



**Australian Government**  

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**Civil Aviation Safety Authority**

# ADVISORY CIRCULAR

## **AC 21-19**

### **Aircraft modification – flight test considerations**

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.

**Advisory Circulars should always be read in conjunction with the relevant regulations.**

## Audience

This Advisory Circular (AC) applies to:

- applicants seeking approval of a change to a type design of a type certificated aircraft, aircraft engine or propeller
- holders of a Supplemental Type Certificate (STC)
- holders of a Type Certificate (TC)
- people responsible for certification and flight testing aircraft with modifications fitted.

## Purpose

This AC provides background information and general technical guidance regarding the flight test considerations relating to aircraft modified in accordance with Subparts 21.E and 21.M of the *Civil Aviation Safety Regulations 1998 (CASR)*. While the considerations are applicable to all aircraft, the information provided is focussed on flight testing of lighter weight and/or lower speed aircraft, principally those in the primary, normal, utility or acrobatic categories.

## For further information

For further information on this AC, contact CASA's Airworthiness and Engineering Standards Branch (Telephone: 131 757; Email: [airworthiness.standards@casa.gov.au](mailto:airworthiness.standards@casa.gov.au)).

## Status

Version	Date	Details
v1.0	May 2015	Initial issue of this AC.

Unless specified otherwise, all subregulations, regulations, Divisions, Subparts and Parts referenced in this AC are references to the *Civil Aviation Safety Regulations 1998 (CASR)*.

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# 1 Reference material

## 1.1 Acronyms

The acronyms and abbreviations used in this AC are listed in the table below.

Acronym	Description
AC	Advisory Circular
ADO	Approved Design Organisation
AFM	Aircraft Flight Manual
AP	Authorised Person
CAR	<i>Civil Aviation Regulations 1988</i>
CASA	Civil Aviation Safety Authority
CASR	<i>Civil Aviation Safety Regulations 1998</i>
CG	Centre of Gravity
FMS	Flight Manual Supplement
LBA	Limit Basic Airframe (or Aircraft)
STC	Supplemental Type Certificate
TC	Type Certificate

## 1.2 Definitions

Terms that have specific meaning within this AC are defined in the table below.

Term	Definition
Approved Design Organisation (ADO)	A design organisation approved under Subpart 21.J.
Authorised Person (AP)	An AP is an individual or an organisation that has been appointed as an AP under regulation 201.001 for the purposes of a provision in the regulations.
Certification Basis	The set of requirements, special conditions, equivalent safety findings, and exemptions that identify the airworthiness standards and other standards for which compliance must be shown.
Certification flight testing	Flight tests conducted for the purpose of demonstrating, or verifying, compliance with the applicable airworthiness standard.
Experimental/developmental flight testing	Flight tests conducted for the purpose of defining or expanding an aircraft's flight envelope.
Flight test	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 (subregulation 21.35 of CASR refers). In this AC, flight test does not mean a practical test of a person's aeronautical knowledge and flying skill (as per Part 1 of the CAR).

## 1.3 References

### Regulations

Regulations are available on the ComLaw website <http://www.comlaw.gov.au/Home>

Document	Title
Part 21 of CASR	Certification and airworthiness requirements for aircraft and parts
CASR Dictionary	

### CASA advisory material

CASA's advisory material is available at <http://www.casa.gov.au/AC/>

Document	Title
AC 21-8	Approval of modification and repair designs under Subpart 21.M
AC 21-12	Classification of design changes
AC 21-13	Australian Designed Aircraft – Type Certification
AC 21-15	Supplemental Type Certificates
AC 21-40	Measurement of Airspeed in Light Aircraft – Certification Requirements
AC 21-47	Flight Test Safety
AC 23-1	Airspeed airworthiness standards for the installation of equipment that protrudes into the airflow

