Joint Authorities for Rulemaking on Unmanned Systems

CS-UAS, Annex C - Additional requirements to Subpart F for Systems containing safety critical functions performed by Artificial Intelligence (AI) *(Highly Complex Systems (HCS))*

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Special thanks' to the WG-Airworthiness coming from all over the world.

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CONTENTS

Introduction

The intent of CS-UAS, Annex C

This Annex C to CS-UAS supplements primarily Subpart F for systems built out of subordinated hard- and software items, utilizing AI, producing outputs serving as input for a superordinate system which perform safety critical functions based on these outputs. In this document the term High Complex Systems (HCS) is used for these systems.
At the time of the development of this Annex C, the technologies utilized by these systems are considered as being outside the scope of the existing regulatory framework.

This Annex C does not replace any requirement in CS-UAS.2500 to CS-UAS.2510 and must therefore be used in addition to these requirements and associated AMC.
Some recommendations in this Annex C are process requirements which usually can be found in the Airworthiness Regulations governing the Certification of Aircraft, Parts and Appliances. It is expected that further revisions on the Airworthiness Regulations will address the intent of these process recommendations and can then be removed from this Annex C.

Semantics of the UAS Operational Envelope and HCS Operational Design Domain (ODD)

UAS Operational Envelope

Foreseeable conditions are those internal or external conditions that can be anticipated based on the current level of knowledge, environment and state-of-the-art.

Expected conditions are foreseeable conditions not shown to be extremely improbable. They are related to the operational envelope and limitations of the UAS according to CS-UAS.2005 in that:

(1) The UAS is designed and certified for these conditions; or
(2) Limitations to the operational envelope apply to prevent these conditions

Unexpected conditions are extremely improbable foreseeable conditions and unforeseeable conditions.

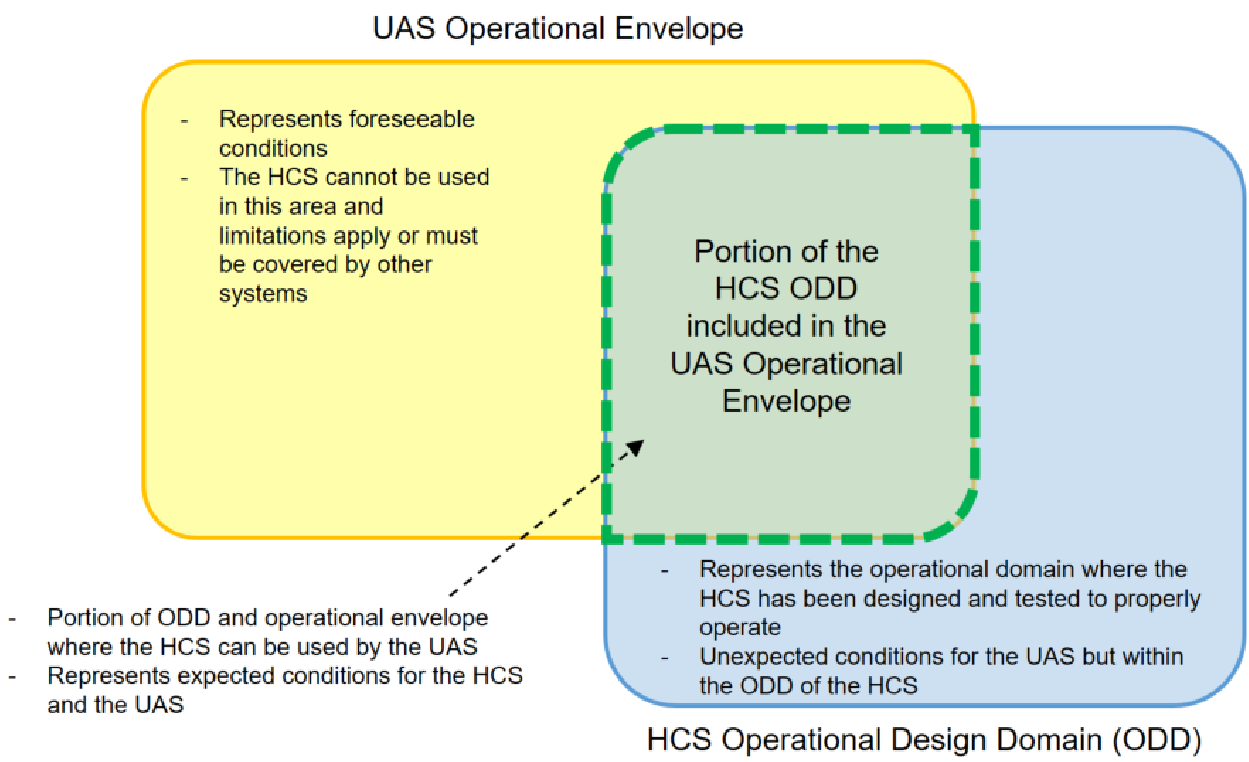
HCS Operational Design Domain (ODD)

