

SPECIAL CONDITION

RPAS Flight Control Systems

Doc. No.: SC-RPAS.FC

Issue : 2

Date : 18/07/2017

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SUBJECT	: RPAS Flight Control Systems
CERTIFICATION SPECIFICATIONS	: CS-VLA / CS-VLR
PRIMARY PANEL	: Panel 04 (Hydromechanical Systems)
SECONDARY PANELS¹	: Panel 01 (Flight and Human Factors), Panel 03 (Structure), Panel 05 (Electrical Systems), Panel 06 (Avionics).
NATURE	: Special Condition

Statement of Issue and Background

1. PURPOSE AND SCOPE

The Certification Specifications for Remotely Piloted Aircraft Systems (RPAS) are currently under development by the Joint Authorities for Rulemaking of Unmanned Systems (JARUS).

This working group starts from using the Certification Specifications for very light fixed and rotary wing aircraft (i.e. CS-VLA and CS-VLR). These products normally comprise simple, conventional and unpowered flight control systems (e.g. control cable-based, Push-Pull rods or Flexball-cables, etc...). Current RPAS products on the other side are equipped with highly integrated and complex flight control computer, smart flight control actuator and open-loop/closed-loop flight control laws allowing full autonomous flight director and auto-land/take-off functionalities.

Therefore, EASA sees the necessity to raise a special condition to address airworthiness requirements for these RPAS specificities.

When assessing compliance to issue 1 of this special condition with industry, it was deemed necessary to provide further guidance material for special condition article SC-RPAS.FC.1329(g). Thus, a second version of this special condition has been issued with an Acceptable Mean of Compliance added in a dedicated paragraph (AMC-RPAS.FC.1329(g)).

2. REFERENCES

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

Reference	Title	Issue	Date
AC 25.672-1	Active Flight Controls	-	15/11/1983

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Reference	Title	Issue	Date
E.Y013-01	EASA Policy statement on airworthiness certification of Unmanned Aircraft Systems (UAS)	-	25/08/2009
CS-AWO	Certification Specifications for All Weather Operations	Latest	-
CS-VLA	Certification Specifications for Very Light Aeroplanes	Latest	-
CS-VLR	Certification Specifications for Very Light Rotorcraft	Latest	-
SC-RPAS.1309-01	Special Condition - Equipment, systems, and installations	Latest	-
SC-RPAS.ERC-01	Special Condition - Emergency Recovery Capability	Latest	-

3. SPECIAL CONDITION

The RPAS flight control system comprises sensors, actuators, computers and all those elements of the RPAS necessary to control the attitude, speed and trajectory of the RPA. The flight control system can be divided in two parts:

- **Flight Control Computer:** A programmable electronic system that operates the flight controls in order to carry out the intended inputs and the emergency recovery capability.
- **Flight Controls:** sensors, actuators and all those elements of the RPAS (except the flight control computer), necessary to control the attitude, speed and flight path of the RPA

As detailed in paragraph 1, for fixed wing and rotary wing RPAS, CS-VLA and CS-VLR do not contain adequate safety standard to cover all aspect of RPAS flight control systems certification. In accordance with Part 21A.16B(a) (1), the EASA team consider that a special condition is needed to address these.

This special condition and the related AMC are applicable to any RPAS:

- For which a type certification is requested,
- For which the kinetic energy assessment in accordance with section 6 of the EASA policy E.Y013-01 results in an initial certification basis according to CS-VLA or CS-VLR, and
- With no occupant on board.

The requirements in Appendix 1 are applicable, in addition to specific airworthiness requirements of the applicable type certification basis, to any equipment or system part supporting the flight control system function in the Remotely Piloted Aircraft System (RPAS):

For fixed wing RPAS, the certification baseline is assumed to be CS-VLA.

For rotary wing RPAS, the certification baseline is assumed to be CS-VLR.

Appendix 2 is providing Acceptable Means of Compliance for Appendix 1 requirements.

Appendix 1

Special Condition

Appendix1 - Subpart I

Requirements applicable to Fixed Wing and Rotary Wing RPAS

Replace applicable CS article 679 by:

SC-RPAS.FC.679 Control system locks

If there is a device to lock the flight controls

- (a) There must be means to give unmistakable warning to the pilot when the lock is engaged
- (b) There must be a means to warn the ground staff when the device is engaged;
- (c) The device must have a means to preclude the possibility of it becoming inadvertently engaged in flight.

