Certification Memorandum

External Installations on Helicopters

EASA CM No.: CM–21.A-D-002 Issue 01 issued 27 September 2019

Regulatory requirement(s): [CS 27/29 Subpart B, CS 27/29 301/303/305/307/321/337/341/351/501/561/563/571/605/607/613/619/621/623/625/725/727/952/1323/1325/1503/1505/1519/1529
CS 27 Appendix B/C
CS 29 Appendix B

EASA Certification Memoranda clarify the European Aviation Safety Agency's general course of action on specific certification items. They are intended to provide guidance on a particular subject and, as non-binding material, may provide complementary information and guidance for compliance demonstration with current standards. Certification Memoranda are provided for information purposes only and must not be misconstrued as formally adopted Acceptable Means of Compliance (AMC) or as Guidance Material (GM). Certification Memoranda are not intended to introduce new certification requirements or to modify existing certification requirements and do not constitute any legal obligation.

EASA Certification Memoranda are living documents into which either additional criteria or additional issues can be incorporated as soon as a need is identified by EASA.

Log of issues

Issue	Issue date	Change description
Issue 01	27.09.2019	First issue

Table of Content

1. Introduction

1.1. Purpose and scope

The purpose of this Certification Memorandum is to provide specific guidance for certification of external installations on helicopters, for modifications for which CS 27/29.865 is not applicable. It deals with external fixtures (see 1.4 Definitions) and devices that are non-extensive in terms of weight, external surface are and/or volume. Large agricultural kits, external rigid water tanks for fire-fighting operations, collapsible buckets or external platforms used for Human External Cargo (HEC), hoist and cargo hook installations are considered to be outside of the scope of this CM.

Additionally this CM provides guidance to ensure the proper classification of design changes involving external installations and any subsequent modifications to them, either by the original approval holder or through the STC process by a third party.

Examples of external installations to which this Certification Memorandum is applicable:

- External equipment boxes with fixed equipment (fixed mass and CG)
- Cameras
- Searchlights
- Loudspeakers

This CM focuses on the technical aspects to be considered to certify such installations from the structural and flight substantiations points of view. Other technical considerations that could affect these installations (electrical, avionic, environmental, etc.) are not within the scope of this CM.

1.2. References

It is intended that the following reference materials be used in conjunction with this Certification Memorandum:

Reference	Title	Code	Issue	Date
CS 27	Certification Specifications and Acceptable means of Compliance for Small Rotorcraft	[code]	Amendment 6	17/12/2018
CS 29	Certification Specifications and Acceptable means of Compliance for Large Rotorcraft	[code]	Amendment 6	17/12/2018
AC 27-1B	Advisory Circular, AC 27-1B, Certification of Normal Category Rotorcraft		Change 7,	04/02/2016
AC 29-2C	Advisory Circular, AC 29-2C, Certification of Transport Category Rotorcraft		Change 7	04/02/2016
Part 21	Certification of aircraft and related products, parts and appliances, and	Annex I to Commission	Initial issue and	03/08/2012

Reference	Title	Code	Issue	Date
	of design and production organisation	Regulation EU No 748/2012	subsequent amendments	
SIB 2012-06R2	Defective Standard Hardware – MS21042, NAS1291 and LN9338 Self-Locking Nuts, and NAS626 Bolts		Revision 2	28/10/2013
CM—S-002	Application of CS 25.561 (c)(2) 1·33 'Wear and Tear' Factor – Frequent Removal of Interior Structures		Issue 1	14/01/2014

1.3. Abbreviations

AC	FAA Advisory Circular
AFCS	Automatic Flight Control System
APDOA	Alternate Procedures Design Organisation Approval
CAMO	Continued Airworthiness Maintenance Organisation
CS	Certification Specification
Cd	Aerodynamic Drag Coefficient
CG	Centre of Gravity
DOA	Design Organisation Approval
ECS	Environmental Control System
FEM	Finite Element Model
FLIR	Forward Looking Infra-Red
FTI	Flight Test Instrumentation
GM	Guidance Material
GPS	Global Position System
HQ	Handling Qualities
H-V	Height – Velocity Diagram
ICA	Instructions for Continued Airworthiness
IGE	In Ground Effect

IFR	Instrument Flight Rules
MOC	Means Of Compliance
NR	Rotor Speed
NVIS	Night Vision Imaging System
OAT	Outside Ambient Temperature
OEI	One Engine Inoperative
OEM	Original Equipment Manufacturer
OGE	Out of Ground Effect
RFM	Rotorcraft Flight Manual
STC	Supplemental Type Certificate
TC	Type Certificate
VFR	Visual Flight Rules
Vd	Maximum Design speed
Vh	Maximum Speed in Level Flight with Maximum Continuous Power
Vmini	Minimum speed for IFR
Vne	Never Exceed Speed
Vnei	Never Exceed Speed for IFR
Vtoss	Take Off Safety Speed for Category A Helicopter
Vy	Best Rate of Climb Speed

1.4. Definitions

External Fixtures:	As defined in AMC 27/29.865 contained in CS-27 and CS-29 Amendment 6.

