Australian Government
Civil Aviation Safety Authority

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Advisory Circular

AC 21-47(0)

FEBRUARY 2012

FLIGHT TEST SAFETY

CONTENTS

1. REFERENCES

- Part 21 of CASR 1998, Certification and Airworthiness Requirements for Aircraft and Parts.
- CASA Type Certification Procedures Manual, Version 1.1, November 2001.
- AC 21-10(2) – Experimental Certificates, July 2011.
- AC 21-13(0) – Australian Designed Aircraft – Type Certification, September 1999.
- CAAP SMS-1(0) – Safety Management Systems for Regular Public Transport Operations, January 2009.
- CAAP SMS-2(0) – Integration of Human Factors into Safety Management Systems, January 2009.
- CAAP SMS-3(1) – Non-Technical Skills Training and Assessment for Regular Public Transport Operations, April 2011.
- ‘Emergency Bailout Procedures’ by Allen Silver; published in ‘Soaring’ and ‘Sport Aerobatics’ magazines, June to August 1992, revised May 2003.
- Federal Aviation Administration (FAA) Order 4040.26A – Aircraft Certification Service Flight Safety Program, January 2001.

Advisory Circulars are intended to provide advice and guidance to illustrate a means, but not necessarily the only means, of complying with the Regulations, or to explain certain regulatory requirements by providing informative, interpretative and explanatory material.

Where an AC is referred to in a ‘Note’ below the regulation, the AC remains as guidance material.

ACs should always be read in conjunction with the referenced regulations.

This AC has been approved for release by the Executive Manager Standards Development and Future Technology Division.

2. PURPOSE

2.1 This Advisory Circular (AC) provides general safety information for those Civil Aviation Safety Authority (CASA) staff, aircraft industry participants and amateur aircraft builders involved with any of the flight testing requirements of Part 21 of the Civil Aviation Safety Regulations 1998 (CASR 1998).

2.2 This AC applies to:

- people responsible for, or participating in, the flight testing of aircraft certificated or manufactured under Part 21 of CASR 1998;
- applicants for, or authorised persons and CASA officers issuing, Experimental Certificates under Regulation 21.191 of CASR 1998; and
- amateur aircraft builders and their flight test pilots.

3. STATUS OF THIS ADVISORY CIRCULAR

3.1 This is the first AC to be issued on this subject.

4. ACRONYMS

4.1 Terms and abbreviations are listed at Appendix A of this AC.

5. DEFINITIONS

5.1 For the purposes of this document:

Crew Resource Management (CRM) means a team training and operational philosophy with the objective of ensuring the effective use of all available resources to achieve safe and efficient flight operations.

Certification Flight Testing means those flight tests conducted for the purpose of demonstrating, or verifying, compliance with the applicable airworthiness standard.

Experimental/Developmental Flight Testing means those flight tests conducted for the purpose of defining or expanding an aircraft's flight envelope.

Flight Test means the process of developing and gathering data during operation and flight of an aircraft and then analysing that data to evaluate the flight characteristics of the aircraft. In this AC *flight test* does not mean a practical test of a person's knowledge and practical flying skill.

Production Flight Testing means those flight tests conducted for the purpose of ensuring each individual aircraft conforms with its Type Design and is in a condition for safe operation.

6. BACKGROUND

6.1 A variety of flight test operations are conducted by sectors of the aviation industry in Australia. These range from the experimental, developmental and certification flight testing of new aircraft types, or of any modification to older types, to the post-production testing of newly manufactured aircraft. Regular flight test activity is also being undertaken by members of Australian amateur aircraft-building associations. Flight testing can involve varying levels of risk. While, in many cases risk levels will be low, and possibly no more than encountered during the normal operations of certificated aircraft, in other instances significant hazards may be present. Also some phases of many test programs, like evaluating stall handling, spinning or flutter characteristics, should always be approached with an extra measure of caution. Since the majority of Australian civilian flight test operations are performed under the auspices of one or more of the subparts to CASR Part 21 CASA has an obligation to provide advice regarding reducing the risks involved. This AC offers some such advice.

6.2 The AC will cover, in general, the provision of resources for an efficient but safety-conscious flight test and evaluation (FT&E) organisation, test planning principles, hazard analysis and risk management procedures and some ideas that may be applicable during actual flight test operations. It also provides references to other relevant publications and websites.

6.3 While the information in this AC may be applicable to the flight testing of all aircraft types it is focussed more toward the test operations of those at the lighter-weight and lower-speed ends of the scale, principally those in the primary, normal, utility, acrobatic or amateur-built categories.

7. RESOURCES

7.1 Engineering or operational organisations involved with flight testing, be they multinational corporations or individual consultancies, should be properly resourced. Access to qualified personnel, functional equipment and appropriate services facilitates safe operations and allows for efficiency in project progression. Resourcing considerations are best set out in an organisational procedures manual as outlined at paragraph 7.2 of this AC. Selected aspects are discussed in more detail at paragraphs 7.3 to 7.7 of this AC.

Procedures Manual

7.2 Describing and documenting the procedures used by an organisation is always a sound idea and is also required, in some circumstances, by the regulations (for example, companies manufacturing aircraft under Subpart 21.G of CASR 1998 are expected to do so in accordance with a quality system procedures manual). Flight test resourcing, procedural and safety aspects can be integrated within an organisation's wider procedures manual however they are more suited to inclusion in a sub-manual, or volume, on their own as such an arrangement affords ready and easy reference to all information that may be needed in preparation for or during operations. A flight test procedures manual would probably include sections detailing:

- an overview of the types of flight test operation to be conducted;
- organisational structure;
- management responsibilities and authorities;
- personnel qualification, experience, currency and training requirements;
- operational policies and limitations;
- test planning procedures and reporting formats;
- flight test technique and reference publications;

- aircraft modification procedures and restrictions;
- test instrumentation;
- ground support facilities;
- use of safety and photographic chase aircraft;
- airspace, test area and range definitions;
- safety equipment;
- emergency services; and
- hazard analysis and risk management policies and procedures.

Flight Test Personnel

7.3 While many, maybe all, of an organisation's personnel roster could have some role to play during flight test operations the primary responsibilities rest with management, engineering and aircrew staff.

- **Management:** Management may have varying levels of working involvement in actual flight test activity. Whether immediately engaged or not managers must realise that they hold direct responsibility for the safety aspects of flight test operations. In all cases a supervisory position that provides higher level project guidance, does not become meddlesome and that is focussed on risk management will be the most beneficial input from a senior manager. An understanding of the ways in which project progression often puts pressure on the flight test phase, and an intention to alleviate such pressure, is also essential (see paragraph 10.9 of this AC). Managers serious about operational safety will also find relevant information in CASA's series of Civil Aviation Advisory Publications (CAAPs) on Safety Management Systems (SMS) – see the References list. While these CAAPs focus on operations under an Air Operators Certificate (AOC) many of the principles could be easily applied to an FT&E organisation.
- **Engineers:** Engineering specialists will be engaged in aircraft development or modification projects from beginning to end. The flight testing phase will most likely include the design engineers and will benefit greatly from the participation of a qualified Flight Test Engineer (FTE)[♣]. For projects where the test flying is being conducted by other than a professional Test Pilot (TP)[♣] the involvement of an FTE will add significantly to the efficiency and safety of the program. The FTE will take control of the test planning process and then, during flight operations, be able to assist aircrew inexperienced in the test flying environment through acting in the test director role and managing the data gathering duties.

[♣] Professional flight test crew normally gain their qualifications through completing a 12 month course of formal training at a recognised Test Pilot School. Shorter courses followed by focussed 'on-the-job' experience in an active flight test organisation may also be used.

- **Test Pilots:** Test flying will inevitably involve aircrew additional to the FTE. Since flight test operations do not fall under any of the commercial purposes defined at Regulation 206 of the *Civil Aviation Regulations 1988* (CAR 1988) the minimum qualification a pilot in Australia must hold in order to carry out test flying in an experimental aircraft is a Private Pilot Licence (PPL) with the endorsements appropriate to the type or class of aircraft being flown. CAR 5.50 also allows CASA, in certain cases, to issue a permission in writing for a PPL holder to fly an aircraft for the purpose of "(i) testing the aeroplane; or (ii) carrying out an experiment in relation to the aeroplane" without those endorsements. While the regulations do not force a requirement for the pilot acting as TP to hold any specific test flying qualifications or knowledge the engagement of a person so qualified will normally enhance the efficiency, progression and safety elements of the program. Additionally though, it would be most unwise for the initial flight tests of a prototype aircraft, or for an aircraft of an established type which has been substantially modified, to be carried out by other than a pilot with such flight test knowledge and experience. Stability and control problems might only become apparent after first flight liftoff, and appropriate technical understanding and skill may be essential to avert a catastrophic event. Advice regarding professional flight test aircrew can be obtained from:
  - CASA Test Pilot, Airworthiness Engineering Branch, GPO Box 2005, ACT, 2601, Telephone 131 757; and/or
  - Flight Test Society of Australia (FTSA): www.ftsa.org.au.