Replace applicable CS article 683 by:

SC-RPAS.FC.683 Operation test

- (a) It must be shown by operation tests that, when the controls are operated with the system loaded as prescribed in sub-paragraph (b), the system is free from
 - (1) Jamming;
 - (2) Excessive friction;
 - (3) Excessive deflection;
 - (4) Excessive freeplay.
- (b) The prescribed test loads are
 - (1) For the entire system, loads corresponding to the limit air loads on the appropriate surface, or the maximum loads and torques generated by the actuating system, whichever are less; and
 - (2) For secondary controls, loads not less than those corresponding to the maximum servocontrols or actuators force.

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Add requirements:

SC-RPAS.FC.1328 Flight envelope protection

(a) Flight envelope protection must be implemented in all modes defined in SC-RPAS.FC-1329 in the flight control system as follows:

(1) Characteristics of each envelope protection feature must be smooth and appropriate to the phase of flight and type of manoeuvre.

(2) Limit values of protected flight parameters must be compatible with:

(i) RPA structural limits,

(ii) Required safe and controllable manoeuvring of the RPA,

(iii) Prevention of hazardous and catastrophic failure conditions,

(iv) RPA rotor rotational speed limits if applicable,

(v) Blade stall limits if applicable,

(vi) Engine and transmission torque limits if applicable.

(3) For fixed-wing RPA, the minimum speed allowed by the flight control system must be compatible with the margin specified in subpart B for minimum demonstration speed (if defined).

(4) The RPA must respond to intentional dynamic manoeuvring within a suitable range of parameter limits.

(5) Dynamic characteristics such as damping and overshoot must be appropriate for the manoeuvre and limit parameter concerned.

(6) Characteristics of the flight control system must not result in residual oscillations in commanded output due to combinations of flight envelope protection limits and any other flight control internal limit.

(b) When simultaneous envelope protection limits are engaged, they must not result in adverse coupling or adverse priority.

(c) The limits and prioritization of the flight envelope protection provided by the flight control system must be clearly and comprehensively defined

Add or replace applicable CS article 1329 by:

SC-RPAS.FC.1329 RPAS Flight Control System

See AMC-RPAS.FC.1329 (g), (i) and (j)

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(a) The modes of control of the RPA must be defined in one or more of the following categories, which may be selected at any time in flight by the flight crew:

(1) Automatic: In this mode the RPA attitude, speed and flight path are fully controlled by the flight control system. No input from the Ground Control Station (GCS) is needed other than to load or modify the required flight plan.

(2) Semi-automatic: With this type of control the flight crew commands outer loop parameters such as altitude, heading and air speed. The flight control system operates the RPA controls to achieve the commanded outer loop parameter value.

(3) Manual: In this mode, the flight crew provides direct and continuous control of the RPA, acting as an element of the RPA control inner loop by directly manipulating control force effectors and engine power setting and employing visual line-of-sight cues, video feedback or other sensory feedback, in combination or individually. The RPA control system may still be augmenting stability but the intended trajectory or intended flight parameters of the vehicle are completely dependent upon continuous control inputs from the operator.

(b) The flight control system must be designed so that a crew of average skill can operate the RPAS with acceptable workload,

(c) The flight control system must apply limits to manoeuvres to keep the RPA in the flight envelope as defined in SC-RPAS.FC 1328.

(d) The crews must have the opportunity to intervene at any time during the flight to manage safe control of the RPA, except:

(1) In case of total loss of data link,

(2) For fixed wing RPA, during landing phase after reaching the decision point,

(3) Reserved,

(4) For RPAS with an automatic take-off capability, during initial phase before achieving the minimum safe flight parameters,

(5) For RPA designed to be recovered by parachute, during the landing phase under parachute,

(6) For rocket or catapult assisted take-off RPA, during the launch phase before reaching the limits defined by the applicant.