2. Background

External installations and subsequent modifications on helicopters are common changes to the initial design of a helicopter to fulfil specific needs of operators. Due to EASA's recurrent certification experience with applicants who are not the original TC/STC holder, in particular erroneous classification of changes and

missing elements in the compliance demonstration, EASA is issuing this CM to aid applicants in the properly classification and certification of these of installations and any subsequent changes to them.

3. EASA Certification Policy

3.1. Change classification and applicant required qualification for first external installation

The applicable rules governing the classification of external installations on helicopters are contained in 21.A.91 of Annex I (Part 21) of Regulation (EU) No 748/2012.
An initial modification to the helicopter type design to install external installations should normally be classified as a major change, as these kind of changes typically fulfil one or more of the criteria described in GM 21.A.91 paragraph 3.3 and related Appendix A to GM 21.A.91, for example:

"iv. Where the extent of new substantiation data necessary to comply with the applicable certification specifications and the degree to which the original substantiation data has to be re-assessed and re-evaluated is considerable"

Note: Specially required to perform the necessary flight tests and structural compliance determinations, potentially including re-substantiation of the fuel tank crashworthiness, emergency egress etc.

It is also considered that a change that potentially alters the Airworthiness Limitations or the Operating Limitations has been shown to have an appreciable effect on the structural strength or the operational characteristics respectively, and therefore it should be classified as a major change.
In particular there may be an effect on life limitations resulting from the new modification or interface parts of the helicopter can also be affected. Additionally performance/handling qualities can be negatively affected which may degrade the operation limitations. These would need to be assessed on a case by case basis.

Note that an assessment of the effect on operational characteristics should take into account whether the helicopter is VFR or IFR certified (see 3.4.4 and 3.4.9) or if it is certified for CAT A operations (see 3.4.18) or for NVIS (see 3.4.19).

The following modifications are considered major change and therefore require the applicant to hold a DOA (or they need to seek Agency agreement for the use of procedures setting out the specific design practice, resources and sequence of activities (AP to DOA) or - in the case of an ELA1 aircraft - for the approval of a certification programme (refer to 21.A.92/21.A.14, and to 21.A.112B respectively), depending of the assessment consequences in terms of handling qualities and performance:
- Utility basket installations
- Agricultural spray installations
- Flotation gear installations
- Nose, Rear or Side mounted camera installations

FLIR or surveillance camera installation are direct examples given in GM 21.A.101 of major non-significant changes.

In case of complete new installations, paragraphs 3.3 & 3.4 of this CM provide guidance and a list of affected structural and flight airworthiness requirements and possible means of compliance.

3.2. Classification of changes to already approved external installations

3.2.1. Reference configuration

Appropriate helicopter configuration management should be exercised by the applicant and the reference starting configuration for certification should be the "already approved basic helicopter + initial external installation" - (for example the basic helicopter + initial Camera/FLIR installation) to be modified, and not the basic helicopter.
It is the responsibility of the applicant to clearly identify in the certification programme the pre and post configuration, regardless of the classification of the change.

3.2.2. Major Change versus STC in case of modifications to an approved external installation

In the case of a major change to an already approved external load installation:

- If the applicant is the original installation certificate holder, an application for a major change is expected.
- If the applicant is not the original installation certificate/approval holder then an application for an STC is expected.

In case of a major change to an already approved STC:

- - If the applicant is the STC holder then a major change to the STC will be issued.
- - If the applicant is not the STC holder then a new STC will be issued. Further considerations regarding demonstration of capability for STCs can be found in GM 21.A.112B.

3.2.3. Consideration of similarity in change classification

In the context of this CM "Similarity" means a compliance demonstration methodology applicable to a new design and based on a previous showing of compliance accepted by the Authority on another similar design. This concept requires access to the original design and compliance data (either being the owner of that data or by having an appropriate agreement with that owner).

In case of similarity between the original approved design and the new proposed design, the degree to which the original substantiation data has to be re-assessed and re-evaluated will be one of the criteria to determine the classification. If this is significant then it is often classified as a major change to the STC or a new STC.

An example of a change to an installation for which some similarity in design exists is the replacement of an external camera/FLIR/Searchlight on an already approved external installation. In this case EASA considers that the extent of the need for new substantiation data for flight test and ground test (including compliance demonstration with xx.241 Ground Resonance and xx.251 Vibration for example), in order to show compliance with the applicable certification specifications and the degree to which the original substantiation data has to be re-assessed and re-evaluated to add or replace the original camera/FLIR is enough in order to classify this as a major change to the STC / new STC.

However EASA can accept, upon request by the applicant, the additional of new camera/FLIR models to existing major changes/STCs as minor changes when the three criteria below are met:

- The same main original fixed structural provisions are kept and are installed in the same location on the helicopter;

- The new camera/FLIR has:

  the same or lower weight;

the same or lower exposed surface area; and

the same or greater ground clearance than the one approved in the initial major change/STC; and

This does not relieve in any case the applicant for a minor change to the STC from performing an appropriate compliance demonstration for the new camera/FLIR, even if the weight/exposed surface are lower than those of the original STC. This includes compliance demonstration with xx.241 Ground Resonance and xx.251 Vibration, and performance/handling qualities amongst other requirements as required.