### Other documents

EASA CS-23

EASA documents are available at <http://easa.europa.eu/>

FAR Part 23

FAA documents are available at <http://www.faa.gov/>

## 2 Aircraft modifications

### 2.1 Background

- 2.1.1 Australian aircraft are often modified under the provisions of Part 21. This applies to aircraft that have been type certificated in Australia, or certificated overseas and then accepted for use in Australia through the issue of a type acceptance certificate.
- 2.1.2 Other aircraft, such as amateur-built aircraft operating under an experimental certificate, may also be modified.
- 2.1.3 An STC under Subpart 21.E or a modification/repair design under Subpart 21.M are two methods under which design approval can be granted.<sup>1</sup>
- 2.1.4 Once modified, aircraft previously issued with a TC must, in order for their certificate of airworthiness to remain in force, continue to meet the requirements of their certification basis and the associated airworthiness standards. For modifications that have flight type implications, continued compliance with the relevant airworthiness standards (e.g. FAR Part 23 or EASA CS-23 for normal, utility, acrobatic and commuter category aircraft) may require the applicant for the modification to conduct some form of flight testing or assessment.<sup>2</sup>

**Note 1** The need for flight testing should be considered in relation to the proposed modification, the applicable airworthiness requirements and the regulations. This AC provides general guidance in relation to the types of modifications for which particular consideration should be given to flight testing; it does not imply that flight testing is always required for a modification that falls within one of those general descriptions.

**Note 2** This AC primarily covers flight testing considerations for the purposes of showing that a modification complies with the applicable airworthiness requirements in order for the modification to be approved. Flight testing following incorporation of an approved modification (e.g. a post-installation verification flight) is only required if such flights have been specified as a condition of the approved design.

Information provided in AC 21-47 on flight test safety is directly applicable to the flight test considerations discussed in this AC.

### 2.2 Types of modification

- 2.2.1 Modifications that may have flight type implications would include:
- a. any modification that influences the performance or handling characteristics of the aircraft
  - b. any systems changes with the potential to affect aircraft operation or that have consequences for the pilot and crew
  - c. any change that results in amendment to the Aircraft Flight Manual (AFM).

<sup>1</sup> See AC 21-15 for more information on STCs and AC 21-8 for more information on approvals granted under Subpart 21.M.

<sup>2</sup> Certification flight testing should be conducted in accordance with published guidance material applicable to the relevant airworthiness standard.

## 2.2.2 Performance and handling characteristics

2.2.2.1 Modifications that are likely to affect an aircraft's performance or handling characteristics, as discussed in the following sections, include:

- a. any piece of equipment that protrudes into the airflow or any alteration to the basic shape of the airframe
- b. wing or profile modifications that may alter the aerodynamic qualities of the aircraft
- c. changes to flight control systems
- d. changes to engines and propellers
- e. changes to weight and/or centre of gravity (CG).

### **Any piece of equipment that protrudes into the airflow or any alteration to the basic shape of the airframe**

2.2.2.2 This form of modification normally increases the aircraft's overall drag index and consequently degrades performance capabilities. Stability and control characteristics may also be altered if the wake of the attached equipment affects the airflow over the wing or empennage, and especially if it impacts downstream flight control surfaces. The creation of such effects is not necessarily restricted to large protuberances; even small attachments may generate significant vortices in certain locations.

2.2.2.3 Consideration should also be given to any changes that affect the airflow over, or the pressure field around, pitot tubes or, more importantly, static ports. Such effects would require a recalibration of the aircraft's airspeed-indicating and static pressure instrumentation (see paragraph 3.3.2).

2.2.2.4 Examples of protuberance type modifications include:

- a. camera, laser or radar pods (or other similar stores) mounted on aircraft wings, struts, skids or undercarriage legs, etc.
- b. cargo pods or panniers, including those typically fitted to the underside of an aircraft's fuselage
- c. external fuel tanks
- d. agricultural or fire-fighting spray equipment
- e. radio or avionics antennae
- f. nose booms, tail-stingers, or equipment mounted at wing-tips
- g. ski or float landing gear.

### **Wing or profile modifications that may alter the aerodynamic qualities of the aircraft**

2.2.2.5 Examples of wing or profile modifications include:

- a. changes to the size, profile or shape of wings, wing-tips, empennage or rotors
- b. introduction of fences, vortex generators or boundary layer control equipment
- c. addition of fuselage fairings, undercarriage spats etc. that reduce drag.