(e) The system must be designed so that any adjustment, within the range of adjustment available to the flight crew, cannot produce hazardous loads on the RPA or create hazardous deviations in the

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flight path under any flight condition appropriate to its use, either during normal operation or in the event of a malfunction, assuming that corrective actions begins within a reasonable period of time.

(f) Reserved

(g) There must be protection against adverse interaction of integrated components, resulting from a malfunction.

(h) There must be a means in the GCS to indicate to the flight crew the active mode of control of the flight control system. If semi-automatic mode or manual mode is engaged, a specific indicator must be activated in clear view of the flight crew

(i) Use of active flight controls for load alleviation, stability augmentation, and/or flutter suppression must comply with the control system stability requirements. (See AMC associated to SC-RPAS.FC 1329.i)

(j) The flight control system must have pre-flight self-tests and a comprehensive set of monitoring functions available and operating during all phases of flight. (See AMC associated to CS.RPAS 1329.j)

(k) Data exchanged between components of the flight control system or received from components external to the flight control system must be verified for the integrity of the information prior to use. Information received from external sources must be verified within appropriate rate of change and range boundaries for the appropriate phase of flight before using in the computations

(l) The flight crew must be alerted by suitable means if any change in envelope limiting or manoeuvrability is produced by single or multiple failures of the flight control system not shown to be extremely improbable.

Appendix1 - Subpart II**Requirements applicable to Fixed Wing RPAS only**

Replace applicable CS article 677 by:

SC-RPAS.FC-FW.677 Trim systems

If a trimming system is installed the following must be applied:

- (a) Reserved
- (b) Trimming devices must be designed so that, when any one connecting or transmitting element in the primary flight control system fails, adequate control for safe flight and landing or for emergency recovery according to SC-RPAS.ERC-01 is available.
- (c) Tab controls must be irreversible unless the tab is properly balanced and has no unsafe flutter characteristics. Irreversible tab systems must have adequate rigidity and reliability in the portion of the system from the tab to the attachment of the irreversible unit to the aeroplane structure.
- (d) The Flight Control System (FCS) must trim the RPA in such a manner that a maximum of control remains and that dynamic characteristics and safety margins are not compromised.
- (e) It must be demonstrated that the aeroplane is safely controllable and that the flight crew can perform all the manoeuvres and operations necessary to effect a safe landing following any probable powered trim system runaway that reasonably might be expected in service, allowing for appropriate time delay after pilot recognition of the trim system runaway. The demonstration must be conducted at the critical aeroplane weights and centre of gravity positions.

Replace applicable CS article 699 by:

SC-RPAS.FC-FW.699 Wing flap position indicator

Where a RPA is equipped with wing flaps, there must be a wing flap position indicator in the Ground Control Station (GCS).

Replace applicable CS article 701 by:

SC-RPAS.FC-FW.701 Flap interconnection

The RPA must be shown to have safe flight characteristics and structural integrity with any combination of extreme positions of individual movable flap surfaces not shown to be extremely improbable (mechanically interconnected surfaces are to be considered as a single surface).

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Add requirements:

SC-RPAS.FC-FW.703 Take-off protection

If the RPA is an unsafe take-off configuration, either

- (a) The flight crew and ground staff (where applicable) must be notified; or
- (b) The initiation of take-off must be automatically prevented.
- (c) The engine shut down procedure must be analysed considering the existence of the emergency recovery capability as defined by SC-RPAS.ERC-01.

Add requirement:

SC-RPAS.FC-FW.745 Nose/tail-wheel steering

- (a) If nose/tail-wheel steering is installed, it must be demonstrated that it properly works during take-off and landing, in cross-winds and in the event of an engine failure or its use must be limited to low speed manoeuvring.
- (b) Movement of the steering control must not interfere with correct retraction or extension of the landing gear.

Add requirement:

SC-RPAS.FC-FW.1490 Automatic Take-off system – Automatic landing system

See AMC.1490 (e) (2) and (f) (2)

When a RPA System, designed for conventional take-off and landing on a runway is equipped with an automatic take-off system or an automatic landing system or both, it should meet the following requirements

- (a) Once the automatic take-off or landing mode has been engaged, the flight crew monitors the whole process from the Ground Control Station (GCS) via the command and control data link, but is not required to perform any manual “piloting action”, except manual abort, where required, as per provisions of SC-RPAS.FC-FW.1492.
- (b) The automatic function will reside in the RPA airborne control laws algorithms and will utilize navigation and flight path tracking inputs in such a manner as to not degrade the overall redundancy or level of safety of the flight control system. When off-board sensors are utilized via data-links, the continued safe flight of the vehicle must be ensured in the event of a loss of that data-link.