Establishing a "Similarity" statement might be an acceptable MOC in the case of the original certificate holder or appropriate internal competence in the required domains in order to be able to technically assess and justify such statements. It is considered not possible to perform the necessary technical assessment to propose such MOC to show compliance if the applicant is not in possession of the design and compliance data for the initial original installation.

Other considerations could limit the eligibility of an applicant for an alternative external equipment (e.g. camera/FLIR installation) on an already approved major change/STC. For example the need to properly dispatch the CAW responsibilities after initial approval.

3.3. Structural Requirements

The following are the potential applicable certification specifications (Structures) for external installations:

- Weight and CG: xx.XX.27 xx.XX.29 XX.xx.1519
- Vibration: xxXX.251
- Static analysis: xxXX.301, XX.303, XX.305, XX.307, XX.321, XX.337, XX.341, XX.351, XX.561
- Attachment to Skid landing gear: XX.241, XX.501, XX.571
- Structural ditching and emergency flotation provisions: xx.563
- Fabrication methods: xx.605
- Fasteners: XX.607
- Material strength properties and design values: xx.613
- Special factors: XX.619, XX.621, XX.623, XX.625
- Ground clearance: XX.725, XX.727
- Fuel tank drop test: XX.952(a)(4)
- ICAW: XX.1529
- Never-exceed speed: XX.1503, XX.1505

Based upon the above list of affected CS provisions the following aspects should be considered:

- Weight and CG: XX.27 XX.29 XX.1519
  - The change on the rotorcraft weight and balance should be assessed for the External Fixture and Device.
  - The Applicant should ensure that with the external installation installed on the rotorcraft that the weight and centre of gravity (CG) will remain inside the allowable mass/cg limits during operations. Both the lateral and longitudinal weight and CG should be assessed.
  - The weight and CG of the external installation should be published in the Flight Manual Supplement to allow operators to manage the rotorcraft weight and CG.
  - This could be separated into the weight and CG for the removable parts and for the fixed parts of the external installation.

- Vibration: XX.251
  - Resonance frequencies of the installation should not be in the excitation frequency range of the rotorcraft (both power on and power off NR).
  - Care should be taken when certifying the external installation on multiple variants of the same type to ensure that the rotor speed ranges of all variants are taken into account.

  - Flight Test Authorisation:
    - Natural frequency checks on ground (e.g. impact hammer test, rap test, bang test, bonk test) are usually proposed with the external equipment installed on the aircraft
    - This may be supported also by analysis, and
    - The outcome of the test should be submitted to EASA Panel 1 and Panel 3 before flight test begins.
  - Certification:
    - Instrumentation (accelerometers) should be installed on the external fixture or device during the flight test trials to confirm that no critical vibration levels in flight.
    - Qualitative assessment may also be acceptable depending on the results of the ground test and experience with similar installations.
    - If local vibration is measured, evidence should be provided that this is not damaging to the attachment and local structure. Additional inspections of the attachment structure of the STC and aircraft could be proposed.

- Static analysis: XX.301, XX.303, XX.305, XX.307, XX.321, XX.337, XX.341, XX.351, XX.561,
  - The external installation attachment static analysis should cover the highest inertia loads defined in accordance with XX.337 (i.e. -1.0g to +3.5g unless otherwise substantiated).
  - However, some applicants include crash loads (with ultimate factor of 1), local acceleration measurements or information from the TC holder. (Local acceleration from landing loads may be significant depending on the location of the external installation.).
  - Depending on the external device location and size, aerodynamic loads should be considered in addition to the inertia loads.
  - A simple drag analysis is acceptable with an appropriate conservative coefficient of drag (Cd) assumption based on the shape of the external installation. Data from wind tunnel testing or validated Computational Fluid Dynamics analysis can also be used.
  - For aerodynamic loading, forward flight up to V_D, gust loads and yawing conditions up to V_{NE} or V_H should be analysed.
  - Care should be taken to conservatively combine the aerodynamic and inertia loading as appropriate, for example maximum normal load factor with drag at V_D and aerodynamic loading from the yawing conditions with 1g level flight.
  - Compliance with strength requirements may be demonstrated by test and/or analysis. If used, Finite Element Analysis should be validated by hand calculations or by test.
  - In addition to the local attachment static analysis, the impact of the external installation on the overall rotorcraft loading should be considered in terms of overall aerodynamic and inertia loading.

- Skid landing gear: XX.251, XX.501, XX.571
  - Often applications consider the attachment of the external fixture or device to the landing gear skid cross-tube.
  - In this case the following points should be addressed:
    - Flight loads are introduced, which may cause higher loading or loading in a different direction than that considered during Type Certification. Both static and fatigue consideration of this load on the skid landing gear should be analysed.
    - The behaviour of the landing gear may be modified in the landing phase. This should be evaluated and if significant the impact on the overall rotorcraft addressed.
    - Ground resonance mode may be modified, particularly if the device or fixture is also attached to a hard point on the airframe.
    - Care should be taken to protect the cross-tube against degradation at the attachment or fitting point.

- In general, it is recommended that the attachment points of the skid landing gear to the airframe are used instead of the cross tube.