Qualifications, Experience, Currency and Training

7.4 All personnel involved in flight test operations should be appropriately qualified, experienced and current. The nature and scope of the project will dictate what qualifications the flight test aircrew will most suitably possess. A formal experimental test flying certificate does not, in itself, necessarily mean that the holder is the best person to employ for a specific flight test project. For example, a qualified TP, who graduated from Test Pilot School over thirty years ago and who has only operated military fast jets or transport category airliners since that date, may not be the ideal pilot to choose for the developmental test flying of a Light Sport Aircraft (LSA) with a tail-wheel landing gear configuration. If, however, they had also regularly spent weekends at the local aero club flying similar machines they would probably be well suited. The point is that, when selecting a suitable TP for a specific project, relevant experience and currency in the aircraft type, or in types similar to that being tested, is just as important as any formal qualification. In all cases general refresher and focussed work-up training is advisable prior to embarking on actual project test flying. Additional considerations with respect to suitable TPs for various scenarios are as follows:

- **Experimental/Developmental Flight Testing:** The initial and developmental test flying for newly designed or substantially modified aircraft will be most safely conducted under the command[*] of a qualified professional TP. A sufficiently and appropriately experienced pilot who does not hold formal TP qualifications may be suitable for some simple projects, or for the mundane aspects of more complicated ones after the initial envelope expansion has been conducted, but would best be employed with the assistance of an experienced FTE.

[*] In the case of the modification of some large multi-crew aircraft the TP may not necessarily be the command pilot but should occupy an appropriate control seat and be the flying pilot for the test sequences.

- **Certification Flight Testing:** Certification flight testing will also be best conducted by a professional TP, preferably one with specific certification experience, or with guidance from an experienced certification engineering team. Under the supervision of such a team a sufficiently and appropriately experienced pilot who does not hold formal TP qualifications may be a suitable alternative, however, if the aircraft under test exhibits any handling or operational characteristics that could be considered only marginally compliant with the applicable airworthiness standard then a certification TP should still be consulted.
- **Production Flight Testing:** In the production case the advisability of the TP having experimental test flying qualifications and experience is not necessarily as strong as for the developmental or certification cases, although it could still be appropriate. Either way the best production TP is going to be someone with a solid background in operating the general type of aircraft being produced and preferably extensive experience on the actual model - i.e. someone who knows the aircraft well and who can easily detect any anomalies with its performance, handling or systems that would constitute non compliances with the production test schedule.

Instrumentation

7.5 The provision of flight test instrumentation can entail the use of simple tools like hand-held force gauges, flight control position measuring tapes and the aircraft's installed flight and engine instruments, or sophisticated suites built in to the systems onboard prototype aircraft and monitoring multiple measurands. The design, installation and use of such instrumentation is a multifaceted topic in its own right and beyond the scope of this AC. Many authoritative references are available. Nevertheless, the provision of test instrumentation tools or systems that are simple and easy to use will improve flight test efficiency and thereby enhance flight safety. The less time the test aircrew have to spend setting up and manipulating instrumentation or directly recording data while airborne the more time they have for accurately flying the test points, monitoring results and maintaining operational situational awareness (SA).

Safety Equipment

7.6 Some flight test operations, for instance those in support of an innocuous modification of an established aircraft type, may be safely conducted in the shirtsleeve environment of an everyday cockpit. However any test program or sortie that entails elevated levels of risk will justify the use of safety equipment additional to that normally used in or fitted to an aircraft under a standard Certificate of Airworthiness (CoA). Some considerations are as follows:

- **Flying Clothing:** Various items of specialised flying clothing are recommended. Flying suits and jackets, particularly those made from Nomex or any similar flame retardant material provide sensible covering of exposed skin areas. Suitable flying gloves and sturdy boots afford additional protection. For the early flights of an experimental or major developmental program, and for any flight in which there is a chance that the aircraft may be subject to a loss of control near or on the ground, or may have to be abandoned while airborne, a protective helmet should also be worn.

- **Escape Assistance:** Subregulation 21.35 (4) of CASR 1998 gives the following requirement in relation to certification flight testing: *'Each applicant must show CASA for each flight test…that adequate provision is made for the flight test crew for emergency egress and the use of parachutes.'* A number of modifications or additions can be made to an experimental aircraft that will facilitate the ability of the aircrew to escape from it should they need to. For emergency exit from an aircraft while it is still on, or has returned to, the ground standard exit provisions can be supplemented by supplying the crew with crash axes or canopy breakers. Large aircraft should be provided with escape ropes at all exits. Abandoning an aircraft while airborne entails additional exit considerations especially since, in an emergency situation, there will probably not be much time available and the aircraft may be gyrating out of control. Doors and canopies should be modified to allow for quick, easy opening and jettison (for example, in small aeroplanes, hinges can be removed and replaced with temporary fastenings that enable the door to be simply pushed or kicked open and clear of the airframe). More than one way out should be available and cleared. In larger aircraft, knotted escape ropes, ladders or nets set up along the walls of each compartment, which enable the crew to reach the exit(s) in a dark, tumbling cabin, are simple and inexpensive additions. Harnesses should be easily releasable as should any other attachments between the crew and the aircraft (e.g. intercom leads). Consideration to providing a 'weak link' to such attachments may be worthwhile. Aircrew, when kitted out in boots, helmet, personal parachute and any other survival equipment, should ensure that they are still able to fit easily through all emergency exits.
- **Personal Parachutes:** The type of personal parachute – pack, harness and canopy – most suitable for flight test projects will depend on the size and configuration of the aircraft under test and the size and weight of the individual crewmembers. The TP, when wearing the parachute and strapped in to his/her seat, must retain full freedom of movement and access to all controls. The slim-pack chute designs favoured by glider pilots are often also the most suitable for use during flight test operations. Regardless, any parachute must be personally fitted and adjusted to its wearer and must be serviceable (inspected and repacked within the previous six months by a qualified rigger). Additionally, flight test personnel will be wearing and, maybe, using personal parachutes as emergency equipment. As such, they will probably not be experienced or trained parachutists and advice from a professional parachuting organisation or authority should be sought. The Australian Parachute Federation (www.apf.asn.au) may be able to provide information directly or supply contact details for the nearest qualified specialist. See also the References at paragraph 1 of this AC.
- **Ancillary Equipment:** Depending on the normal equipment fit-out of the test aircraft, and the area over which the test operations are to be conducted, the provision of additional safety equipment may be warranted. Items to consider are fire extinguishers, emergency oxygen systems and smoke hoods, survival packs, emergency beacons and radios, knives, lifejackets and dinghies.

- **Spin Recovery Systems:** Prudent program managers will have a prototype or certification aircraft subject to spin testing, or to any testing at high angles of attack where there is a danger of departure from controlled flight, fitted with a system that can assist with recovery from a spin should normal flight control inputs prove ineffective. Various spin recovery systems have been developed or tried over the years. By far the most successful, especially in relation to the flight testing of small aeroplanes, is the tail mounted, anti-spin parachute. Information that may assist in developing such parachute systems is provided at Appendix B of this AC. Alternative methods, generally more complex, expensive and less reliable, include rockets, wing and nose mounted parachutes, and moveable or jettisonable ballast systems. As per Section 6.4 of the Type Certification Procedures Manual, CASA personnel will not conduct any spin testing required during an aircraft type certification program unless a spin recovery system, preferably an anti-spin parachute, has been fitted to the test aircraft.

Facilities and Ground Support

7.7 Flight test support can range from complex to simple. However, whether the facilities provided to the flight test organisation include engineering flight simulators and advanced flight following telemetry systems or are restricted to a corner in the hangar, some basic requirements remain the same. Safety considerations include:

- **Flight Following:** It is a good idea to have someone on the ground monitoring the progress of a test aircraft while it is operating. Certain sorties will also warrant the provision of a safety chase aircraft (see paragraph 10.6 of this AC). A sophisticated test operations centre will enable the engineering crew to follow the entire flight, observe the progression of the test sequences, monitor data trends and maybe intervene if any dangerous bias is noticed. While such specialist facilities may not always be available, having an engineering or operational team member follow the test flight using a radio capable of monitoring discrete frequencies and a pair of binoculars can be as valuable.
- **Airfield and Airspace:** Factors affecting the choice of airfield from which flight test operations are to be conducted can vary with the type of testing being undertaken. Generally the ideal airfield will be one equipped with long, wide, sealed runways bordered by unobstructed and level surrounds. The availability of suitable forced landing areas off the airfield itself is also important. Flight testing is best conducted away from urban or populated areas and such will be a restriction placed on the applicable experimental certificate when issued by CASA or an authorised person (see paragraph 9.5 of this AC). These considerations usually mean that major city airfields are unsuitable, especially if the test program involves a new or substantially modified aircraft. Similar factors are applicable when considering the airspace in which the test exercises will be conducted. Preference should be to operate away from busy air-traffic centres or air-routes, although in some circumstance, for example systems testing in transport category aircraft, the protection afforded through using controlled airspace and the positive separation or traffic advice provided therein may be appropriate.

- **Emergency Services:** Ideally, the airfield from which test operations are conducted will be supported by certified rescue and fire fighting (RFF) services, although these are normally only provided for major airports with a significantly large number of daily aircraft movements. For test flights out of smaller or regional airfields, especially for any first or high risk flights, the local fire station and ambulance service should be advised of the details of the times and areas of operation. In some cases local members of the State Emergency Service (SES), or similar organisations, may be able to make themselves available to act as dedicated rescue crew. Whether emergency service personnel are assigned or casual they should be provided with relevant information such as the location of airfield entry gates and the layout of the surrounding road network. A map or satellite photo of the local area, overlaid with crash locater gridlines, will be a worthwhile supplementary aid. Emergency crews must also be specifically briefed regarding the test aircraft – for example, manipulation of normal and emergency exits or access points, fuel, engine and electrical controls and how to operate them, the location of any hazardous stores, cargo, systems or fixtures.