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(c) The automatic system may cause no unsafe oscillations or undue attitude changes or control activity as a result of configuration or power changes or any other disturbance to be expected in normal operation.

(d) Automatic take-off system or automatic landing system data and status must be displayed in the GCS. All indications must be designed to minimise crew errors.

(e) Take-off

(1) Once the automatic take-off mode has been engaged, the brake release, the take-off run and the rotation are fully automatic: RPA runway steering flightpath, speed, configuration, engine settings and RPA flightpath after lift-off shall be controlled by the automatic take-off system.

(2) In case of failure that could adversely affect safe flight or exceedance from predefined limits occurring during the take-off run at every speed up to the rotation speed VR or the proper refusal speed (if applicable), an automatic abort function shall be provided to stop the RPA on the runway.

(f) Landing

(1) Once the automatic landing mode has been engaged, the approach, landing and ground roll are fully automatic until the RPA reaches full stop or after a safe taxiing speed is reached and flight crew changes to a manual taxi mode: RPA flightpath, speed, configuration, engine settings, runway steering and braking after touch down shall be controlled by the automatic landing system.

(2) In case of failure or exceedance from the predefined limits of a convergence window occurring during the approach, an automatic go around function shall be provided above a certain height called "Decision Point", at which such a go around may be safely performed (i.e. with no ground contact that may damage the RPA).

Add requirement:

SC-RPAS.FC-FW.1492 Manual abort function

Where a RPA System is designed for conventional take-off and landing on a runway, it must include the following function:

(a) The automatic system must incorporate a manual abort function. Its control shall be easily accessible to the flight crew in order to

(1) Stop the RPA on the runway during the take-off run at every speed up to refusal speed (if applicable), or rotation speed VR, whichever is less.

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(2) Where it is safe to perform, initiate a go around during the landing phase at every height down to a Decision Point.

(b) Specific go around procedure shall be provided in the RPA System Flight Manual.

Appendix 1 - Subpart III

Requirements applicable to Rotary Wing RPAS only

Replace applicable CS article 691 by

SC-RPAS.FC-RW.691 Autorotation control mechanism

If autorotation capability is implemented, each main rotor blade pitch control mechanism must allow rapid entry into autorotation after power failure.

Add requirement:

SC-RPAS.FC-RW.1490 Automatic Take-off system – Automatic landing system

The rotorcraft RPA must include an automatic take-off and landing system under the following requirements:

(a) Once the automatic take-off or landing mode has been engaged, the process is fully automatic and the flight crew monitors the take-off from the Ground Control Station (GCS), via the command and control data link, but is not required to perform any manual “piloting action”, except manual abort, where required, as per provisions of SC-RPAS.FC-RW.1492.

(b) The automatic function will reside in the RPA airborne control laws algorithms and will utilize navigation and flight path tracking inputs in such a manner as not to degrade the overall redundancy or level of safety of the flight control system. When off-board sensors are utilized via data-links, the continued safe flight of the vehicle must be ensured in the event of a loss of that data-link.

(c) The automatic system may cause no unsafe oscillations or undue attitude changes or control activity as a result of configuration or power changes or any other disturbance to be expected in normal operation.

(d) Automatic take-off system or automatic landing system data and status must be displayed in the GCS. All indications must be designed to minimise crew errors.

(e) Take-off

(1) Once the automatic take-off mode has been engaged, the process is fully automatic: hovering, actuating flight path, speed, engine settings shall be controlled by the automatic take-off system.

(2) In case of failure that could adversely affect safe flight or exceedance from predefined limits occurring during the take-off process an automatic abort function shall be provided to land the rotorcraft RPA on the pad up to “Take-off Rejection Point.”

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(f) Landing

(1) Once the automatic landing mode has been engaged, the approach, hover and landing are fully automatic: rotorcraft RPA flight path, speed, engine settings, hovering, touch down point, actuating shall be controlled by the automatic landing system.