The Operational Design Domain ODD is the envelope within which the HCS is designed, validated and tested.

The HCS may not be designed and tested on unexpected conditions.

It is expected that the ODD and the operational envelope have overlapping areas as shown by the picture below:

Aircraft level constraints coming from the operational envelope should be traceable to direct inputs and outputs to the HCS.


UAS Operational Envelope
- Represents foreseeable conditions
- The HCS cannot be used in this area and limitations apply or must be covered by other systems
Portion of the HCS ODD included in the UAS Operational Envelope
- Portion of ODD and operational envelope where the HCS can be used by the UAS
- Represents expected conditions for the HCS and the UAS
- Represents the operational domain where the HCS has been designed and tested to properly operate
- Unexpected conditions for the UAS but within the ODD of the HCS
HCS Operational Design Domain (ODD)

REFERENCES

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- FAA_Roadmao for AI Safety Assurance_issued August 2024
- EASA Concept Paper First Usable Guidance For Level 1 & Level 2 Machine Learning Applications Issue 02
- EASA SC-AI-01 Trustworthiness of Machine Learning based Systems
- JARUS AMC RPAS.1309 and Scoping Paper
- SAE ARP4754B / EUROCAE ED-79B
- RTCA DO-178C/EUROCAE ED-12C, Software Considerations in Airborne Systems and Equipment Certification
- RTCA DO-254/EUROCAE ED-80, Design Assurance Guidance for Airborne Electronic Hardware
- RTCA DO-297/EUROCAE ED-124 IMA Development Guidance and Certification Considerations
- SAE / EUROCAE ES-022 AI in aeronautical Systems statement of concerns
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  https://www.caa.co.uk/our-work/publications/documents/content/cap2966/
- ASTM "Standard Practice for Methods to Safely Bound Flight Behavior of Unmanned Aircraft Systems Containing Complex Functions"
- EASA/DAEDALEAN IPC Report Concepts of Design Assurance for Neural Networks (CoDANN)
- EASA/DAEDALEAN IPC Report Concepts of Design Assurance for Neural Networks (CoDANN) II
- FAA/DAEDALEAN tc21-48 NN Based Runway Landing Guidance GA

DEFINITIONS

Whenever possible, use definitions from EASA/FAA/SAE/RTCA etc. Others only in exceptional cases with good reasons (will be deleted before publication)

Abnormal Condition:

A condition requiring action, either by onboard systems or by a remote crew, due to failure of a system or component, to maintain an acceptable level of airworthiness for continued safe flight and landing.

Adversarial Testing:

A Method for systematically evaluating an ML model with the intend of learning how it behaves when provided with malicious or inadvertently harmful input (https://developers.google.com/machine-learning/resources/adv-testing)

Artificial Intelligence:

The definition of Artificial Intelligence (AI) is widely and controversially discussed and changes over the time. Users of this document are referred to the different existing literature discussing this subject if additional explanation is required.

Some are listed below as examples, without any priority or preference.