8. FLIGHT TEST PLANNING AND PREPARATION

8.1 The more thoroughly a test program, or an individual flight test sortie, is planned the less likely it will be that things will go wrong, or, if they do go wrong, the more likely it will be that the test team will be prepared and able to deal safely with the problem. Some factors relating to flight test planning are outlined in the following paragraphs. Hazard analysis/risk management is discussed in more detail in section 9 of this AC.

Test From Inside Out

8.2 The basic premise used in planning any flight test exercise should be that of going from the centre of an envelope toward its edges – going from test conditions of low or known risk levels toward those of the increased or unknown. The principle holds up no matter what parameter or envelope is being expanded (e.g. Airspeed/Altitude; Weight/Centre of Gravity (CG)). For example, when testing a new or modified aircraft it would be sensible to evaluate stability and handling characteristics initially with the CG in a more forward position and then to carefully move it aft. Additionally, the stall speed should be measured with the CG in a forward position and then, providing stall handling is acceptable in the forward CG case, stalling characteristics should be further evaluated as the CG is moved aft. Associated sub-principles are, firstly, that test point increments should be small, especially as the edges of an envelope predicted by the design engineer are approached, and secondly, testing should be discontinued if, as these small increments are applied, unpredicted or unsafe trends are encountered. Any unexpected or marginal behaviours encountered during this process of stepping toward the design limit should cause a halt until the unforeseen phenomena are properly analysed. Unsatisfactory characteristics may warrant engineering modifications or the application of operational limits (i.e. the edge(s) of the envelope forecast at the design stage are truncated prior to the aircraft being cleared for operational service).

Test Plan Contents

8.3 There are valid and different ways a flight test plan (FTP), or 'schedule', can be compiled. One suggested outline/list of contents for a certification flight test plan is at Appendix C of this AC. In the case of type certification projects, there is no regulatory requirement for CASA to approve, or even review, an applicant's certification flight test plan. However, such review is available as part of the aircraft type certification process and, as well as enabling CASA to check that all required areas of the airworthiness standard are to be covered, it will also allow for an objective authority to consider and perhaps provide suggestions regarding the safety aspects of the plan.

Preparation

8.4 Besides compilation of the test plan there are other preparatory issues that will require consideration, for example engineering, resource and budgetary matters will vary with the size of individual projects. In regards to flight test safety, there are additional preliminary aspects that can be addressed:

- **General and Safety Training:** The overall competency status of personnel who will be involved in the flight test program can be enhanced through general safety training. Many course options such as first aid, Occupational Health and Safety (OHS) and accident investigation are available and can be of benefit. Survival training is advisable, especially where test operations will be conducted over water or in remote locations. Specific training, depending on the nature of the flight test program, may also be required. For example; teams involved in flutter testing should have a good knowledge of the principles of aeroelasticity, while upset recovery training is highly recommended for all high speed test participants. Helicopter underwater escape training (HUET) is well worth consideration and could be treated as a prerequisite for any crew involved in testing rotary-wing aircraft over water (shipboard landings, oil rig platform operations, etc.).
- **Work-Up Training:** Focussed work-up training is advisable prior to embarking on actual project test flying. This would also entail aircraft or type related crew familiarisation, endorsement or refresher training. The test specific work-up program, which may best be flown in either an engineering flight simulator, an example of the test aircraft or a similarly configured type, should cover practice in the individual flight test techniques to be used. This is particularly relevant to any testing that involves elevated risk profiles. Familiarity with, and practice at, loss of control (LOC) procedures is especially recommended. Rehearsal of test sortie profiles, during which the most efficient and safest sequence for flying the test points is developed, may also be of benefit. Planning and risk management practices should be applied to work-up training programs in the same manner as they are applied to the actual testing.
- **Safety Review and Authorisation:** A process whereby test plans and preparations are reviewed prior to implementation is well worthwhile. Reviews within test and project teams are part of normal procedure but value is often added by having independent specialists carry out an appraisal as well. A final review and formal authorisation process on the part of the appropriate manager or chief test pilot provides another layer of protection. Also, as per paragraph 8.3 of this AC, CASA review of certification flight test plans is available.

9. HAZARD ANALYSIS/RISK MANAGEMENT

9.1 Project managers are strongly urged to conduct a detailed hazard analysis/risk management exercise as part of the test planning and the ongoing flight testing processes. Risk management is known by many acronyms and can be simple or detailed. Principally, it involves the application of common sense to the flight test program and to aircraft operations in general. Formally it is a process by which:

- hazards are identified;
- an assessment is made of the risks involved;
- mitigating procedures are established to reduce or eliminate the risks; and
- a conscious decision is made, at the appropriate level of authority, to accept residual risk.

General Flight Test Hazard Analysis/Risk Management References

9.2 Advice regarding flight test safety and hazard analysis/risk management procedures can be obtained from the following:

- The CASA Test Pilot or Flight Test Engineer (Airworthiness Engineering Branch, CASA, GPO Box 2005, Canberra ACT 2601, Telephone 131 757);
- FAA Order 4040.26A, available through the FAA website (www.faa.gov);
- The National Aeronautics and Space Administration (NASA) Flight Test Safety Database (https://ftsdb.grc.nasa.gov/); and
- The National Test Pilot School website (www.ntps.edu).

9.3 Fundamental risk management information is provided at Australian/New Zealand Standard – Risk Management (AS/NZS 4630:2004). A good reference for general flying risk management information is the FAA's 'Risk Management Handbook' also available through the FAA website.

Flight Test Hazard Analysis/Risk Management Procedures

9.4 Risk management is normally conducted through a safety review process in which a flight test plan is examined by project and non-project personnel in order to draw out potential hazards and recommend mitigating (or minimising) procedures. It can be carried out informally, however, most benefit will be gained through formalising the process and writing down the outcomes in a risk management plan. More information and some suggested procedures are available at Appendix D of this AC.

Experimental Certificates – Risk Assessment

9.5 The operation of experimental aircraft, especially those flown during the test phases of developmental or modification projects, can, by its very nature, involve elevated levels of risk. So there are no regulations attempting to limit the risks involved, or stipulating that an operator of such experimental aircraft carry out the formal risk management procedures, with respect to the aircraft itself or the occupants thereof, as recommended in the preceding paragraphs. Nevertheless paragraph 21.193 (c) of CASR 1998 requires that an applicant for an experimental certificate provide CASA or the authorised person with any information reasonably needed to enable the imposition of conditions or limitations necessary in the interests of the safety of other airspace users and persons on the ground or water.

This implies that at least a fundamental risk management process considering the safety of other persons must be conducted. CASA AC 21-10(2) – Experimental Certificates, provides information and guidance to those CASA officers or authorised persons who, in the course of contemplating an application for an experimental certificate, need to assess whether information sufficient to satisfy the requirements of paragraph 21.193 (c) of CASR 1998 has been submitted. This guidance also appears at Appendix E of this AC.

10. FLIGHT TEST OPERATIONS

10.1 Once suitable resources have been put into place, a comprehensive FTP has been compiled, a common-sense hazard analysis/risk management exercise has been conducted and appropriate preparatory training is completed the flight testing itself will probably proceed in as safe a manner as any other typical flying operation. While normal operational factors continue to apply there are some additional considerations particularly relevant to flight test operations.

Weight and Balance

10.2 The importance of weight and balance, and in particular knowing the exact location of the CG, cannot be overemphasised. Dangerous flight characteristics are usually associated with an aircraft’s CG being beyond established limits. When intentionally approaching those limits, especially for the first time, disciplined procedures for determining the position of the CG are essential. Weighing the test aircraft in its precisely loaded pre-take-off condition is the recommended method for achieving this. If this is not practical, in the case of large aircraft for instance, accurate weight and balance data, based on a recent weighing, an inventory of configuration changes and a validated loading system, may be acceptable. The after landing condition is determined similarly. The precise weight and balance of the aircraft at specific test points can then be derived by considering fuel burn and elapsed time from engine start.

Briefings

10.3 Pre-briefings, during which team members are made aware of details for the planned operation, should be conducted prior to the various overall flight test phases and then prior to each individual flight. All participants, or at least the principal representatives from support functionaries, should attend pre-flight briefings as should the relevant manager or authorising officer. Post-flight briefings, whereby the success or otherwise of the mission and any safety lessons are drawn out while still fresh in the group’s memory are also worthwhile. A good ‘Flight Test Briefing Guide’ is available in FAA Order 4040.26A.

Plan the Test, Fly the Plan

10.4 The FTP will cover the overall objectives of and methods to be used during the testing. The requirements for each individual flight will be distilled from the FTP and will normally be produced in the form of test cards, which can be clipped to the pilot’s knee-board or carried in the FTE’s flight folder. The test cards, copies of which should also have been distributed to all test participants at the pre-flight brief, provide a ready reference to the flight sequence and test point parameters while also presenting prepared tables for manual data recording. Memory joggers for test limitations and the initial actions in the case of emergencies can also be included. Once each individual test flight is underway the safest general principle is to follow the plan as presented in the test cards. If unexpected or otherwise interesting results are observed the temptation to investigate or to pursue impromptu deviations from the plan should be resisted. After landing, the cause of any surprising development can be safely considered and any amendments to the FTP devised.

This is not to say some alternate or reserve test points cannot be carried into each test flight to cater for various contingencies such as, for example, unsuitable weather or unacceptable turbulence at the planned test altitude. However, the alternate plan should also have been covered during the pre-flight brief and all test participants should be familiar with any change in sequence.