(2) In case of failure or exceedance from the predefined limits of a convergence windows occurring during the approach, an automatic go around function shall be provided before "Landing Rejection Point."

Add requirement:

SC-RPAS.FC-RW.1492 Manual abort function

The rotorcraft RPA take-off and landing System must include the following function:

(a) The automatic take-off and landing system must incorporate a manual abort command. Its control shall be easily accessible to the rotorcraft flight crew in order to:

(1) Interrupt take-off and either land or hover the rotorcraft RPA up to "take-off rejection point".

(2) Initiate a go around or hover during the landing phase before the "landing rejection point", at which such a go around may be safely performed.

(3) Initiate a return to hover and/or a go around after the landing rejection point.

(b) Specific go around procedure shall be provided in the RPA System Flight Manual.

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Appendix 2
ACCEPTABLE MEANS OF COMPLIANCE

AMC-RPAS.FC.673 Primary Flight Controls
Abbreviations:

Abbreviation	Meaning
AC	Advisory Circular
AMC	Acceptable Means of Compliance
CM	Certification Memorandum
CRI	Certification Review Item
CS	Certification Specification
EASA	European Aviation Safety Agency
ERC	Emergency Recovery Capability
FCS	Flight Control System
FW	Fixed Wing
GCS	Ground Control Station
JARUS	Joint Authorities for Rulemaking of Unmanned Systems
RPA	Remotely Piloted Aircraft
RPAS	Remotely Piloted Aircraft System
RW	Rotary Wing
SC	Special Condition
UAS	Unmanned Aircraft Systems
VLA	Very Light Aeroplanes
VLR	Very Light Rotorcraft

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Definitions:

Airfield: An area that is used or intended to be used for the landing and take-off of RPA, and includes its buildings and facilities, if any.

Automatic: The execution of a predefined process or event that requires RPA System crew initiation.

Autonomous: The execution of predefined processes or events that do not require direct RPA System crew initiation and/or intervention.

Conventional take-off: A take-off performed without external mean such as catapult, launch ramp or rocket.

Decision Point: The height below which a go around may not be safely performed (i.e., there will be ground contact that may damage the fixed wing RPA).

Emergency Recovery Capability: Procedure that is implemented through flight crew command or through autonomous design means in order to mitigate the effects of critical failures with the intent of minimising the risk to third parties. This may include automatic pre-programmed course of action to reach a predefined and unpopulated forced landing or recovery area.

Failure Conditions: Failure Conditions are classified according to the severity of their effects in Special Conditions SC-RPAS.1309-01. (Refer to this Special Condition for further details)

Flight Crew: The RPA system designated RPA operator in the RPA Control Station tasked with overall responsibility for operation and safety of the RPAS. Equivalent to the pilot in command of a manned aircraft.

Flight Controls: sensors, actuators and all those elements of the RPAS (except the flight control computer), necessary to control the attitude, speed and flight path of the RPA.

Flight Control Computer: A programmable electronic system that operates the flight controls in order to carry out the intended inputs and the emergency recovery capability.

Flight Envelope Protection: System that prevents the RPA from exceeding its designed operating limits.

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Forced Landing: A condition resulting from one or a combination of failure conditions that prevents the RPA from normal landing on its planned main landing site although the flight control system is still able to maintain the RPA controllable and manoeuvrable.

Ground Control Station: The component of the remotely piloted aircraft system containing the equipment used to pilot the remotely piloted aircraft.

GCS Flight Control: Flight controls used by the flight crew in the GCS to operate the RPA in the semi-automatic mode or manual mode of control as defined in SC-RPAS.FC 1329.

Landing Rejection Point: Point in the landing trajectory beyond which the rotorcraft RPA has automatically determined to continue to its touchdown. Beyond this point, the rotorcraft RPA will only abort the landing and continue to a safe and stabilized airborne state if manually aborted by the flight crew.

Refusal Speed (V_{Rf})

The speed above which a take-off may not be safely aborted. V_{Rf} is equivalent to V_1 as used for manned aircraft.

Remotely Piloted Aircraft (RPA): An unmanned aircraft which is piloted from a remote pilot station. (Note this is a subcategory of Unmanned Aircraft).