The American Heritage® Dictionary of the English Language, 5th Edition

- The ability of a computer or other machine to perform those activities that are normally thought to require intelligence.
- The branch of computer science concerned with the development of machines having this ability.
- Intelligence exhibited by an artificial (non-natural, man-made) entity.

IBM (https://www.ibm.com/topics/artificial-intelligence)

- "As a field of computer science, artificial intelligence encompasses (and is often mentioned together with) machine learning and deep learning. These disciplines involve the development of AI algorithms, modeled after the decision-making processes of the human brain, that can ‘learn’ from available data and make increasingly more accurate classifications or predictions over time."

CAA’s Strategy for AI, Speaking a Common Language, A terminology framework for AI (https://www.caa.co.uk/publication/download/21088

- The development of computer systems that can perform tasks which typically require human intelligence

Emergency Condition:

A condition requiring immediate action, either by onboard systems or by a remote crew to protect the UA, third parties and critical infrastructure from serious harm.

Generalization

The generalization is a property of ML Constituent that is satisfied when the ML Model computes correct predictions on data (belonging to the ODD) it has never seen before. This property should be verified in-sample and out-of-sample

A generalization is a form of abstraction whereby common properties of specific instances are formulated as general concepts or claims. Generalizations posit the existence of a domain or set of elements, as well as one or more common characteristics shared by those elements (thus creating a conceptual model). As such, they are the essential basis of all valid deductive inferences (particularly in logic, mathematics and science), where the process of verification is necessary to determine whether a generalization holds true for any given situation. => https://en.wikipedia.org/wiki/Generalization

Generalization refers to your model's ability to adapt properly to new, previously unseen data, drawn from the same distribution as the one used to create the model. => https://developers.google.com/machine-learning/crash-course/generalization/video-lecture

Generalization gap

The difference between the in-sample error and the out-of sample error

Generalization requirements

Requirements set to a ML-HCS related to in-sample error, out-of-sample error and generalization gap

Ground Truth:

Ground truth is information that is known to be real or true, provided by direct observation and measurement (i.e. empirical evidence) as opposed to information provided by inference.

In statistics, "Ground truth" may be seen as a conceptual term relative to the knowledge of the truth concerning a specific question. It is the ideal expected result. This is used in statistical models to prove or disprove research hypotheses.

In remote sensing, "ground truth" refers to information collected on location.

Sorce: https://en.wikipedia.org/wiki/Ground_truth

High Complex System

A High Complex System (HCS) is defined as a system in which certain allocated functions are performed by technologies such as Artificial Intelligence (AI), Machine Learning, Symbolic Artificial Intelligence, Numerical Analysis etc., utilising large amounts of data (see GM C1-UAS.1)

Inference Model:

The ML model obtained after transformation of the trained model, so that the model is adapted to the target platform.

Input data:

Data from a wide variety of sensors that map the operational environment and are entered into the HCS.

This data can be pre-processed outside or inside the HCS.

In-sample Data

The in-sample data is what is used to design and train a machine learning model.

Machine Learning:

The branch of AI concerned with the development of algorithms that allow computers to evolve behaviors based on observing data and making inferences on these data.

ML-BASED ITEM

An item containing at least one software or hardware element developed using Machine Learning Technology

ML-MODEL

A parameterized function that maps inputs to outputs. The parameters are functions ed during the training process

Neural Networks:

(a) A neural network is a group of interconnected units called neurons that send signals to one another. Neurons can be either biological cells or mathematical models. While individual neurons are simple, many of them together in a network can perform complex tasks. There are two main types of neural network:
   - In neuroscience, a biological neural network is a physical structure found in brains and complex nervous systems – a population of nerve cells connected by synapses.
   - In machine learning, an artificial neural network is a mathematical model used to approximate nonlinear functions. Artificial neural networks are used to solve artificial intelligence problems.