Crew Resource Management

10.5 The constructive concepts espoused under the theories and practice of CRM can also be applied to the flight test environment. Whether the flight test task relates to a large multi-crew airliner or a small single pilot machine there will usually be a team of people involved in the program. The general principles of CRM, as applicable to the normal operational environment, can be easily extended to take in the additional support teams that will be involved in flight testing[*]. For example:

- **Knock-It-Off:** The 'knock-it-off' (time-out) (KIO) principle can be usefully applied to flight test operations. A KIO call instigates an immediate halt to test proceedings and establishes the aircraft in a benign, straight and level, or climbing, state while situational awareness is recovered or the source of a problem is investigated. A positive decision regarding recommencement or termination of the sortie is then made. Pre-established company rules should normally be in place regarding who can make a KIO call and when one should be made although the best method is usually the most conservative – i.e. *any* team member should be encouraged to make the call when they note any limit excedence, or dangerous trend toward such.
- **Fatigue:** Fatigue management is relatively well understood with respect to wider aircraft and airline operations. CASA has published the Civil Aviation Order (CAO) Part 48 series regarding Flight Time Limitations. Although flight testing is normally classified as a private operation, so CAO 48 is not strictly applicable, it does offer some good guidelines. The physical effects are not discriminatory and, as flight testing often involves long periods of operation beginning or ending at odd hours, fatigue can become an issue. Note that the ideal flight test conditions are mostly found very early in the morning or after sunset.

Chase Aircraft

10.6 As well as the use of ground based flight following support services particularly helpful input can be gained through having the test aircraft accompanied by a dedicated safety/photographic chase aircraft. This is especially relevant to any sortie involving elevated risk or high intensity testing. Chase aircraft can provide wide-ranging contributions to the testing through external and direct observation of the test aircraft during and after each test (including assessment of damage should that occur), assisting or directing operations, monitoring and clearance of surrounding airspace, taking charge of air-traffic communications, controlling emergency or rescue operations (if required) and generally watching and verifying the progress of the testing. Nevertheless, there is potential for the chase aircraft to become a hindrance or a hazard in itself. Chase flying is a particular skill involving not just basic close and loose formation techniques but the ability to position the chase aircraft appropriately during dynamic test events. It should only be conducted by trained, experienced and operationally mature crews.

[*] Most Test Pilot Schools offer short courses relating to CRM in the flight test environment and any of these are recommended.

Altitude

10.7 The adage, 'altitude above you is like runway behind you – useless', is well worthy of consideration when conducting test point sequences. Flight testing with plenty of space between the aircraft and the ground is normally the safest option. A couple of related concepts are as follows:

- While certain tests will require operations at low level (e.g. handling tests, like V_{MCA}, that depend on engines developing maximum power, or systems tests, like enhanced ground proximity warning system (EGPWS), where proximity to the ground is a prerequisite) a cautious tester will fly the profiles at a safe altitude in the first instance. Then, when the tests are reflown at the lower levels an understanding of the expected performance and handling characteristics of the aircraft will have already been acquired.
- For dynamic or rapid-manoeuvre testing the definition of a 'hard-deck' minimum altitude is sensible.
- The hard-deck principle can be further refined through delineation of a series of critical altitudes. For example, during spin testing of a small, single engine aeroplane the critical altitudes may be something like – minimum entry altitude - 8000 ft (AO) – anti-spin chute deployment altitude - 6000 ft – abandonment altitude - 4000 ft.

Basic Airmanship

10.8 Flight testing is often an interesting and challenging exercise and there is an occasional tendency to become so engrossed in the detail of the tests that the overarching concepts of airmanship fade into the background. Lookout, listen-out, airspace awareness, basic aircraft limitations, fuel consciousness, etc. are all just as important during a flight test sortie as they are during other forms of flying. In addition, especially if a tense test profile is to be flown, there can be an inclination to relax after the actual test points have been achieved – remember, the sortie is not over until the engines have stopped and the pins are in.

Perceived Pressures

10.9 The flight test stage normally comes toward the end of an aircraft development or certification project. More often than not, by the time this phase begins, most of the contingency scheduling and funding that was added when the initial project planning took place has already been used up. Progress slows, milestones slide to the right and the increasing, undue, financial and program pressure is placed right where, safety-wise, it should not be i.e. the flight test phase is squashed up against an 'immovable' end-date. Project and senior managers must be aware of this tendency and realise that any such pressure is, in reality, perceived pressure. The job needs to be completed, but not at the expense of the aircraft. Often the safest option of a few more days or weeks is, on balance, also the cheapest and best choice. Notwithstanding, flight test crews should also understand that the ultimate decision regarding whether it is safe to fly or not rests with them.

11. SUMMARY

11.1 Flight testing can, by its very nature, involve varying levels of risk. To try and pass specific safety advice relating to the multitude of potential flight test scenarios is not practicable; however this AC is presented in an attempt to provide some background flight test safety information. As such it may, or may not, be relevant to a particular project. Additionally though, the concept of safety itself cannot always be isolated from common operational principles and some of what has been presented relates to the broader aspects of running a proficient flight test organisation. The AC covers, in general, the provision of resources for a safety-conscious flight test and evaluation office, test planning principles, hazard analysis and risk management procedures, and some ideas that may be pertinent during the conduct of flight test operations. Not all relevant information is necessarily presented and the recommendation is that the References and other authoritative publications should also be consulted for a fuller understanding of the topic.

Executive Manager
Standards Development and Future Technology

February 2012

APPENDIX A

TERMS AND ABBREVIATIONS

Symbol/Term	Definition
AC	Advisory Circular
AFM	Aircraft Flight Manual
AO	Above Obstacles
β	Angle of Sideslip
CAAP	Civil Aviation Advisory Publication
CAO	Civil Aviation Order
CAR	Civil Aviation Regulations 1988
CASA	Civil Aviation Safety Authority
CASR	Civil Aviation Safety Regulations 1998
CG	Centre of Gravity
CoA	Certificate of Airworthiness
CRM	Crew Resource Management
EGPWS	Enhanced Ground Proximity Warning System
EMI	Electromagnetic Interference
FAA	Federal Aviation Administration (of the USA)
FADEC	Full Authority Digital Engine Control
FAR	Federal Aviation Regulations (of the USA)
FTCM	Flight Type Compliance Matrix
FT&E	Flight Test and Evaluation
FTE	Flight Test Engineer
FTP	Flight Test Plan
FTSA	Flight Test Society of Australia
FTT	Flight Test Technique
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
H/V	Height / Velocity
KIO	Knock-It-Off
LAME	Licensed Aircraft Maintenance Engineer
LOC	Loss of Control
M_{MO}	Maximum Operating Limit Mach Number
MTOW	Maximum Take-off Weight
PEC	Pressure Error Correction
PFL	Practice (or Precautionary) Forced Landing
PIO	Pilot Induced Oscillations
PPL	Private Pilot Licence
RFF	Rescue and Firefighting

Symbol/Term	**Definition**
RTO	Rejected Take-Off
SA	Situational Awareness
SES	State Emergency Service
SHSS	Steady Heading Sideslip
TAWS	Terrain Awareness and Warning System
TP	Test Pilot
V_1	Take-Off Decision Speed
V_A	Design Manoeuvring Speed
V_D	Design Diving Speed
V_{FE}	Maximum Flap Extended Speed
V_{MCA}	Maximum Control Speed
V_{MCG}	Maximum Control Speed on the Ground
V_{MO}	Maximum Operating Limit Speed
V_{MU}	Minimum Unstick Speed
V_{NE}	Never Exceed Speed
V_S	Stalling Speed
WAT	Weight Altitude Temperature

APPENDIX B

SPIN RECOVERY PARACHUTES FOR LIGHT AEROPLANES

Most, if not all, modern airworthiness standards require that single engine aeroplanes demonstrate the ability to recover from a spin of at least one turn (or an innate resistance to enter a spin). Moreover, the occasionally unpredictable nature of the spin characteristics displayed by some aircraft means that flight testing in this regime involves elevated levels of risk. Prototype or certification aircraft subject to spin testing, or to any testing at high angles of attack where there is a danger of departure from controlled flight, should be fitted with a system that can assist with recovery from a spin should normal flight control inputs prove ineffective. The most successful system, especially in relation to the flight testing of small aeroplanes, is the tail mounted, anti-spin parachute. The detailed principles involved in developing, fitting and using anti-spin parachute systems are available in the literature so the aim of this Appendix is to provide a brief summary of some of the more important aspects and to point the reader to the sources and documents where this information is expounded.

An anti-spin system should be capable of providing sufficient counter forces to a spinning aircraft such that, following activation of the device, the aircraft recovers to controllable flight, ideally within two further turns of the spin. A properly designed tail mounted parachute should deliver anti-spin yawing and pitching moments regardless of the direction, orientation or mode of the spin. An anti-spin parachute system will normally consist of the following components:

- the main parachute canopy, risers and lanyards;
- the parachute carriage container, mounting and support structure;
- a means of deploying the main canopy clear of the spinning aircraft's wake;
- jettison mechanism; and
- activation and jettison controls and instrumentation.

Design Information

Since there are so many factors involved in the configurations, dimensions, weights, aerodynamic characteristics and consequent spinning behaviours of different aircraft there are going to be as many more intricacies associated with designing a suitable spin recovery parachute system for each of those different aircraft. Consequently there will not be a one-size-fits-all solution and specialist design advice should be sought. Some established authoritative information is available in the References given at the end of this Appendix. In Australia a small number of individuals and companies have specific experience with the design and installation of anti-spin parachute systems and contact information for these experts can be obtained from the CASA Test Pilot, Airworthiness & Engineering Branch, CASA, GPO Box 2005, Canberra ACT 2601, telephone 131 757.