Remotely Piloted Aircraft System (RPAS): A remotely piloted aircraft, its associated remote pilot station(s), the required command and control links and any other components as specified in the type design.

RPAS Flight control system: The flight control system or control system comprises sensors, actuators, computers and all those elements of the RPAS necessary to control the attitude, speed and trajectory of the RPA. The flight control system can be divided into 2 parts: Flight Control Computer and Flight Controls.

Take-Off Rejection Point: Point in the take-off trajectory before which a rejected take-off results in the rotorcraft RPA: either automatically returning to a touchdown (if already airborne), or holding on the pad (if not already airborne); and after which, the rotorcraft RPA will automatically continue to a safe and stabilized airborne state.

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AMC-RPAS.FC.1329(g)

It is recognized that in Remote Piloted Aircraft Systems, the flight control functions are closely integrated with other avionics functions, and that the physical integration of these systems, may have a bearing on how RPAS level safety is assessed. The following paragraphs provide guidance on the likely FCS system integration issues found in Remote Piloted Aircraft Systems, and the interfaces which should be considered within the bounds of demonstrating the intended function, performance and safety of the FCS.

1. System Integration Issues

Integration of other aircraft systems with the FCS has the potential of reducing the independence of failure effects and partitioning between functions. This is particularly the case where hardware and software resources are shared by different systems and functions (e.g., data highway and Integrated Modular Avionics (IMA) architectures either in the RPA or in the Ground Control station). In addition to consider the reliability and integrity aspects of the FCS as a separate system, it may be necessary to address the effects of FCS failures with respect to fault propagation, detection, and isolation within other systems and vice versa. The overall effect on the RPA of a combination of individual system failure conditions occurring as a result of a common mode/cause or cascade failure, may be more severe than the individual system effect. With regard to isolation of failures, and particularly combination failures, the ability of the alerting system to provide clear and unambiguous information to the flight crew, becomes of significant importance.

Complex and highly integrated avionics and Flight Control Systems present greater risk for development errors. With non-traditional human-machine interfaces, there is also the potential for operational flight crew errors. Moreover, integration of systems may result in a greater likelihood of undesirable and unintended effects.

Within the FCS, where credit is taken for shared resources or partitioning schemes, these should be justified and documented within the Common Cause and System Safety Analysis, for example per the guidance of ED-135 / ARP 4761. When considering the functional failures of the system, where such partitioning schemes cannot be shown to provide the necessary isolation, possible combination failure modes should be taken into account. An example of this type of failure would be multi-axis active failures, where the control algorithms for more than one axis are hosted on a single processing element.

2 Functional Interfaces

The functional integration of control functions such as control surface operation, stability augmentation and envelope protection should be considered as well. The FCS may require inputs from interfacing sensors, engine data and/or integrated avionics function providing air data parameters like air, inertial and navigation data to enable the flight control computers to perform their intended function and computation of flight control orders. The FCS should also be considered as providing inner loop closure to outer loop commands as failures of the FCS can cascade into the higher functions.

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In demonstrating the intended function and performance of both the FCS and systems providing data inputs and outer loop commands, the applicant needs to address potential inconsistencies between limits of the two (e.g. with basic FCS pitch and bank angle limits). Failure to address these points can result in discontinuities, mode switching, and reversions, leading to erroneous flight control system behaviour, malfunctions and other possible safety issues (e.g. loss of control, hardovers, etc...).

The applicant should demonstrate the intended function and performance of the FCS across all possible functional interfaces. The alerting system should also be assessed to ensure that accurate and adequate information is provided to the flight crew when dealing with failures across functional interfaces.

3. Safety Assessment

SC-RPAS.1309-01 defines the basic safety specifications for airworthiness approval of RPAS and the associated acceptable means of demonstrating compliance. This section provides additional guidance and interpretative material for the application of SC-RPAS.1309-01 to the approval of FCS in particular in the scope of SC-RPAS.FC.1329(g).

