SUBJECT	:	**RPAS Flight Control Systems**
CATEGORY	:	Special Condition and Acceptable Means of Compliance
CERTIFICATION SPECIFICATIONS	:	CS-VLA / CS-LURS
PRIMARY PANEL	:	Panel 04 (Hydromechanical Systems)
SECONDARY PANELS[1]	:	Panel 01 (Flight and Human Factors), Panel 03 (Structure), Panel 05 (Electrical Systems).
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 low end product 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.

2. REFERENCES

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

Reference	Title	Issue	Date
AC 25.672-1	Active Flight Controls	-	15/11/1983
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	-
CS-LURS	Certification Specification for Light Unmanned Rotorcraft Systems	Latest	-
SC-RPAS.1309-01	Special Condition - Equipment, systems, and installations	Latest	-
SC-RPAS.ERC-01	Special Condition - Emergency Recovery Capability	Latest	-
STANAG 4617	Unmanned Aerial Vehicles Systems Airworthiness Requirements (USAR)	Latest	-
STANAG 4701	Rotary Wing Unmanned Aerial Systems Airworthiness Requirements	Latest	-

[1] The Secondary Panels can be adapted depending on the project.

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.

In 2013, JARUS committee published CS-LURS which supersedes the applicability of CS-VLR to rotary wing RPAS.

The requirements in Appendix 1 are applicable, in addition to specific design requirements of the applicable type certification basis, to any equipment or system part of 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-LURS.

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

Appendix 1
Special Condition

Appendix 1 - 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) The flight crew must be warned when the device 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.

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.

(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 (i) and (j)

(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 trajectory of the vehicle is 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 launch 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 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.

Appendix 1 - 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 surfaces not shown to be extremely improbable (mechanically interconnected surfaces are to be considered as a single surface).

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.

(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 or rotation speed VR, whichever is less.

(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

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."

(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.

Appendix 2

ACCEPTABLE MEANS OF COMPLIANCE

AMC-RPAS.FC.673 Primary Flight Controls

Abbreviations:

Abbreviation	Meaning
AC	**A**dvisory **C**ircular
AMC	**A**cceptable **M**eans of **C**ompliance
CM	**C**ertification **M**emorandum
CRI	**C**ertification **R**eview **I**tem
CS	**C**ertification **S**pecification
EASA	**E**uropean **A**viation **S**afety **A**gency
ERC	**E**mergency **R**ecovery **C**apability
FCS	**F**light **C**ontrol **S**ystem
FW	**F**ixed **W**ing
GCS	**G**round **C**ontrol **S**tation
JARUS	**J**oint **A**uthorities for **R**ulemaking of **U**nmanned **S**ystems
RPA	**R**emotely **P**iloted **A**ircraft
RPAS	**R**emotely **P**iloted **A**ircraft **S**ystem
RW	**R**otary **W**ing
SC	**S**pecial **C**ondition
UAS	**U**nmanned **A**ircraft **S**ystems
VLA	**V**ery **L**ight **A**eroplanes
VLR	**V**ery **L**ight **R**otorcraft

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.

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.

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.

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.

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.