Critical design considerations with respect to the actual anti-spin effectiveness of the parachute include:

- the dimensions and planform of the canopy;
- the porosity of the canopy material;
- the stability of the trailing canopy and its distance behind the spinning aircraft; and
- the efficiency with which the canopy deploys.

General advice, derived from the References, indicates that the best anti-spin parachute systems will incorporate the following characteristics:

- **Reliability:** Confidence that the parachute will deploy clear of the aircraft and its wake and provide positive spin recovery action, and that such will be a consistent outcome if the device has to be used on more than one occasion. Confidence that the chute will not deploy inadvertently during other critical phases of flight and that if it does it will break free from the aircraft of its own accord.
- **Simplicity:** Such that installation complexity, hardware costs and special maintenance procedures are minimised. Deployment and jettison controls are obviously identifiable, easily reached and are simple and unambiguous in their modes of operation.
- **Redundancy:** Consideration should be given to providing backup to both the deployment and jettison functions. Visual indication that the system is armed or safe, locked or unlatched should be provided and, preferably, these indications should be available both in the cockpit for the pilot and for support crew external to the test aircraft.
- **Safety:** A number of additional safety features can be incorporated. The ability to arm the device only for the specific testing environment is worthwhile. The danger of accidental functioning would then be reduced. Additionally, the system should be designed such that if the parachute accidentally deploys it will break free from the aircraft – i.e. the attaching mechanism could be secured by breakaway devices or weak links so that only during the test period would the chute be locked to the aircraft. A further safety feature can be designed into the control system by ensuring that, when the system is armed, jettison cannot be initiated prior to deployment. The safety of ground crew, especially if the system includes any pyrotechnic devices, must be considered.
- **Unobtrusiveness:** The parachute system, its container and mounting structure should have minimal effect on the moments of inertia and aerodynamics, and consequently the spin characteristics, of the aeroplane under test.

Operational Considerations

A few aspects of operating an aircraft fitted with an anti-spin parachute system should be considered, for example:

- **System Set Up:** The test pilot should be consulted, during the design of the system, with respect to operational requirements, especially regarding the preferred location of cockpit controls. Ideally the primary controls, for deployment and subsequent jettison of the chute, will have differently coloured handles and be located, while both within easy reach of the pilot, in positions far enough apart to minimise the possibility that the jettison handle will be activated prior to that for deployment – i.e. the deployment control should be the more prominently placed such that it can be located instinctively during the heat of the moment in an unresponsive spin.
- **Functional Testing:** Before declaring the equipment suitable for use during the extended spin test program it ought to be subject to its own clearance testing. This functional checking itself has the potential to be dangerous and should be approached with proper caution. Airborne testing would normally be preceded by a series of ground tests where the deployment and jettison mechanisms are checked. This could occur, in the first instance, from the back of a vehicle but should also be undertaken during high speed taxi tests with the system rigged in the aircraft itself. Any airborne testing of parachute deployment and release should be conducted at a safe height and in a build-up sequence. The first deployments would best be from the aircraft under controlled low speed flight. If warranted, deployments when the aircraft is stalled and then, maybe, after a one or two turn spin could follow. The use of a photo and safety chase aircraft is recommended, and this chase aircraft can then be used to track the jettisoned parachute to ensure its subsequent recovery.
- **Procedures, Preparation and Practice:** Spin-chute testing as well as the spin program proper or any other testing that warrants fitting of the anti-spin system should be subject to separate and rigorous hazard analysis/risk management exercises. Plans can be drawn up for scenarios such as the chute failing to deploy correctly or unsuccessful jettison. The test pilot is advised to familiarise herself thoroughly with the system, and practise using it, prior to any sortie wherein its service may be required.

References

- NASA Technical Note D-6866, 'Summary of Design Considerations for Airplane Spin-Recovery Parachute Systems' by Sanger M. Burk Jr., August 1972.
- NASA Technical Paper 1076, 'Spin Tunnel Investigation of the Spinning Characteristics of Typical Single-Engine General Aviation Airplane Designs – Tail Parachute Diameter and Canopy Distance for Emergency Spin Recovery' by Sanger M. Burk Jr., James S. Bowman Jr., and William L. White, November 1977.
- NASA Technical Memorandum 80237, 'A Spin-Recovery Parachute System for Light General-Aviation Airplanes' by Charles F. Bradshaw, dated April 1980.
- AIAA-90-1317-CP, 'A Summary of Spin-Recovery Parachute Experience on Light Airplanes' by H. Paul Stough, III, dated 1990.

- Flight Test Society of Australia, 'Spin Recovery Parachutes for GA Aircraft – The Australian Experience' by Dafydd Llewellyn and Keith Engelsman, March 2009.
- Flight Test Society of Australia, 'Spin Recovery Parachute Installations for Small Aeroplanes' by Dafydd Llewellyn, dated 2009.
- Flight Test Society of Australia, 'A Drogue Gun for Small Spin-Recovery Parachutes' by Dafydd Llewellyn, dated 2009.
- FAA Action Notice – Implementation of Guidance on the Use of Spin Recovery Parachutes on Aircraft Requiring Spin Testing or Other High Angle of Attack Testing for Certification; Manager, Aircraft Engineering Division, AWS-100; dated February 12, 1989.
- 'Emergency Spin Recovery Devices' from 'The Pilot's Handbook for Critical and Exploratory Flight Testing', Society of Experimental Test Pilots, dated 1972.

APPENDIX C

GENERIC FLIGHT TEST PLAN CONTENTS

While the format and details of any FTP can be flexible the contents will probably cover certain essential subject matter areas. Some suggestions for inclusion in a FTP, in this case a generic FTP for use during an aircraft type certification project, follow the outline in the table below.

INTRODUCTION	An *INTRODUCTION* section could comprise the following three subsections:
Background	A *Background* subsection would outline the circumstances that led to the task. There would normally be reference to the regulations and category under which the aircraft or system subject to the testing will operate and some introduction to the broader aspects of the certification project.
Objectives	The *Objectives* subsection states exactly what the flight testing is intended to achieve.
Terms and Abbreviations	A reference to the list of acronyms and terms used throughout the document.
RELEVANT CONDITIONS	The *RELEVANT CONDITIONS* section details the conditions which will influence the validity of the results of the test activity. Depending on the nature of the task, some or all of the following subsections could be included.
Description of Test Aircraft	This subsection provides a general description of the aircraft and systems with emphasis on those features particularly relevant to the flight testing. A reference to the flight manual, or supporting documentation, for a full description of the aircraft should be made. Details of the particular aircraft (tail-number(s)) to be flown during the test program should be provided.
Certification Basis	The details of the exact Certification Basis, including the airworthiness standard at the applicable amendment status, for the aircraft under test should be provided.
Certificate of Airworthiness	Reference to, and or a copy of, the applicable CofA, or Experimental Certificate issued in accordance with CASR 21.191, should be included.
Project Authorisation	Reference to, and or a copy of, any formal (company) written authorisation allowing the flight testing to proceed should be included. Any applicable program limitations should be highlighted.
Conformity and Engineering Compliance	Reference as to how engineering conformity will be guaranteed, and who is responsible, should be provided.
Flight Test and Project Personnel	A list of personnel involved in the test program and their responsibilities.

Instrumentation and Test Equipment	This subsection should describe all instrumentation and other test equipment to be utilised. Calibration information would form part of this description. Detailed listings of the parameters to be measured, the measurement characteristics, and their expected ranges may be included.
Data Reduction	Data processing support requirements and/or the officer to be responsible for processing and analysis can be nominated. Any requirement for special application software can be outlined.
SCOPE OF TESTS	A *SCOPE OF TESTS* section can be used to outline the range of tests to be conducted and general related limitations, configurations, loadings and standards, etc, which will influence the validity of the results of test activity. Depending on the nature of the task, some or all of the following subsections could be included.
Tests and Test Conditions	A statement as to the nature of the testing.
Flight Type Compliance Matrix	A FTCM, which details all those clauses of the applicable Certification Basis that are subject to flight test or to assessment by the flight test team, can be generated and referred to at this subsection. Normally, since this can be quite a substantial document in itself, the FTCM should be included as an annex or as a soft copy link to a related electronic file.
Sortie Plan and Test Progression	A summary of the test program, stating the number of phases, tests, flights (including each required take-off weight and balance condition), flight hours and general scheduling. Normally presented as an annex.
Test Matrix	If not included as part of the annexure associated with the preceding subsections, a matrix of the actual tests to be conducted should be detailed.
Test Limitations	A summary of the test limitations, stating the test envelope or test limits for the tests and their sources. Special attention is normally paid to areas which expand or differ from previously cleared limitations or restrictions.
Test Configurations	Configurations in which the aircraft is to be tested can be defined.
Weight and Balance	Reference to loading information and procedures. Variables which may have a significant effect on the aircraft weight and balance (e.g., crew, stores, fuel, ballast), and how these variables will be controlled to meet each required take-off condition, should be included.
METHOD OF TEST	The *METHOD OF TEST* section should specify general methodology and procedures relevant to the test program.
Test Standards and Advisory Information	Reference to the guidance information or publications that will be used as a basis for the test program and subsequent compliance determinations.
Test Techniques	Flight test techniques (FTTs) and methods should be specified in this subsection. If standard techniques are to be used then reference to the publications or documentation where these FTTs are described should be provided.