- Structural ditching and emergency flotation provisions: XX.563
  - If applicable, an assessment of the possible adverse effects that the external installation may have on ditching and emergency flotation should be performed:
    - The installation should be positioned to avoid interference with the floats that may prevent their proper deployment and functioning.
    - Likely damage to the rotorcraft structure at water entry due to the external installation should not compromise the flotation, capsize resistance or cabin egress behaviour of the rotorcraft

- Fasteners: XX.607
  - Standard Fasteners:
    - Several manufacturers have received numerous reports of defective standard hardware installed on different areas of their products.
    - EASA has issued a Safety Information Bulletin 2012-06R2 containing recommendations on the use of standard hardware, applicable to MS21042, NAS12914 and LN9338 self-locking nuts and Certification Memo CM-S-003 on the subject of standard fasteners in general.
    - The use of standard fasteners in the external installation should be take into account the guidance of the above publications.

- Fabrication methods: XX.605 / Material strength properties and design values: XX.613
  - External installations may require new attachment points on the rotorcraft airframe. The determination of the design allowable for these attachments must be in accordance with XX.613.
  - In some cases the attachment may include the use of inserts in sandwich panels. The determination of the design allowable for the insert assembly must consider the variability of the installation process. The process for the installation of the insert should be clearly defined and shown to produce a consistently sound structure in accordance with XX.605.

- Special factors: XX.619, XX.621, XX.623, XX.625
  - A factor of 1.15 should be applied to fitting, means of attachment and bearing on the joined members for fittings whose strength is not proven by limit and ultimate load tests.
  - If the external fixture or device is frequently removed, a “wear and tear” factor of 1.33 is recommended (see Cert Memo CM-S-002) to be applied.

- Ground clearance: XX.725, XX.727
  - AC 27-1B and AC 29-2C provide guidance for different types of external installations (see Annex), which is described in AC29.727 (b)(2), AC29 MG 6 (b)(8) External Devices and in AC 27.727(b)(2), AC27 MG 6 (b)(8) External Devices .

- Fuel tank drop test: XX.952(a)(4)
  - For rotorcraft with XX.952 included in the certification basis, it is advisable that the external fixture or device is not located underneath the fuel tank region.
  - Otherwise, it should be demonstrated that the STC fixture or device is free of projections or other design features that are likely to contribute to the rupture of the fuel tank
    - Compliance can be demonstrated by drop test
    - Compliance can also be demonstrated by simulation (appropriate support from the TC holder may be necessary).

- ICA: XX.1529
    - ICA should consider the new components and any region of the rotorcraft that is affected by the external installation.

3.4. Flight Tests

3.4.1. Introduction

When a certification flight test plan for an external installation is prepared, the applicant should consider the following areas of investigation and determine the most appropriate means of compliance and flight test methodology.

3.4.2. Airspeed and Altimeter Calibration (CS 27/29.1323, CS 27/29.1325)

The effect of the external installation on the airspeed and altimeter calibration is the first area to be assessed. As a matter of fact, if an external installation has the potential to impact the airflow around the pitot and/or the static port, the applicant should address this area before proceeding any further with the flight test activity, as the results of all the subsequent tests may be affected by the errors induced by the altered calibration.
The material contained in FAA AC 27-1B and AC 29-2C provides a good guidance on the test methodologies available for airspeed calibration.
In addition, even if not directly quoted by the AC material, GPS calibration has been accepted by EASA for substantiation against the airspeed calibration requirements for external installations.

3.4.3. Flying Characteristics

The extent and depth of the necessary investigation in order to determine the effect on flying characteristics of an external installation is strongly dependent on:

- The drag and mass of the external installation, and
- The kinds of operation rotorcraft is approved for (VFR or IFR).

The mass characteristics of external installation may require, in some cases, a change in the rotorcraft longitudinal and/or lateral CG envelopes. Possible cases include:

- The extension of the lateral CG envelope for asymmetrical installations with respect to the helicopter centre line. This case is not an easy one, since it could drive additional substantiation for structural strength, fatigue and load spectrum due to the revised CG envelope, not to mention all other flight characteristics (including performance) that are normally not investigated when the CG envelope is not altered.
- The reduction of the longitudinal CG envelope due to weight and balance constraints induced by the mass of the external installation itself.

This should be ascertained before progressing any further in the development of the certification flight test plan in order to ensure a timely identification of the correct weight and CG envelope for the change and therefore the most appropriate test conditions to be flown for each area under investigation.

The external installation drag characteristics should be adequately estimated in order to achieve a preliminary assessment of the overall change of drag and any asymmetry introduced in the rotorcraft by the installation.

The target kind of operation is very important as the handling qualities requirements for IFR are more stringent than those applicable to VFR.

Flying characteristics testing is expected to include at least a low altitude assessment and an assessment at the maximum altitude for which certification is sought for the external installation. For additional info on the extrapolation and interpolation criteria refer to the paragraph 45 of the relevant AC material (AC 27-1B and AC 29-2C).

3.4.4. VFR approved rotorcraft

For a VFR approved rotorcraft the following are the main areas of investigation:

- Controllability (CS 27/29.141, CS 27/29.143)
- Longitudinal and Lateral Stability (CS 27/29.171, CS 27/29.173, CS 27/29.175, CS27/29.177)
- Dynamic Stability (for CS 29 Category A only)
- Roughness (CS 27/29.251)

All the above areas of investigation are key elements in establishing the envelope within which the external installation can be approved.