   Source: https://en.wikipedia.org/wiki/Neural_network

(a) A class of machine learning algorithms,
loosely inspired by the human brain. They consist of connected nodes ("neurons") that define the order in which operations are performed on the input. Neurons are connected by edges which are parametrized by weights and biases. Neurons are organized in layers, specifically an input layer, several intermediate layers, and an output layer. Given a fixed topology (neurons and connections), a model is found by searching for the optimal weights and other parameters.
Sourcs: https://www.easa.europa.eu/en/document-library/general-publications/concepts-design-assurance-neural-networks-codann

Normal Condition:

A condition associated with systems that are functioning in their usual manner.

Offline learning:

The process of learning, to optimize the certified HCS with data gathered during the operation. The optimization and recertification will then be done offline, while the HCS is not in operation.

Online learning:

The process of continued learning of the certified HCS during the operation with data out of the operation.

Out-of sample Data

The out-of-sample data is the set of data that the model has never been exposed to during design and training.

Operational Design Domain (ODD):

Operating conditions under which a given AI/ML constituent is specifically designed to function as intended, including but not limited to environmental, geographical, and/or time-of-day restrictions

(adapted from SAE J3016, Level of driving automation, 2021.)

Out of Distribution (OoD):

Out-of-Distribution (OOD) detection refers to a model's ability to recognize and appropriately handle data that deviates significantly from its training set.

Output data:

Output of the HCS based on the input data and the functionality inside the HCS. This data can be post-processes inside or outside the HCS and can be further processed by other systems.

Performance requirements

Performance requirements define those attributes of the function or system that make it useful to the aircraft and its operation. In addition to defining the type of performance expected, performance requirements include function specifics as: accuracy, fidelity, range, resolution, speed, and response times.

Source: EUROCAE ED-79B/SAE ARP4754B

Robustness requirements:

The requirements on:

- Algorithm Robustness as how robust the learning algorithm is to changes in the underlying training dataset
- Model Robustness which quantifies a trained model's robustness to input perturbations

Sourcs: https://www.easa.europa.eu/en/document-library/general-publications/concepts-design-assurance-neural-networks-codann

Sensor:

A sensor in the context of this Annex C includes one or more sensors including those designed for postprocessing for signal conditioning

Stability requirements

Stability, also known as algorithmic stability, is a notion in computational learning theory of how a machine learning algorithm output is changed with small perturbations to its inputs. A stable learning algorithm is one for which the prediction does not change much when the training data is modified slightly.

Source: https://en.wikipedia.org/wiki/Stability_(learning_theory)

Superordinate System:

The superordinate system in the context of this Annex C is a system or subsystem in which the HCS is integrated.

Target System:

Known as well as Target Environment, Target Platform.
The target system in the context of this Annex C is the system or subsystem in which the HCS is implemented. It consists out of hardware and software.

Training

The process of optimizing the parameters of a ML-model, given a dataset and a task to achieve on that dataset.

Trained Model

The ML model which is obtained at the end of the learning/training phase.

Testing

The process of exercising a system or component to verify that it satisfies specified requirements

Validation

The determination, or process of determining, that the requirements for a product are correct and complete (ARP4754B/ED-79B)

Verification

The evaluation of an implementation of requirements to determine that the requirements have been met. (ARP4754B/ ED-79B)

Section 1, General Requirements for High Complex Systems

C-UAS.1 Applicability

(GM C-UAS.1 Applicability)

Appendix C contains additional requirements, applicable to High Complex Systems utilising AI/ML and the tools to develop and test them.

These additional requirements must be taken into account in addition to the requirements in CS.UAS and the standards and guidance used to fulfill the requirements in CS-UAS.

C-UAS.2 Trustworthy Principles

(GM C-UAS.2 Trustworthy Principles)

The superordinate system containing the HCS must ensure that the Trustworthy Principles as defined in the respective documentation of the certifying country or region is adhered to.

C-UAS.3 Expected Conditions

(GM C-UAS.3 Expected Conditions)

The design and testing on the expected conditions must be sufficient to prevent at least any 3rd party risk based on the HCS behaviour and therefore count for any internal or external hazard that may occur in the UAS expected conditions within the ODD of the HCS.

The HCS must be designed and tested within the intersection of the ODD and the expected conditions.