## Changes to flight control systems

2.2.2.6 Examples of changes to flight control systems include:

- a. changes to the size or profile of a primary flight control surface or tab
- b. changes to flight control surface range or rate of movement
- c. modification of tab-gearing ratios, spring sizes, control runs, etc.
- d. changes to automatic flight control, auto-pilot and stability augmentation systems.

## Changes to engines and propellers

2.2.2.7 Any modification to the powerplant or propeller installations that involves a change in power output will affect the performance capabilities of the aircraft and can also affect handling characteristics. Propeller changes can alter slipstream and gyroscopic effects.

## Changes to weight and/or CG

2.2.2.8 Changes to an aircraft's maximum take-off weight (normally an increase) will affect performance and possibly some handling characteristics. Similarly, changes to an aircraft's CG range or limits may alter handling characteristics and affect performance.

2.2.2.9 Changes to other weight limits, e.g. maximum landing weight, may also require flight type consideration to ensure compliance with the aircraft's certification basis.

## 2.2.3 Systems changes

2.2.3.1 Common modifications are those that involve the replacement, improvement or addition of aircraft systems. Any changes to systems that have implications in the cockpit or that otherwise affect the way the aircraft is operated will require flight type assessment to ensure continued compliance with the requirements of Subparts D, E, F and G of the applicable airworthiness standard (e.g. FAR Part 23 or EASA CS-23 for normal, utility, acrobatic and commuter category aircraft).

2.2.3.2 Assessment normally involves human factors operability and effectiveness evaluations. Some systems modifications can also result in flight characteristics changes. Both quantitative and qualitative assessments may be required. Specific consideration will be included with modifications that affect operations under the Instrument Flight Rules, with complications often raised should flight into known icing conditions be involved.

Systems that can be modified include:

- a. cockpit controls
- b. engines, propellers, fuel systems
- c. hydraulics, landing gear, steering, brakes
- d. flight instruments
- e. electrics
- f. avionics and communications
- g. integration and automatic flight systems
- h. electronic flight bags
- i. cockpit environment, pressurisation, ventilation
- j. lighting
- k. fields of view
- l. seating, harnesses
- m. cabin environment, entry and exit.



## 2.2.4 Aircraft flight manual

- 2.2.4.1 Many modifications require an amendment to the AFM or the generation of a Flight Manual Supplement (FMS). CASA recommends that flight test or operational aircrew should be involved with the writing and review of these documents.

## 2.3 Modification approval process

- 2.3.1 The approval process used for the modification will depend on the relevant provisions of Subparts 21.E and 21.M. In both cases, it must be shown that the modification complies with the applicable certification basis.<sup>3</sup> Continued compliance with all requirements of the original or updated certification basis (including compliance with all applicable airworthiness standards, e.g. FAR Part 23 and EASA CS-23) must be redemonstrated, or at least restated, in order to obtain modification approval. CASA, or an ADO or AP, may then approve the modification on the basis that that compliance has been established.

AC 21-15 describes the certification process following major changes to a type design approved under an STC. AC 21-8 covers design changes under Subpart 21.M. In both cases, the same basic certification process applies—the essential difference is the reduced involvement of CASA in granting approvals under Subpart 21.M.

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<sup>3</sup> See AC 21-13 for more information on type certification and AC 21-12 for more information on establishing the certification basis for design changes.

## 3 Flight test requirements

### 3.1 Modifications

3.1.1 Modifications require individual analysis—the flight testing requirements relating to the certification of each modified aircraft may range from nil to substantial. In all cases, the flight test phases are the same as those applicable to accreditation of the aircraft itself. Firstly, the applicant is responsible for developmental flight testing and then for the testing required to demonstrate or claim continued compliance with the relevant requirements of the certification basis. CASA, or an ADO or AP, may then conduct their own additional flight tests to validate the applicant's results and compliance claims.