3.4.5. Controllability

Controllability is likely to be affected whenever the external installation overall drag is significantly changed with respect to the drag of the clean rotorcraft configuration. A significant drag increase may result in a reduction of the longitudinal cyclic or pedal margins as the VNE (Power ON, OEI or Power OFF) is approached, due to the need to fly, for the same combination of altitude, weight and CG, at different attitudes with respect to the clean configuration. In these cases, the controllability may become a factor in establishing the Vne Power ON or Power OFF, along with the vibration requirements (CS 27/29.251). Typically, max weight and aft CG conditions are the most critical for this type of testing. For the power off case, the test should be performed with the most critical rotor rpm.

Low speed controllability may be affected if the external installation is such that a significant amount of drag is placed in the front of the rotorcraft with a significant moment arm with respect to the longitudinal CG or the external installation wake interacts with the tail rotor. For conventional tail rotor configurations, the effects on the low speed controllability (typically the tail rotor control margins) are a function of the Gross Weight (GW)/sigma and therefore they are less evident at low density altitude. Therefore, if the low speed controllability cannot be ruled out from the list of the change affected areas, the applicants should investigate it in altitude conditions (for a CS-27 at 7000 ft density or up to the maximum take-off and landing altitude for a CS-29 and CS-27 Category A).

Whenever the assessment of cyclic and collective margins is the objective targeted, very simple instrumentation may be sufficient to the scope of testing (even a tape fixed to some part of the cockpit that is taken as a reference may be used).
However, when the pedal position is the subject of the investigation, simple recording methodologies may not be sufficient and some basic FTI is necessary.

3.4.6. Longitudinal and Lateral Stability

Longitudinal and lateral stability have to be investigated at the most critical weight and CG combinations. Typically, as it applies to the controllability, but this is not a general rule, max weight and aft CG are for most rotorcraft the most critical conditions. The applicant has to confirm this in its certification flight test plan.

3.4.7. Dynamic Stability

Dynamic stability is only a requirement for CS-29 rotorcraft to be approved for Category A. Typically, critical weight and CG conditions for dynamic stability are not the same as for static stability as the inertia momentum around the body axis play a role in the reaction to an external gust or disturbance.

3.4.8. Roughness (CS 27/29.251)

Roughness testing is to be carried out to ascertain the level of vibration of the external installation subject of the change and of the entire rotorcraft. Current requirements and certification policies require the roughness to be tested in different flight conditions and up to 1,11 of the target Vne Power On and Power OFF for the installation. Conditions to be tested include hover, transition to forward flight, level flight at Vh, flight at Vne (with 30 degrees angle of bank turns), 1,11 Vne Power on and Power off, climbs, descents.
For the external installation, some form of instrumentation is required to measure the vibration level and ensure that it complies with the limits provided by equipment provider. For the effects on the rotorcraft, instead of dedicated instrumentation to monitor the vibration level, qualitative vibration scales may be used by the test crew.

3.4.9. IFR approved rotorcraft

Flying Characteristics requirements for rotorcraft that are IFR approved are more stringent and, in some cases, this results in the definition, for the basic aircraft, of a dedicated envelope for IFR approval in terms of airspeed (Vmini and VNEi) and/or other crew controllable variables. Applicants should carefully consider the intended final target in terms of approval. This is typically the case of external installations on IFR approved rotorcraft where the applicants aim is to show that the rotorcraft remains compliant with IFR requirements with the external installation fitted and operational or fitted but not operational. In other cases, the installation may require the establishment and definition of a different IFR envelope.

Longitudinal and lateral directional stability testing for an IFR rotorcraft require additional test conditions to be assessed and recorded (as, for example, static stability along the maximum approach path angle for which the rotorcraft is approved) and consideration of two additional characteristics that qualify the rotorcraft handing qualities:

- Stick forces (force stability), and
- Return to trim.

To correctly qualify and document these two characteristics some dedicated flight test instrumentation is normally required.
Return to trim may be difficult for trim points around the Vmini and therefore a careful investigation is required.

Also, the dynamic stability requirements are more detailed than the damping characteristics required in CS 27/29 Appendix B paragraph VII are given as a function of the frequency of the induced motion. If the external installation is asymmetric with respect to the centre line, at least the lateral directional modes should be investigated. However, when the rotorcraft does not embody an AFCS providing decoupling characteristics, also the modes of oscillations around the other axis should be investigated.

For external installations on a rotorcraft approved for both VFR and IFR, showing compliance with IFR static and dynamic stability requirements has been accepted by EASA as a means to show compliance with VFR requirements as well. This approach may not be a viable and acceptable solution if the two envelopes (VFR and IFR) are different.

3.4.10. Performance

When considering the impact of an external installation, the following regulatory performance need to be considered:

- Hovering,
- Climb,
- Glide, and

- H-V diagram

The impact of the external installation on hovering and climb performance should be determined over the entire envelope for which certification with the external installation is required. It should be noted here:
- The available power that is one of the two contributing factors behind climb and hovering performance, determination depends on the density altitude, may be “limited” either by the transmission or by the engine ratings;
- The climb efficiency is normally not a constant; and
- The minimum installed engine power (sometimes referred as minimum spec engine) should be known in order to perform a detailed assessment.