It is expected that the HCS is designed or contains means/features so the UA will not intentionally exit from the UAS operational envelope based on the HCS behaviour in all expected conditions.

(a) A clear specification of the expected conditions for which the HCS is designed and verified must be agreed with the competent authority.

(b) The expected conditions defined at the UAS level must:

(1) At least cover the operational envelope and limitations according to CS-UAS.2005 and,

(2) Cover normal, abnormal and emergency conditions and,

(3) Include Emergency Recovery Capability and Procedures (ERCP) according to CS-UAS.2570 and Command, Control and Communication Contingency according to CS-UAS.2575.

(c) An operation outside the operational envelope according CS-UAS.2005 but inside the expected conditions on UAS level are considered as an abnormal condition

(d) The ODD of the HCS must be a subset of the expected conditions and may reach beyond the expected conditions of the UAS.

(e) Where the ODD of the HCS does not completely cover the expected conditions at the UAS level for normal, abnormal and emergency conditions

(1) Limitations either at the aircraft or system level must be implemented, or

(2) The remaining expected conditions must be covered either by other systems or by the remote crew.

(f) The HCS must have ODD monitoring capability

(g) Departing from the HCS ODD is an occurrence which must be recorded together with the action taken.

(h) An HCS used to recover from conditions not classified as expected or foreseeable according C1-UAS.3 should be designed and validation by standards accepted by the competent authority, but might not be verified.

C-UAS.4 HCS Data requirements

(GM C-UAS.4 HCS Data requirements)

(a) Due to the interdependency between:

(1) the input data to the HCS,

(2) the ODD and

(3) the quality of the output data of the HCS,

the input data must be representative to cover the complete ODD.

(b) A data management process must be implemented to ensure:

(1) That sufficient data quality exists throughout the complete life cycle of the data, and

(2) Data controls are implemented that support system level objectives.

(3) Aircraft level constraints coming from the operational envelope are traceable to direct inputs and outputs to the HCS

(c) Different independently developed input datasets must be used for the design and for the testing of the HCS

C-UAS.5 Sensor requirements

(GM C-UAS.5 Sensor requirements)

(a) Where the HCS is processing sensor-data:

(1) It must be ensured that the input to the HCS represents the real environment with a performance:

(i) Required by the criticality of the function supported by the HCS as determined by CS-UAS.2500 to 2510

(ii) Allowing OOD determination

(2) Where the sensors used in the design are different to the sensors used in operation, all sensors must be specified and it must be ensured the output in relation to the input is within the approved performance.

C-UAS.6 Learning in operation

(GM C-UAS.6 Learning in operation)

(a) For data gathered during the operation, which will be utilised by the HCS, the data management process per C-UAS.12 applies.

(b) An HCS, where the Inference-Model was updated using new data, must be recertified. The extent of the certification must be agreed with the competent authority.

(c) If adaptive behavior (online learning) is used during operation, processes must be agreed with the competent authority on how to ensure the validity of the certification or the recertification in the continuously changing system in operation.

C-UAS.7 System monitoring

(GM C-UAS.7 System monitoring)

(a) The system containing the HCS must be monitored to perform as intended if CS-UAS.2500(b) applies to this system. For all other systems CS-UAS.2510(b) applies and monitoring may not be required.

(b) If the monitoring requirement as per (a) applies, the HCS must, as a minimum, be monitored to ensure it operates within its ODD.

(c) Depending on the criticality of the function supported by the HCS per CS-UAS.2510 (a), a dedicated visual and/or aural warning or alert must be provided to the remote crew or a superordinate system when:

(1) The HCS operates outside its ODD, or

(2) Processed input data required for the safe operation of the HCS is not recognizable.

(d) The warnings or alerts per (c) must fulfil:
(1) The system safety requirements per CS-UAS.2500 to 2510, and in addition;
(2) The human factors requirements per CS-UAS.2605 where the warning and/or alerts are provided to the crew to take the appropriate action.

(e) Where the output of a HCS will be processed by another system or subsystem without human monitoring or interaction, the MoC to the requirements CS-UAS.2570 and CS-UAS.2575 must consider this absence of human control.