### 3.2 Compliance matrix

3.2.1 The applicant should generate a compliance matrix against all applicable requirements of the certification basis. Care must be taken to ensure all relevant clauses of the airworthiness standard are included since, occasionally, a change in the parameters satisfying one requirement can have a ripple effect and compliance with other clauses previously adjudged unaffected may be compromised. One method that can guard against this possibility is to include all the flight type requirements in the matrix then after considered assessment those found to be unchanged can be marked as such. Clauses clearly not applicable (e.g. commuter category requirements when considering a modification to a normal category aeroplane) can be excluded or designated N/A. In cases where compliance is being claimed through some method other than flight test (e.g. analysis or similarity) the reasoning should be included, or referenced, in the comments column of the matrix. Thus, a complete analysis of the certification basis is presented to the certification authority and the possibility of overlooking an applicable requirement is minimised.

### 3.3 Noteworthy test considerations

3.3.1 Some types of modification may require special attention when flight testing. These considerations are discussed in the following sections.

#### 3.3.2 Pressure error corrections

3.3.2.1 Any modification that changes the pressure field around the aircraft has the potential to cause errors to be introduced to the aircraft's airspeed and altitude measurement systems. This is particularly relevant for protuberances or attachments upstream of, or near, the aircraft's static ports. Should there be any question that the airflow around the static ports would be altered by the modification, then an airspeed system recalibration should be carried out.<sup>4</sup>

3.3.2.2 Major changes to the pressure error correction data may then require redefinition of the operational airspeeds presented in the AFM or FMS. Changes to V-speeds will also need to be taken into account during any performance and handling testing that is required as a result of the modification.

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<sup>4</sup> Calibration requirements are discussed in AC 21-40.

### 3.3.3 Performance requirements

3.3.3.1 Modifications that are likely to cause changes to the performance capabilities of an aircraft can be considered from three aspects:

- a. minor but noticeable increase in drag that causes a small decrease in performance
- b. small but noticeable increase in performance
- c. significant change in performance.<sup>5</sup>

3.3.3.2 Where a modification is expected to cause a minor but noticeable increase in drag, which is then likely to result in a small decrement in performance, CASA may accept a reduced testing philosophy to verify the predicted outcome. This would entail the accurate measurement of the decrement as it applies to the most critical performance requirement, followed by the conservative factoring of related requirements based on the first set of test results. Such acceptance would depend on the basic, unmodified, aircraft comfortably meeting all the relevant certification class limits. For example, the maximum stall speed or minimum climb rate requirements stipulated in FAR Part 23 for a normal category aircraft.

3.3.3.3 Where a modification results in a small but noticeable increase in performance, the certification authority may accept a claim of compliance with the performance requirements based on the reduced testing philosophy, provided the applicant does not plan on claiming any extension to flight envelope or performance data. In this case, the original figures would be retained in the AFM even though the modified aircraft would be capable of outperforming them.

3.3.3.4 Significant changes, or any claims for improvement in performance would require a comprehensive retesting of the modified aircraft such that continued compliance with the relevant requirements can be confirmed and accurate data can be provided to the operational pilot via an AFM amendment or FMS.

### 3.3.4 Spinning

3.3.4.1 Single-engine normal, utility and acrobatic category aircraft must meet the various spinning requirements set out in the certification basis (e.g. FAR 23.221 or EASA CS 23.221).

3.3.4.2 Spin flight testing can be an arduous exercise involving elements of elevated risk. For modifications that have limited effect on the flying qualities of the aircraft, the certification authority may accept a claim of compliance based on analysis, as long as the other handling quality requirements, especially the stalling characteristics of the modified aircraft have been tested and been shown to have suffered minimal effect.

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<sup>5</sup> The definitions of the magnitudes that constitute 'small', 'minor' or 'significant' changes would vary with individual cases. In general though, provided defined limits within specific airworthiness clauses were not being threatened, variations of 2 knots or 2% (whichever is greater) may be taken as indicative.