TC holders have good performance prediction tools that are validated through a significant amount of data collected in different weight and CG configurations and ambient conditions. The same tools and supporting data are not available to STC applicants who first have to ascertain if a given external installation is likely to impact regulatory performance. Whilst this may be carried out with some basic techniques for the climb performance, it may be significantly more challenging for hovering and H-V diagram.

Wind conditions are an essential element in performing performance tests as a lack of strict control of the required wind conditions (below 3 kts) can easily invalidate the results obtained. Therefore applicants should implement methods to control the wind speed and direction when a flight test plan for performance is proposed. Another element to be considered is the amount of power that is absorbed by the accessories (as electrical equipment or ECS (if installed)). A correct understanding of the power adsorbed is of paramount importance, in particular when data is compared to substantiate the effects of external installations on regulatory performance.

Details on the flight test methodologies to be applied for determining the impact on performance can be found in the relevant paragraphs of the AC material (AC 27-1B and AC 29-2C).
Within this CM the focus is on some tips that can be useful when a STC applicant is approaching the relevant testing.

3.4.11. IGE and OGE hovering performance (CS 27/29.45 and CS 27/29.49)

In most of the cases, STC applicants cannot access the installed minimum spec engine data, unless they have an agreement with the TC Holder. Under these conditions, the IGE and OGE hover performance impact determination may present some practical difficulties and the comparison of flight test data gathered with a normal engine with the ones published in the RFM that are obtained without a minimum spec engine power is not a valid approach. In the vast majority of the cases the only viable approach may be a comparison between the clean configuration and the modified one (this approach is often referred to as “back to back” approach, see also the “additional considerations paragraph for the power required to hover. It is highly recommended that this approach is implemented by using generalised variables so that, with an appropriate choice of weights (obtainable through the use of appropriate combination of ballast and fuel) and ambient conditions (Pressure Altitude and OAT), generalised power required to hover IGE and OGE curves are generated for both the configurations. Before collecting the data, it is highly recommended that engine power assurance check margins are verified so that enough engine power is available to explore an adequate range of generalised weight. Once the two curves (clean and modified configurations) have been determined from the experimental data, a good estimation can be performed of the impact on hovering performance and a penalty factor (if any) that is applicable to the entire hovering envelope can be derived.

3.4.12. Climb Performance (CS 27/29.65 and CS 27/29.67)

Before preparing the test plan for climb performance, some consideration is necessary to ascertain if the external installation is so “intrusive” that a change in the best rate of climb airspeed (Vy) is expected.

In the absence of other analytical methods, a comparison between the power required for level flight between the clean and modified configuration performed at an appropriate number of altitudes may provide a useful tool to assess the overall effect of the installation and confirm if Vy is unaffected.

As far as the minimum spec engine is concerned, similar considerations to those applicable to hovering performance apply for climb performance. Therefore, the comparison at selected conditions may result in the only approach that is available.

When the climb performance comparison between the clean and modified configuration is made, it is strongly recommended to select a number of pressure altitudes at which to perform the tests that cover the entire envelope and to use the correct data reduction methodologies to compare the results obtained. Consideration should be given to the areas of the envelope where the rotorcraft is transmission limited and engine limited.
The conventional saw tooth method and the associated reduction methodology have been proved to be very useful to the scope. As a general tip, the shorter the altitude interval on which the climb test is carried out, the more precise are the results that can be obtained.

OEI climb performance (see CS 29.67) are very important for:
- CS-27 and CS-29 Category A rotorcraft as they impact the first and second segment of the climb procedure flown at Vtoss and Vy and
- For CS-29 Category B rotorcraft with more than 9 passenger seats, as they are one contributing factor limiting the take-off weight.

Therefore, for multi-engined rotorcraft, selection of the appropriate OEI conditions to be tested is of paramount importance at the beginning of the programme.
Climb performance are normally to be flown at forward CG at which a greater frontal areas is expected during the climb.

3.4.13. H-V diagram (CS 27.79, CS 29.89)

The impact of an external installation on the H-V diagram is difficult to predict as the diagram is made up of different parts that are demonstrated with different techniques during flight tests. Also, a lot depends on the level of conservativeness that the Type Certificate Holder included in the RFM published diagram.
An analytical preliminary estimation of the new H-V diagram may need special engineering tools which are likely to be not available to the applicant (if they are not the type certificate holder). However, the following general considerations can be made:

- If an impact on the hovering performance has been already substantiated as part of the hovering performance assessment, then it is likely that the high and low hover points of the diagram are impacted.
- If a significant increase in drag is confirmed, then it is likely that “the knee” of the diagram moves forward and the low altitude/high speed portion of the diagram is increased.

If flight testing is carried out for the H-V diagram the following is to be taken into account:

1. For a CS/FAR 27 rotorcraft, the diagram is required up to 7000 ft density altitude and therefore is normally presented as a single diagram, valid up to 7000 ft density altitude and for maximum take off weight (with the exemption of the high hover point for which the maximum weight of hover OGE is accepted). In such a case the impact determination requires testing in the same ambient conditions. However, the applicant may propose alternative means of compliance with testing at a different altitude.
2. For a CS-29 rotorcraft, the diagram is presented as a function of the weight and density altitude for all the altitudes for which take off and landing operations are allowed. This may allow more “freedom” in the

selection of the ambient conditions. However, the results have to be valid up to the maximum take off and landing altitude for Category A rotorcraft.