REPORTING	A statement as to what type of report will be the outcome of the test program and a target date for that report to be finalised.
SAFETY	A dedicated *SAFETY* section is always warranted. Safety aspects for the entire activity must be considered. Particular attention should be paid when tests will be made outside the cleared flight envelope, or in uncleared configurations. The following subsections should be included:
Hazard Analysis and Risk Management	A detailed hazard analysis / risk management plan should be included, normally as an annex.
Preparation and Training	Details of work-up and preparatory training requirements.
Safety Equipment	Safety and special equipment requirements.
Briefings, Safety Review and Flight Authorisation	Briefing and flight authorisation procedures should be defined.
ADMINISTRATION	An *ADMINISTRATION* section specifying resources, administrative details and schedule can be included.
Test Location	Where will the test program be conducted?
Task Schedule	When will the test program be conducted?
Travel and Finance	How will personnel and assets get to where they need to be? What other costs will be involved?
Resource Authorisation	Who will authorise the program? Who will pay for it?
ANNEXES	Annexes are to be listed in this section.
REFERENCES	Documents referenced in the FTP should be listed in this section.

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APPENDIX D

FLIGHT TEST HAZARD ANALYSIS/RISK MANAGEMENT

There is a lot of information available in the literature regarding general hazard analysis and risk management and there are plenty of professional risk management consultancies. The following paragraphs provide some information with respect to flight test risk management, most of which has been derived from the references quoted at paragraph 9.2 of this AC. There is no absolute right or wrong way to conduct the process and the following is only intended to provide general guidance. Consultants are readily available if more detailed assistance is required.

Concepts

Risk management is the process by which:

- hazards are identified;
- an assessment is made of the risks involved;
- mitigating procedures are established to reduce or eliminate the risks; and
- a conscious decision is made, at the appropriate level, to accept residual risks.

In the flight test environment risk management is normally conducted through a safety review process in which a flight test plan, and its ongoing application, is examined by project and non-project personnel in order to draw out potential hazards and recommend mitigating (or minimising) procedures. Applicable conceptual definitions could be as follows:

- *Hazard* – A condition, event, or circumstance which could lead to an unplanned or undesired event (injury to personnel, damage to equipment, loss of material, or loss of function).
- *Risk* – Expression of the impact of an undesired event in terms of event severity and probability.
- *Hazard Analysis* – The process of identifying hazards and systematically quantifying or qualifying the degree of risk they pose for exposed individuals or equipment.
- *Risk Management* – The process of reducing vulnerability to the identified risks through eliminating, mitigating, minimising or controlling them and then making a conscious decision to accept the residual risk.

A flight test organisation should define some underlying risk management principles to which it will operate. Some suggestions are outlined below:

- Unnecessary risks should not be accepted. An 'unnecessary risk' is any risk that, if taken, will not contribute meaningfully to task outcomes.
- Risks should be reduced to an acceptable level. Risk is part of flight test but by applying risk management principles flight testing can be accomplished in a safe and efficient manner.
- Hazard analysis/risk management occurs at the planning stage of the project and should then be ongoing, with regular reviews and updates taking place throughout any program.
- Risk decisions should be taken at the appropriate level. The higher the risk the higher the level of management that must be involved in task authorisation.

Procedures and Considerations

This section outlines one method for formalising the hazard analysis risk management process. There are other formats or systems which may be more suited to individual needs or preferences and the reader is encouraged to seek them out. The featured method follows the steps outlined below:

- **Initial Hazard Identification and Risk Assignment:** Individual test events or flight test technique (FTTs) should be listed with any likely hazards identified. The probability of these hazards occurring and the associated outcome of such an occurrence then leads to an assignment of an initial risk level.
- **Risk Minimisation/Corrective Action:** Risk minimisation considerations are then listed, followed by any corrective actions required should the hazard still eventuate.
- **Residual Risk:** Assessment of the effects of the minimisation factors and corrective action definitions should then allow an allocation of a residual risk level. Consideration of this residual risk should involve senior management in accepting any risk above 'medium' (or as designated in company policy documentation).

A matrix is a convenient way of documenting the process and tabulating the results. An example of a matrix, with some indicative examples in relation to testing a small single engine aeroplane, is presented at the end of this Appendix.

Risk is normally evaluated as a function of the probability of an undesirable event occurring and the consequences should such event occur. The following are further definitions addressing levels of risk, hazard categories and probabilities relative to the assessment of a specific test condition. These definitions are subjective in nature and can be used in the assignment of risk levels. They may be taken as applicable to flight test operations and not necessarily relevant in other scenarios:

- *Unacceptable Risk.* Tests or activities which present a significant risk to personnel, equipment or property and which will probably eventuate even after all precautionary measures have been taken. Acceptance of this level of risk should not be authorised.
- *High Risk.* Tests or activities which present a significant risk to personnel, equipment or property and may eventuate even after all precautionary measures have been taken. Acceptance of this level of risk would not normally be authorised. If any such activity was to go ahead then it should only do so in extenuating circumstances and then only with authorisation from the highest levels. (Regardless, flight test crews are advised to consider whose personal presence is being exposed to such risk and make their own decisions accordingly.)
- *Medium Risk.* Tests or activities which present a risk to personnel, equipment or property that is greater than that expected during normal or routine flight operations.
- *Low Risk.* Tests or activities which present no greater risk to personnel, equipment or property than that encountered during normal or routine flight operations.
- *Hazard Outcome – Catastrophic.* Loss of the aircraft and/or loss of life.
- *Hazard Outcome – Critical.* Major damage to the aircraft and / or injury to personnel.
- Hazard Outcome – Marginal. Damage to the aircraft.
- *Hazard Outcome – Acceptable.* Unserviceabilities or wear and tear common to normal operations.
- *Subjective Probability – Probable.* This hazard has better than a 50 percent chance of occurring and should be expected.
- *Subjective Probability – Possible.* This hazard could occur under some conditions but is not expected.

- *Subjective Probability – Unlikely*. This hazard is unlikely to occur or there is uncertainty as to whether the hazard is possible.
- *Subjective Probability – Remote*. This hazard is extremely unlikely, the probability of occurrence being similar to that of a catastrophic event during normal operations.

These probability and consequence parameters can be arranged in a table which then provides a tool for assigning risk levels:

Hazard Outcome Category	Subjective Probability of Occurrence			
	Probable	Possible	Unlikely	Remote
Catastrophic	UNACCEPTABLE	HIGH	Medium	Low
Critical	HIGH	HIGH	Medium	Low
Marginal	Medium	Medium	Medium	Low
Acceptable	Low	Low	Low	Low

Factors Affecting Flight Test Risk Ratings: Some factors which may be worth taking into consideration when assigning flight test risk ratings are as follows:

- The test team's proficiency with, currency on and familiarity with the test aircraft and the type of tests being conducted.
- The existence of any previous test program, the thoroughness thereof and the relevant results.
- Test techniques and workloads.
- Altitude and airspeed in relation to terrain and/or aircraft recovery systems.
- Gross weight and centre of gravity.
- Environment (weather, air traffic control, airfield conditions, darkness, turbulence etc.).
- Aircraft internal environment (temperature, pressurisation level etc.).
- Design maturity.
- Test condition sequencing.
- Adverse system or software effects.
- Specific aircraft limitations.

- Consequence of failure in technique, system or structure.
- Intentional multiple failure conditions.

Risk Alleviation: Risk alleviation procedures are actions taken, or factors assessed, in order to understand, respond to and minimise identified risks. They should be conditions over which the test team has control or events that the crew can confirm have occurred (e.g. simulator evaluations). Some considerations and examples, by no means all inclusive, are:

- Is the test condition in its present form really needed? Can results be determined or compliance recommendations made based on other testing or information?
- How long has it been since the conformity on the test aircraft configuration was conducted? Has anything changed since the design was reviewed?
- Review test techniques and specify steps to reduce risks.
- Design the test sequence with a conservative build-up of speed and manoeuvre.
- Design the test sequence with a conservative build-up of weight/CG. Review weight and balance computations. Weigh the loaded aircraft if possible. This is particularly important for critical handling qualities tests at the extremes of the weight/CG envelope and on weight altitude temperature (WAT) limited performance tests.
- Review the test environment and specify steps to reduce risks (e.g. Specify limits with respect to temperature, wind, visibility etc.).
- Specify minimum test altitudes to allow for anti-spin chute deployment, then aircraft abandonment if necessary.
- Provide predictions and expectations to prepare participants. Update performance predictions with flight test data when possible.
- Run test sequences in simulators.
- Provide special training and consultation.
- Specific training with equipment (helmets, goggles, masks, oxygen, escape provisions, parachutes, fire extinguishers etc.). All personnel should be briefed on egress procedures. For high altitude tests all crewmembers must be briefed on oxygen use and equipment location. For overwater flights all crewmembers must be briefed on survival equipment use and location.
- Use of chase aircraft to provide visual data and safety support.
- Use of photo/video recording.
- Use of telemetry to monitor tests in ‘real time’.
- Use of ground support monitoring test comms frequencies.
- Install hardware to protect structure and personnel (e.g. Anti-spin chute, door/canopy jettison, V_{MU} tailskid).
- Limit personnel onboard to the absolute minimum required to safely conduct the test (do not arbitrarily set a limit on the number of personnel, take the right number to safely conduct the test).
- For build-up tests utilise the right personnel to evaluate the data and plan for subsequent tests. Allow adequate time to evaluate the build-up test points.
- Request a thorough briefing on previous testing, techniques and results. On tests that are highly dependent on pilot technique, allow the practised pilot to conduct the initial tests and observe his/her performance before conducting independent tests.
- On potentially hazardous ground tests (e.g. high energy rejected take-offs (RTO)) experienced ground crews should be briefed during the pre-flight briefing and be immediately available to support the tests if necessary (e.g. cooling fans, fire trucks, aircraft-jacks, tow-motors etc.). The ground crews should be advised as to who is in charge regarding their participation.