(f) UAS unsafe conditions based on leaving the HCS ODD must be resolved by a superordinate or equivalent system

C-UAS.8 Interface requirements

(GM C-UAS.8 Interface Requirements)

(a) Where a system or subsystem provides information to superordinate systems, based on the output from one or more HCS without human monitoring or interaction, the requirements of CS-UAS.2500-2510, CS-UAS.2570 and CS-UAS.2575 are applicable.

(b) Where a system or subsystem provides information to crew members, based on the output from one or more HCS, the human factors requirements of CS-UAS.2605 are applicable in addition to the requirements in (a).

(c) Depending on the criticality of the information submitted to a superordinate system or crew members, this information may require quality attributes to show compliance to the requirements in CS-UAS.2500 to CS-UAS.2510 and CS-UAS.2605.

C-UAS.9 HCS Control and Explainability

(GM C-UAS.9 HCS Control and Explainability)

The HCS must generate sufficient data to:

(a) Determine the successful execution of intended HCS functions

(b) Allow the interconnected systems to operate as designed

(c) Enable decisions by the crew to manage the safe operation of the UA

(d) Allow post failure assessment in the event of an unexpected occurrence

C-UAS.10 Recording for occurrences, incidents and accidents investigation

(GM C-UAS.10 Recording for occurrences, incidents and accidents investigation)

(a) If required by the operating rules, the UAS must contain the functions to permanently record all relevant technical and operational parameters of the HCS in every phase of flight. The recording must fulfill the requirements per CS-UAS.2555.

(b) The software must be designed or have means to allow in case of an occurrence, incident or accident, the investigating authorities to evaluate the causes.

C-UAS.11 HCS Continued Safety

(GM C-UAS.11 HCS Continued Safety)

(a) The HCS must provide and record sufficient information to determine if the assumptions specifying the ODD used to support the design and certification of the HCS are still valid in operation.

(b) Where these assumptions are no longer valid, appropriate CAW actions are required to assure the HCS works as intended.

(c) The information being recorded must consider the novelty of the HCS and the criticality of this information.

C-UAS.12 Configuration management for Data used in HCS

(a) Where the behavior of the HCS or the function supported by the HCS is depending the data used for the compliance demonstration, this data is part of the configuration of the UAS.

(b) The requirements set to the configuration management depend on the criticality of the function supported by the HCS and the requirements in CS-UAS.2500 to 2510 apply.

GM to Section 1, General Requirements for High Complex Systems

GM C-UAS.1 Applicability

A High Complex System (HCS) is defined as a system in which certain allocated functions are performed by technologies such as Artificial Intelligence (AI), Machine Learning, Symbolic Artificial Intelligence, Numerical Analysis etc., utilising large amounts of data.

GM C-UAS.2 Trustworthy Principles

Guidance to the Trustworthiness of AI can be found in documentation of the certifying country or region, as e.g.

- Ethics Guidelines for Trustworthy AI. Issued on the 8 April 2019 by the independent High-Level Expert Group on Artificial Intelligence set up by the European Commission

  https://digital-strategy.ec.europa.eu/en/library/ethics-guidelines-trustworthy-ai
- OECD Human centered Principles to AI, agreed by the G20 Trade Ministers and Digital Economy Ministers on 8 and 9 June 2019 in Tsukuba City, Ibaraki Prefecture, Japan

  https://www.oecd.org/digital/artificial-intelligence/
- CAP2970: Building Trust in AI: 5 Principles for AI and Autonomy | Civil Aviation Authority (caa.co.uk)

  https://www.caa.co.uk/our-work/publications/documents/content/cap2970/

GM C-UAS.3 Expected Conditions

(a) The specification of the expected conditions builds the basis for the UAS design and must consider any foreseeable operational conditions not shown to be extremely improbable. These conditions can be:
  (1) Failures and malfunctions on systems, sensors, parts,
  (2) Foreseeable external conditions or,
  (3) Human errors in systems where the safe operation requires one or more crew members.