- 3.3.4.3 Notwithstanding paragraph 3.3.4.2, spin flight testing of a modified aircraft is recommended when:
- moments of inertia have changed by more than approximately 5 per cent
  - power available increases by more than approximately 10 per cent
  - the modification introduces major changes to the aircraft's flight control system
  - the modification introduces major changes in control rigging, especially rudder and elevator
  - the modification includes the incorporation of canards
  - the modification introduces major wing changes
  - the modification introduces major changes to the airflow over the aircraft's empennage.

### 3.3.5 Vibration, buffet and flutter

- 3.3.5.1 Flight testing for any modification that is likely to affect the flight characteristics of the aircraft should ensure that compliance with vibration and buffet requirements have not been compromised. This is especially relevant where the modification includes an attachment or a protuberance into the airflow. In these cases, testing should assess both the effect the modification may have on the vibration characteristics of the aircraft overall, as well as the vibratory behaviour of the modification itself. Specialised cameras and other flight test instrumentation may be required if direct observation of the modification is not possible.
- 3.3.5.2 Flutter characteristics should be reassessed after major modifications, particularly if the aircraft structure, the airflow over control surfaces, or the flight control system itself, have been altered.

### 3.3.6 Limit airspeeds and flight envelopes

- 3.3.6.1 When flight testing, the general aim should normally be to check that the modified aircraft continues to meet certification requirements when operating to the edges of the flight envelopes (i.e. weight or CG; airspeed or altitude) originally applicable to the basic aircraft (sometimes known as Limit Basic Airframe (or Limit Basic Aircraft, LBA)). Nevertheless, some modifications may require adjustment to the LBA envelopes as described in the following paragraphs.

#### **Contraction**

- 3.3.6.2 Modifications may affect the flying qualities of the aircraft such that, for continued compliance with the requirements of the certification basis, additional limitations—more stringent than those established for the basic aircraft—must be imposed. For example, certain handling requirements may only be acceptable if the aft limit of the CG range is moved forward, or performance requirements satisfied if weight constraints are applied, or vibration and buffet requirements met if maximum speed restrictions are introduced.
- 3.3.6.3 All limitations associated with a specific modification, or combination of modifications, must be provided in the FMS. In the case of speed limitations, the inclusion of a cockpit

placard is recommended (e.g. Maximum Airspeed when fitted with the ACME Camera Pod – 100 KIAS).<sup>6</sup>

### Expansion

- 3.3.6.4 Modifications, particularly engine changes that allow for substantial increases in performance (as per paragraph 3.3.3.4) may also require expanded operational limits after the results of the flight test program are consolidated. In such cases, the FMS must include all new limits and the cockpit placards should be changed.
- 3.3.6.5 Applicants should also be aware that should a substantial increase in capability be achieved, such that the design cruising speed ( $V_C$ ) is increased, then a revision of the velocity-load factor diagram may be required (e.g. FAR 23.333 and 23.335). In these cases, the applicant should refer to AC 21-12 in order to establish acceptable classification of changes and further processing requirements for the modification.

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<sup>6</sup> See also AC 23-1.

## 4 Flight test methods

- 4.1.1 Any certification flight test program that is to be conducted on a modified aircraft should be completed using the guidance material relevant to the certification basis, or using agreed flight test techniques and data reduction methods of equal engineering rigour.
- 4.1.2 While the same methods and test techniques as the initial flight tests are applicable, there may be scope for simplification in the way in which they are applied. The use of comparative tests is one useful method that can be applicable to the modification of a single aircraft under Subpart 21.M. In these cases, the particular aircraft, which is often already well into the ageing aircraft class, is tested in its unmodified state and the detailed results recorded. The modification is then incorporated and the aircraft subjected to the same flight tests again under, as nearly as possible, the same test conditions. The two sets of results are compared and the effects of the modification defined. Additionally, depending on the projected magnitude of the effects of the modification, the certifying authority may accept testing at the most operationally demanding conditions followed by some extrapolation to other points about an envelope.
- 4.1.3 This comparative method should only be applied in cases where compliance with class limits is not threatened. If doubts about such certification basis requirements exist, then the flight testing of the modified aircraft should be conducted against the specific airworthiness standards and not just the capabilities of the unmodified aircraft.

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May 2015