3. For a multi engine rotorcraft, when the failure of the first engine is carried out the live engine power has to be at the minimum installed power for the ambient conditions. If the minimum installed power is not available, then a "back to back" approach may be proposed.

In the case of single engine or Cat B multi engine helicopters, while determining the new H-V diagram, particular attention should be given to ensure that sufficient airspeed margins remain along the normal take off profiles as published on the RFM. In case this is not anymore ensured, a new take off procedure (and related performance) is to be established for compliance with CS 27.51 and CS 29.63(c).

3.4.14. Glide Performance (CS 27.71 and CS 29.71)

If the installation produces a drag increase at medium and high speed, glide performance are also affected. In particular, if the climb performance is reduced, the glide angle is expected to increase at any speed, as the rate of descent in autorotation is expected to increase.

Glide angle should be determined at the maximum weight altitude sought for certification up to the maximum density altitude sought for certification.

3.4.15. Human Machine Interface and Crew Workload (CS 27/29.771, CS 27/29.773, CS 27/29.1301, CS27/29.1309, CS 27/29.1523)

In case of external installations in the front part of the helicopter, the effect on pilot external view should be evaluated for compliance to CS 27/29.773. The evaluation should encompass all the manoeuvres appropriate to the type, with particular regard to take off, landing and low height manoeuvres. For night operations, in case the installation includes reflecting surfaces, the absence of reflections that could impair the safe conduct of operations should be ensured. Also, the landing lights or other installed lights may be totally or partially obscured to the extent that night operations may be affected.

In addition, most external installations affect the cockpit and/or the cabin configuration with additional panels and controllers. These additional equipment need to be evaluated for:

- readability under all the possible flight conditions,
- colour coding consistency with the remainder of the cockpit and CS 27/29.1322 requirements,
- glares and reflections that can be introduced during night operations,
- the logic used to annunciate failure cases (when applicable), and
- the impact on the external field of view.

The ability of the flight crew to reach the control panels is another factor to be evaluated as it is essential to establish the minimum crew for the external installation to be operated.

3.4.16. AFCS

Whenever the AFCS is part of the rotorcraft basic configuration, one of the key element in the development of a flight test plan is the determination of the AFCS configuration necessary for flying characteristics testing. Typically, during type certification, most manufacturers demonstrate the rotorcraft capability to cope with the most common "first" failure of the AFCS (loss of one lane, etc...) so that, with the AFCS in degraded mode, VFR or IFR requirements are still met in the original envelope or in a reduced envelope, as applicable. The applicant seeking approval for an external installation should follow the same approach. This implies that, when performing testing for an external installation, the correct AFCS configuration has to be selected in order to be consistent with the assumptions made at the time of the original certification.

If the external installation has significant asymmetrical drag characteristics, consideration should be given to the effect this may have on the AFCS performance, in particular when upper or navigation modes are available.

If an AFCS is not part of the basic configuration but it is available as an optional kit, the effect of the external installation should be considered as well unless the external installation is declared incompatible with the AFCS kit.

3.4.17. Extrapolation criteria

Extrapolation of the results beyond the extrapolation criteria laid down within the FAA AC 27-1B and 29-2C material are not accepted and may result in the EASA approval being granted for a reduced envelope with respect to the basic rotorcraft.

3.4.18. Category A

The assessment of the impact of external installations on Category A limitations and associated performance may require a deep knowledge of the methodology used by the Type Certificate Holder to derive the procedures, the associated limitations and the regulatory performance. Therefore it is difficult to provide any general guidance.

However, at least the following aspects need to be taken into consideration when preparing a flight test plan for an external installation:

1. The drag associated with the external installation. If the external installation drag reduces the OEI climb performance:
- The climb rates of the first and second segment are affected.
- If the climb rate reduction is such that it erodes the minimum requirements laid down in CS 29.67, then a take off weight reduction is necessary.
2. The external installation may impact the external field of view that is used by the crew during normal and emergency conditions. Many procedures use external cues that the crew can see through the windshield and/or the chin window. External installations that reduce the external view through these windows require careful evaluation.
3. External installations may partially obscure the landing lights and therefore make a procedure not flyable at night.
4. The external installation may affect the handling of the helicopter in a specific manoeuvre (this may happen when, for instance, the installation alters the weight and CG envelope or when an asymmetric drag is such that the procedure cannot be flown with the required precision and workload) or reduces the ground clearance (this may be a factor in a rejected take-off). Under these cases an assessment has to be included in the certification flight test plan to determine if a given procedure has to be considered incompatible with the installation.

3.4.19. NVIS approval

External installations may impact the NVIS approval for the following main three reasons:

A) They may create reflections either in the cockpit or in the cabin when the other external lights are operated;
B) If they are source of light, the light they emit may reflect on the rotorcraft structure or other kits or not be compatible with the NVIS approval; or

C) Cockpit/cabin control panels (in case they are installed) may be light emitting sources that may not be NVIS compatible or their position/intensity may require reassessment of the NVIS approval.