- Minimise the number of actual engine cuts during runway performance testing if spool-down thrust can be properly accounted for by analysis and related systems failures can be simulated accurately.
- Test personnel involved with hot/cold weather testing should be briefed on appropriate survival skills and be properly equipped to endure the anticipated environment.

Risk Level Examples: Examples of tests which could be considered to carry different risk levels, initially and unmitigated, are grouped below. These are typical examples only and are provided for general guidance. The actual risk category for each test condition must be evaluated on a case-by-case basis.

- **High Risk:** Tests that could be considered to involve high risk factors are as follows:
    - Stall Characteristics:
        - Aft CG accelerated stalls with rapidly changing dynamic conditions.
        - On aeroplanes equipped with unproved pusher systems that are masking potential deep stalls.
        - High altitude stalls on aeroplanes with potential engine flameout problems.
        - With critical ice shapes.
    - High speed tests above $V_{NE}/V_{MO}/M_{MO}$.
    - V_{MCA} tests at low altitude, particularly dynamic V_{MCA}.
    - Flight control malfunction testing during take-off and landing phases of flight, and asymmetric deployment of roll controls at high speeds.
    - Ice shape testing, especially during the take-off phase where special procedures are required.
    - Icing tests flown behind a tanker (formation flying with potentially restricted field of view).
    - Maximum energy RTOs where wheel brake fires are a possibility.
    - Autopilot malfunction tests at low altitudes.
    - WAT limited take-offs with actual engine cuts.
    - V_{MU} tests at low thrust to weight ratios.
    - V_{MCG} testing.
    - Nosewheel steering malfunction tests.
    - Spin testing.
    - Lateral-directional testing on aircraft that can achieve large sideslip angles.
    - Dynamic lateral-directional testing (Dutch rolls) on aeroplanes that are unstable under certain conditions.
    - Inflight thrust reverser deployments.
    - Stall characteristics on Restricted Category aeroplanes with asymmetric wing store configurations.
    - Helicopter H/V envelope determination.
    - Helicopter low speed testing.
    - Autorotation testing.
    - Pilot Induced Oscillations (PIO) testing.
    - Flight tests in which the test pilot is the sole occupant because of the nature of the test and/or configuration and pilot proficiency is in question.

- **Medium Risk:** Tests that could be considered to involve medium risk factors are as follows:
  - Any tests involving low altitude operations (e.g. ground course pressure error correction (PEC) testing).
  - Tests involving formation flying.
  - Aerobatic manoeuvres.
  - Actual V_1 fuel cuts for take-off performance.
  - Inflight unusable fuel tests that result in engine flameout.
  - Stall speed, or glide performance, measurement with the engine actually inoperative.
  - Low speed and high speed stability and control tests.
  - Emergency electrical power landings at night using standby instruments and/or reduced lighting (both external and internal).
  - Emergency descents to demonstrate high altitude special conditions (possible physiological effects).
  - Abnormal flight control configuration testing. Includes pitch and roll disconnects or manual reversion for hydraulic systems.
  - Natural ice flights with large shapes on unprotected surfaces.
  - Cockpit and cargo smoke evacuation testing.
  - Engine water ingestion testing.
  - Asymmetric thrust reverser testing on the ground.
  - Abnormal operation of onboard systems.
  - Flights involving Full Authority Digital Engine Control (FADEC) testing (Electromagnetic Interference (EMI), software, etc.).
  - Terrain Awareness Warning Systems (TAWS) ground proximity warning systems (GPWS/EGPWS).
- **Low Risk:** Examples of low risk testing could be as follows:
  - Basic system function tests (electrical, hydraulic, fuel, environmental, anti-ice, avionics etc.) not involving abnormal or emergency conditions.
  - High altitude airspeed calibrations (e.g. GPS, trailing cone).
  - Climb performance/speed power etc.

EXAMPLE HAZARD ANALYSIS RISK MANAGEMENT MATRIX

Hazard Analysis Risk Management Method

Table D-1 gives an example of a hazard analysis risk management matrix developed using the process outlined above. It shows some indicative deliberations in relation to certification testing for a small single engine aeroplane. The 'Events' included, and their associated assessment sequences, are meant as typical examples only and the table does not necessarily include all testing considerations that would apply to such a program.

Table D1 – Hazard Analysis Risk Management Matrix

Ser.	Event	Hazard	Worst Effect/ Probability	Initial Risk Level	Minimisation Procedures	Corrective Action	Minimisation / Corrective Effect	Residual Risk Level
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
1	SHSS	Structural failure due to excessive sideslip loads.	Catastrophic/ Unlikely	Medium	Confirm aircraft β limit with applicant and observe this limit during tests. Apply and remove pedal deflection in slow, smooth manner.	If β limit exceeded statically, release pedal slowly and smoothly.	Probability reduced to remote.	Low
2	Roll Rate	Structural failure after exceeding aircraft limits.	Catastrophic/ Unlikely	Medium	Discuss roll characteristics with applicant test pilot prior to tests. Centralise skid ball during testing. Knock-it-off (KIO) if control reversal or significant stick force lightening experienced. Buildup by Half then Full Aileron Clean then Takeoff then	Loss of Control (LOC) recovery technique: Simultaneously; Select engine to Idle, Centralise controls, Maintain neutral aileron until Vs+5kts, Retract flaps at pilot's discretion, Recover from dive.	Probability of aircraft damage reduced to remote.	Low

Ser.	Event	Hazard	Worst Effect/ Probability	Initial Risk Level	Minimisation Procedures	Corrective Action	Minimisation / Corrective Effect	Residual Risk Level
					Landing configuration. V_A or V_{FE} – 20% Minimum altitude during roll testing 2000 ft AO.			
3	Static Stability and Flight Path Stability	Airframe damage after exceeding aircraft limits	Marginal/ Unlikely	Medium	All appropriate airspeeds will be briefed/reviewed by crewmembers and adhered to. High and low speed data points will be reviewed and correlated to the appropriate high or low speed aircraft limits.	Decelerate to below V_{NE} or V_{NO} in 1-*g* flight. Accelerate to Vs+5kts.	Probability of aircraft damage reduced to remote.	Low
4	1G Wings Level Stalls	Stall departure, loss of control leading to ground impact.	Catastrophic/ Uncertain	Medium	Discuss stall characteristics with applicant test pilot prior to tests. Centralise skid ball during approach to stall. Target speed bleed rate 1 kt/sec. Knock-it-off if control reversal or significant stick force lightening experienced. Buildup by Heavy to light weight, Forward to Aft C.G., and Clean then Takeoff then Landing configuration. Minimum altitude during stall testing 4000 ft AO.	Loss of Control (LOC) recovery technique: Simultaneously; Select engine to Idle, Oppose yaw/roll with rudder, Lower pitch attitude to accelerate, Maintain neutral aileron until Vs+5kts, Retract flaps at pilots discretion, Recover from dive.	Probability of violent loss of control reduced to remote. Probability of inability to regain control reduced to remote.	Low
		Aircraft overstress or overspeed during stall	Critical/ Uncertain	Medium	Brief aircraft limits for test configuration prior to test conduct.	Crew to monitor speed and G during recovery.	Probability reduced to remote.	Low

Ser.	Event	Hazard	Worst Effect/ Probability	Initial Risk Level	Minimisation Procedures	Corrective Action	Minimisation / Corrective Effect	Residual Risk Level
		recovery.						
5	Engine Off Stalls	Engine fails to restart leading to forced landing.	Catastrophic/ Uncertain	Medium	Discuss glide / PFL characteristics with applicant test pilot prior to tests. Practise PFL profiles before engine off sorties. Study AFM and practise engine restart procedures. Crew to wear helmet / flying suits / gloves. Minimum altitude during stall testing 4000 ft AO. Minimum altitude for engine off 3000 ft AO. Testing to be conducted only within gliding range of the airfield.	Do not conduct tests if discussions/review/practice suggest unacceptable characteristics.	Probability of inability to recover aircraft reduced to unlikely.	Low
6	Accelerated Stalls	As per Serial 4.	Catastrophic/ Uncertain	Medium	Discuss stall characteristics with applicant test pilot prior to tests. Review 1G stall characteristics prior to accelerated stall tests. Enter stall from balanced turn. Knock-it-off if control reversal or significant stick force lightening experienced. Brief aircraft limits for test configuration prior to test conduct. Minimum altitude during stall testing 4000 ft AO.	Do not conduct tests if discussions/review suggest unacceptable characteristics. Release G at point of departure then employ LOC recovery technique. Crew to monitor speed and G during recovery.	Probability of violent loss of control reduced to remote. Probability of inability to regain control reduced to remote	Low

