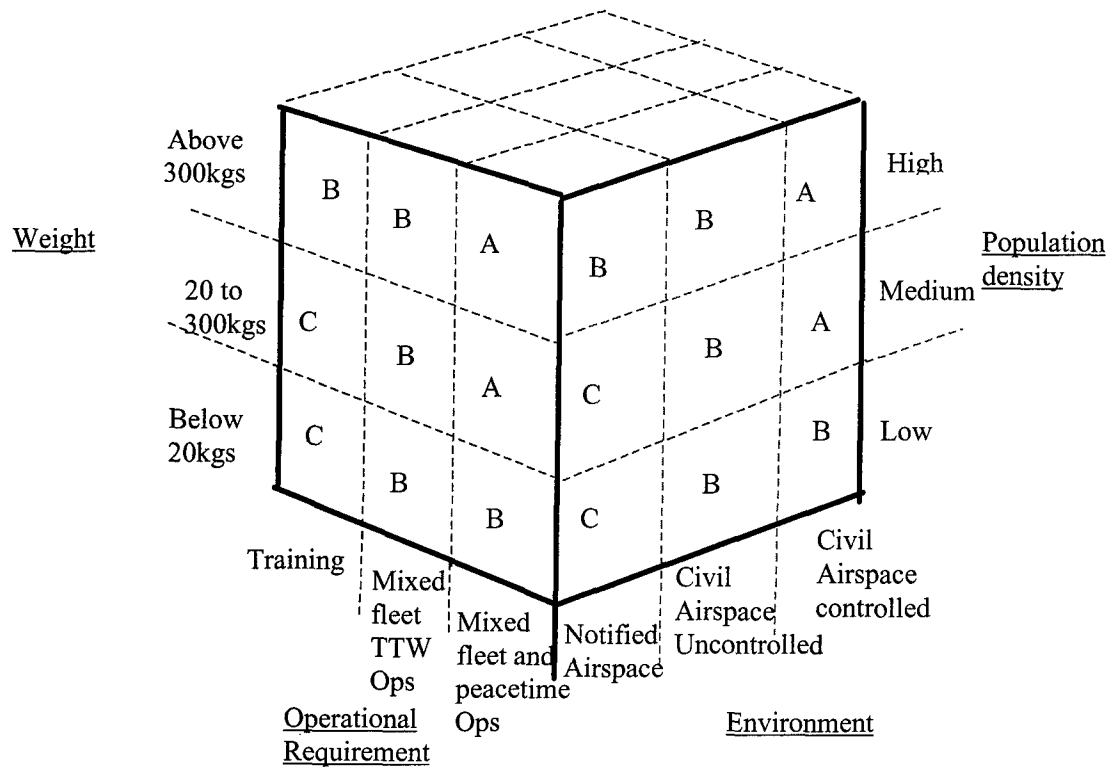


Fig 4