For more information on this topic refer to the EASA Certification Memorandum CM-FT-001.

3.4.20. Ground Clearance and Slope Landings

The ground clearance may be affected and therefore consideration should be given to this issue when presenting the certification plan. It may not be possible to test in flight the ground clearance and therefore some means should be developed by the applicant to reduce the risk of damage.
The slope landing envelope should also considered to ascertain that no problem exists within the envelope already certified by the TC Holder.

3.4.21. Rotorcraft Flight Manual Supplement

As a general principle, the RFM Supplement should only include the differences with respect to the basic RFM of the rotorcraft on which the installation is embodied. Also, the STC applicant is recommended to follow the layout of the basic RFM to allow flight crew to easily retrieve the information they need.
The Rotorcraft Flight Manual Supplement should include at least the following information:

1. Limitations (Minimum Crew, Kinds of Operation, envelope within which the external installation is approved (Vne, Pressure Altitude vs OAT), limitations for the use of the installation (if any)….).
2. Normal Procedures
3. Emergency Procedures. It is recommended that a review of the basic rotorcraft emergency procedure is carried out to ascertain the ones that are impacted by the installation.
4. Performance.
5. Weight and Balance.

3.4.22. “Back to Back” approach

This approach can be a viable way forward if it is used for performance determination (climb and hover performance, power required for level flight, H-V diagram) when the minimum spec engine is not available and an alternative method is to be implemented. It should however be noted that in order to obtain sound results, the comparison has to be made at the most critical conditions for the testing to be carried out and under a strict control of the critical parameters affecting the test results (weight, airspeed and CG and, as much as possible, ambient conditions). In addition, care should be exercised that the test conditions match the envelope for which approval is sought.

The same approach is not encouraged when HQ testing is considered as there is no possibility to justify that a difference in terms of handling qualities reported under given conditions is representative of the most critical conditions for the specific HQ test. In other words there is no recognised methodology to assess the effect of weight, CG, altitude, OAT on the handling qualities.

On the other hand, a demonstration at the most critical condition is already enough to show compliance with the applicable requirements without requiring additional testing effort based on comparison of the data.

3.4.23. Use of other applicants (including TC holder) approved data

If use of other applicant’s data is made, this should be carried out through an agreement (as per Part 21A.113 (b)) with the original data owner in order to allow the STC applicant to access not only the data but also the methodology that was used to produce it. This will also ensure that all the necessary elements to properly address any continued airworthiness issues are available.

If an agreement is not available, the STC applicant flight test personnel competence and experience should be such that correct interpretation and use of this data is made.

3.4.24. Icing Approval

For rotorcraft approved for full or limited icing, consideration should be given to the effect the external installation has on producing ice under icing conditions. External installations are normally assessed during the icing test campaign for the ice accretion that may affect rotorcraft performance or become a threat in case of shedding.
If no testing or appropriate analysis based on icing tunnel testing is carried out, the external installation should be declared as incompatible with icing operations.

3.4.25. Ground Resonance

If the external installation is attached to the landing skid, it may affect the ground resonance characteristics of the rotorcraft. Verification of the ground resonance characteristics require co-ordination with structural dynamics specialists. Simple qualitative checks performed with manual excitation not supported by a thorough analysis are unlikely to help finding all the potential instability cases.

3.4.26. Effects on fuel consumption

Although the fuel consumption is not a regulatory performance data, it is an essential element in flight planning. Some external installations have the potential to alter it in a significant way. Under these conditions, applicants are encouraged to determine the detrimental effect on fuel consumption and include it in the non-approved part of the RFM Supplement.

3.4.27. Flight Test Category

Appropriate guidelines for the classification of the flight tests part of a certification program can be found in the Appendix XII to Part 21. It is worth noting that for each area of investigation that belongs to a given test plan has to be correctly classified and the different categories that are likely to occur within the same test plan are established.
Additional guidelines and examples are provided in the FAQ published on the EASA website: (https://www.easa.europa.eu/the-agency/faqs/rotorcraft).

3.4.28. Flights carried out outside of the RFM approved envelope

Some flight test points requires the rotorcraft to fly outside of the RFM limitations (typical example are the flights up to 1,11 Vne Power ON and Power OFF). In such cases, the applicant, in agreement with the CAMO supporting the activity, has to put in place all the actions required by the rotorcraft maintenance manual to restore, at the end of the testing, the aircraft to an airworthy condition before the Standard Certificate of Airworthiness is granted.

4. Who this Certification Memorandum affects

TC Holders, DOA and APDOA for an approval of major changes and STCs, concerning external installations on helicopters when:

- CS 27.785/CS 29.785 is not applicable
- External installation is non-extensive in terms of weight, external surface and/or volume.

5. Remarks

1. Comments regarding this EASA Certification Memorandum should be referred to the Certification Policy and Safety Information Department, Certification Directorate, EASA. E-mail CM@easa.europa.eu.

2. For any question concerning the technical content of this EASA Certification Memorandum, please contact:

   Name, First Name: ANGULO-MANSO, Jose Miguel

   Function: PCM VTOL

   Phone: +49 (0)221 89990 4093

   E-mail: Jose-Miguel.Angulo-Manso@easa.europa.eu