Ser.	Event	Hazard	Worst Effect/ Probability	Initial Risk Level	Minimisation Procedures	Corrective Action	Minimisation / Corrective Effect	Residual Risk Level
7	Spin Preparation	Malfunction during antispin chute check.	Catastrophic / Uncertain	Medium	Discuss spin chute mechanism and characteristics with applicant test pilot and review applicant test report prior to tests. Ensure fail safe facilities in place. Check deployment and jettison on ground. Independent pre-flight check by knowledgeable LAME. Minimum crew (TP only). Pilot to wear parachute. Critical heights to be employed Deploy not below 3000 ft AO Abandon not below 1500 ft AO. Flight following to be provided by FTE and applicant with binos on ground and safety chase (also for chute recovery tracking). Emergency services to be available.	Do not conduct tests if discussions/review suggest unacceptable characteristics. If chute does not deploy properly jettison immediately. If chute does not jettison conduct slow speed handling check, consider recovery options – if any doubt, abandon aircraft preferably from height and over clear area.	Probability of inability to regain control reduced to unlikely. Probability of inability to recover aircraft and/or pilot reduced to remote.	Medium
8	Spins	Development of unrecoverabl e spin characteristic s leading to ground	Catastrophic/ Uncertain	Medium	Discuss spin characteristics with applicant test pilot and review applicant test report prior to tests. Review stall characteristics prior to spin tests. Standard spin recovery	Do not conduct tests if discussions/review suggest unacceptable characteristics. Standard spin recovery technique: Select engine to Idle,	Probability of inability to regain control reduced to unlikely. Probability of inability to recover	Medium

Ser.	Event	Hazard	Worst Effect/ Probability	Initial Risk Level	Minimisation Procedures	Corrective Action	Minimisation / Corrective Effect	Residual Risk Level
		impact.			techniques to be used. Antispin chute to be installed for all spin testing. Minimum crew (TP only) for spin sorties. Pilot to wear parachute. Buildup by Light to heavy weight, Forward to Aft C.G., and Clean then Flap and Power configurations. Critical heights to be employed Entry not below 8000 ft AO Antispin chute at 6000 ft AO Abandon not below 4000 ft AO. Flight following to be provided by FTE and applicant on ground and safety chase. Emergency services to be available.	Ailerons neutralised, Full opposite rudder, Forward elevator control as required to unstall wing, Retract flaps as briefed but not until rotation ceased, Maintain neutral aileron until Vs+5kts, Recover from dive.	aircraft and/or pilot reduced to remote.	
9		Aircraft overstress or overspeed during spin recovery.	Critical/ Uncertain	Medium	Brief aircraft limits for test configuration prior to test conduct.	Crew to monitor speed and G during recovery.	Probability reduced to remote.	Low
10	Vibration and Buffeting	Structural failure due to violent vibration build up.	Catastrophic/ Uncertain	Medium	Discuss vibration characteristics with applicant test pilot and review applicant test report prior to tests. . Buildup progressively from low speed to high speed. Minimum altitude during	If abnormal vibration or buffet levels are encountered recovery technique will consist of: Power reduced Reduce speed using minimal G.	Probability of violent loss of control reduced to remote.	Low

Ser.	Event	Hazard	Worst Effect/ Probability	Initial Risk Level	Minimisation Procedures	Corrective Action	Minimisation / Corrective Effect	Residual Risk Level
					high speed testing 2000 ft AO. No attempts will be made to excite flutter and flutter requirements are already to have been checked.			

APPENDIX E

EXPERIMENTAL CERTIFICATE – FLIGHT TEST – RISK ASSESSMENT

Risk Assessment Matrix

The risk factor matrix and worksheet provided at Table E-1 can be used in conjunction with the risk assessment table (Table E-2) to assist in deciding what level of operating conditions and limitations should be applied to an experimental certificate issued in accordance with AC 21.10(2).

Note: The tables should be used as a general guide only to assist in the application of judgement and common-sense. Their completion should not just be treated as a box-ticking exercise. They offer a broad aggregate of general risk factors and do not necessarily provide for individual cases. For example, if an established and professional engineering organisation, with good flight test capabilities and conservative safety practices in place, was proposing to fly a radically new powerplant concept, the risk level would probably be elevated even though the Risk Factor Total from Table E1 indicated a low risk level. On the other hand, an amateur builder or inexperienced organisation, acting in good faith, heeding all available advice and operating well away from populated areas, should not be unduly penalised. The listed risk factors, or indeed additional factors, may or may not be relevant to the specific application under consideration. If doubt exists contact the Flight Test & Evaluation Office, Airworthiness Engineering Branch, CASA, GPO Box 2005, Canberra ACT 2601, Telephone 131 757.

Table E1 – Risk Factor Worksheet

FACTOR	RATING				
	1	2	3	Mitigating or Amplifying Comments (If Required)	Allocation
Applicant	Established aeronautical engineering organisation employing experienced design office and flight test staff	Established engineering and/or aviation organisation but with limited flight test experience.	Organisation or individual with no flight test experience.		
Program	Conventional modification or developmental program. Predictable outcomes are expected.	Developmental program with some unconventional challenges. Particular unusual or untried features may affect outcomes.	Development of completely new or substantially modified aircraft or major subsystem. Novel or untested experimental features or concepts may be involved.		
	No commercial or external imperatives. Delays acceptable.	Some commercial or external imperatives. Delays create pressure.	Significant commercial or external imperatives. Delays create substantial pressure.		
Test Planning	Complete and thorough planning has been conducted in accordance with published guidance material.	Some deficiencies in planning or it is lacking reference to published guidance material.	Poorly or incompletely planned.		

FACTOR	RATING				
	1	**2**	**3**	**Mitigating or Amplifying Comments (If Required)**	**Allocation**
Aircraft	Certificated type involving minor modifications or modifications not affecting flight performance or handling.	Certificated type involving major systems modifications or modifications affecting flight performance or handling.	Non-certificated developmental or experimental aircraft.		
	Normal (or similar) category aircraft of conventional configuration.	Normal (or similar) category aircraft with some 'non-conventional' configuration features (e.g. tailwheel, float or ski landing gear; unmatched powerplant, etc).	Acrobatic (or similar) category aircraft with novel or 'non-conventional' configuration features.		
Flight Crew	Qualified and experienced Test Pilot and/or Flight Test Engineer.	Qualified and experienced pilot with some flight test experience and/or a conservative and flexible nature.	Low time pilot and/or inexperienced in flight test operations.		
	Current and experienced on type.	Current and experienced on similar types.	Not current or experienced on type or similar types.		
	Practised at specific test techniques and sortie profiles.	Practised at general test techniques but not at specific sortie profiles.	Unpractised at test techniques and unexposed to sortie profiles.		

FACTOR	RATING				
	1	2	3	Mitigating or Amplifying Comments (If Required)	Allocation
Safety Equipment	Relevant, complete and tested suite of safety equipment provided (e.g. antispin chute or recovery and escape features, personal protective equipment for test crewmembers).	Incomplete suite of relevant safety equipment provided or some items untested.	No relevant safety equipment provided.		
Airfield / Airspace	Licensed airfield with appropriate runways, facilities and operating environment.	Unlicensed airfield with appropriate runways and operating environment.	Unlicensed or poorly maintained airfield with inappropriate operating environment.		
	Minimal or no air-traffic problems. Few or no other airspace users.	Some air-traffic problems or other airspace users.	Significant air-traffic problems or busy airspace environment.		
	No built-up or significantly populated areas near airfield or under designated flight test area.	Some built-up or populated areas near airfield or under designated flight test area.	Substantially built-up or populated areas near airfield or under intended flight test area.		
	Clear approach and departure lanes between airfield and flight test area.	Limited approach and departure lanes or approach and departure lanes require complicated navigational procedures to negotiate.	No clear approach and departure lanes between airfield and flight test area.		

FACTOR	RATING				
	1	**2**	**3**	**Mitigating or Amplifying Comments (If Required)**	**Allocation**
Ground Support	Flight test support facilities (e.g. telemetry) and flight following in place.	Some flight test support or flight following available.	No flight test support or flight following available.		
	Emergency, crash recovery, fire fighting and medical services available and on stand-by.	Some or limited emergency, crash recovery, fire fighting and medical services available.	No emergency, crash recovery, fire fighting and medical services available.		
Any Other Aspects					
				TOTAL	

Table E2 – Risk Assessment

Low Risk	Overall risk level, to both the aircraft and flight test crews themselves, and to people on the ground or water and other airspace users, is low and / or manageable.	• The Applicant can be advised to go ahead with the flight testing using extant planning and risk management procedures. • Experimental Certificate can be issued with standard or minimal operating conditions, limitations and directions as per AC 21.10.	**<25**
Medium Risk	Overall risk level, to both the aircraft and flight test crews themselves, and to people on the ground or water and other airspace users, is elevated and / or deserving of further mitigation.	• The Applicant should be advised to consider further risk reduction procedures before going ahead with the flight testing. • Experimental Certificate can be issued however restrictive operating conditions, limitations and directions as per AC 21.10 should be imposed in the interests of the safety of people on the ground or water and other airspace users..	**25-35**
High Risk	Overall risk level, to either the aircraft and flight test crews themselves, or to people on the ground or water and other airspace users, is high and / or unmanageable.	• The Applicant should be advised that the flight testing is assessed as involving a high level of risk to both the aircraft and flight test crews themselves, and / or to people on the ground or water and other airspace users. He or she should be strongly urged to introduce risk reduction procedures or to reconsider the intent or scope of the proposed flight test operation. • Experimental Certificate should not be issued unless severe operating conditions, limitations and directions are imposed in the interests of the safety of people on the ground or water and other airspace users.	**>35**

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