A Safety Analysis document should be produced to identify the Failure Conditions, classify their hazard level according to the guidance of SC-RPAS.1309-01, and establish that the Failure Conditions occur with a probability corresponding to the hazard classification or are mitigated as intended. The safety assessment should include the rationale and coverage of the FCS protection and monitoring philosophies employed. Indeed, one output of the safety assessment is the identification and justification of the set of:

- Monitoring and fault management capabilities to minimise significant latent (undetected) failures, and
- Recording capability to facilitate fault diagnosis and timely identification of the root cause of the failures during maintenance activities.

The safety assessment should include an appropriate evaluation of each of the identified FCS Failure Conditions and an analysis of the exposure to common mode/cause or cascade failures in accordance with SC-RPAS.1309-01. Additionally, the safety assessment should include justification and description of any functional partitioning schemes employed to reduce the effect/likelihood of failures of integrated components or functions.

3.1 FCS Failure Conditions

One of the initial steps in establishing compliance with SC-RPAS.1309-01 for a system is to identify the Failure Conditions that are associated with that system. The Failure Conditions are typically characterized by an undesired change in the intended function of the system. The Failure Condition statements should identify the impacted functionality and the effect on the RPA. Any relevant considerations relating to phase of flight and identify any flight crew action, or other means of mitigation should also be specified.

3.2 Type and Severity of Failure Conditions

The type of the FCS Failure Conditions will depend, to a large extent, upon the architecture, design philosophy and implementation of the system. Types of Failure Conditions can include:

- Loss of function where an element no longer provides the intended function.
- Malfunction where an element performs in an inappropriate manner which can include the following sub-types:

a) Hardover the control goes to full displacement in a brief period of time the resultant effect on the flight path of the RPA and structural integrity are the primary concern.

b) Slowover - the control moves away from the correct control or display value over a relatively long period of time the potential delay in recognizing the situation and the effect on the flight path and structural integrity are the primary concern.

c) Oscillatory – when the control is replaced or augmented by an oscillatory element, there may be implications on structural integrity.

Failure Conditions can become apparent due to failures in sensors, primary FCS elements (e.g. Flight Control Computer), control and display elements (e.g., servos, primary flight displays), interfacing systems or basic services (e.g., electrical and hydraulic power).

The severity of the FCS Failure Conditions and their associated classifications will frequently depend on the phase of flight, RPA configuration. The effect of any control system variability (e.g., tolerances and rigging) on Failure Condition should be considered. The severity of the Failure Conditions can also be mitigated by various design strategies (see Section 3.3).

Complex integrated systems may require that the total effect resulting from single failure be assessed. For example, some failures may result in a number of Failure Conditions occur which, if assessed individually may be considered a Major effects, but when considered in combination may be more severe.

3.3 Failure Condition Mitigation

The propagation of potential Failure Conditions to their full effect may be nullified or mitigated by a number of methods. These methods could include, but are not limited to, the following:

- failure detection and monitoring,
- fault isolation and reconfiguration,
- redundancy,
- authority limiting, and
- flight crew action to intervene.

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AMC-RPAS.FC.1329(i)

Consideration should be given to FAA Advisory Circular 25.672-1, "Active Flight Controls" dated 15 Nov 1983, or equivalent means as approved by the Certifying Authority.

AMC-RPAS.FC.1329(j)

Provisions should be made for determining the status of the continuous built-in-test function and alerting the flight crew of degradation of the system as appropriate.

AMC-RPAS.FC-FW.1490(a)

An automatic Take-off System for a fixed wing RPA is typically a system that once the automatic take-off mode has been engaged, the brake release, the take-off run and the rotation are fully automatic : RPA runway steering, flightpath, speed, configuration, engine settings and RPA flightpath after lift-off are controlled by the automatic take-off system.

AMC-RPAS.FC-FW.1490(b)

An automatic Landing System for a fixed wing RPA is typically a system that once the automatic landing mode has been engaged, the approach, landing and ground roll are fully automatic until the RPA reaches full stop or after a safe taxiing speed is reached and the flight crew changes to a manual taxi mode: RPA flightpath, speed, configuration, engine settings, runway steering and braking after touch down are controlled by the automatic landing system.

AMC-RPAS.FC-FW.1490

(e)(2) and (f) (2)

The size of the convergence window and associated tolerances should be defined with the Certifying Authority based on the tailoring of manned aircraft reference documents such as EASA CS-AWO.