(b) It is required that within the operational envelope none of the expected conditions will lead to fatalities or damage to critical infrastructure.

(c) Initiating the ERCP according CS-UAS.2570 for expected conditions can be a possible option.

(d) The system containing the HCS must be designed and verified on all expected conditions and status.

(e) The ODD monitoring capability should allow to determine if the HCS operates within or outside the ODD

The concept of the ODD which is different to the UAS Operational Envelope is introduced to allow the usage of an HCS in a limited area where already sufficient data for design and validation is available. By the use of the HCS in real operation, additional data may be collected to allow the expansion of the ODD at a later stage.

(f) Reserved

(g) An HCS functionality to recover from unexpected or unforeseeable conditions should be designed and validated by following accepted standards. The final verification of these functionalities may be impractical due to the unknown nature of unexpected and unforeseeable conditions.

GM C-UAS.4 Data requirements

(a) The quality of the output data is dependent on how well the input data represents the ODD. It is therefore essential that the input data is representative to cover the complete ODD.

(b) The amount of input data required to certify the HCS depends on the criticality of the functions supported by the HCS.

(c) The input data used must allow a clear distinction of the boundaries of the ODD

(d) Where an operation of the HCS outside of the ODD would be safety critical, sufficient input data must be available, to sufficiently train the HCS to determine the boundaries of the HCS according to the requirements set to the HCS. Therefore, the HCS should not operate outside the ODD but output a respective message to the superordinate system or the human in charge to manage the system.

   (1) This may require having more data in some areas than others, for instance:

      (i) at known ODD boundaries or edge cases, or

      (ii) in areas within the ODD with chaotic characteristics, requiring finer coverage of input/output data to adequately test the chaotic behavior

   (2) This may require adversarial testing with test input data outside the ODD boundaries to generate false positive and false negative output.

(e) The independence means the separation of datasets that assures the accomplishment of objective evaluation, to prevent "tailoring" of the HCS to the different datasets

GM C-UAS.5 Sensor requirements

All sensors used during the design and the operation are part of the certified configuration. The use of a sensor not already part of the certified configuration is considered as a change to the type design and the Airworthiness Regulations governing the Certification of Aircraft, Parts and Appliances applies (Part 21).

GM C-UAS.6 Learning in operation

a) Implementing new data into a certified HCS should be considered as a change to the design in general.

b) Therefore, the requirements of Part 21, CS-UAS, its annexes, and the accepted industry standards applies.

c) It should therefore be ensured, that the system after the change (new data implemented) is still in compliance to the requirements set to the HCS. This can be done e.g., by showing that no regression is imposed, or by other methods agreed with the competent authority.

d) Where online learning is foreseen, the applicant should agree with the competent authority on processes to ensure the continued airworthiness.

e) Under the assumption that an HCS will be installed in more than one UA product, part or appliance a change implemented by online learning must be reviewed and documented for the effects on UA parts, products or appliance, having the same HCS installed.

f) New data is data which is not already used during the design and certification. Data that is revised may be considered as new data

GM C-UAS.7 System monitoring

(a) In general, two concepts are possible, each having a different impact on the certification/assurance:

(1) Monitoring the HCS output against the intended input/output mapping, and/or

(2) Monitoring at least one of the following:

(i) The aircraft or system functions, supported by the output from the HCS, are within their pre-defined limits and are at the level/value expected for the input to the HCS, and/or

(ii) The superordinate systems/subsystems, supported by the output from the HCS, are within their pre-defined limits and are at the level/value expected for the input to the HCS

(3) The operational design domain (ODD) in this context can be interpreted as the description of all expected conditions that the HCS could be anticipated to operate within, including but not limited to operational aspects, environmental conditions, and other domain constraints. Consequently, the HCS ODD, which supports a superordinate or parallel system or subsystem and the operational envelope of the function or the system/subsystem supported by the HCS, may have different properties.

Assurance properties which should ensures the system works as intended according CS-UAS.2500 (b) can be e.g., performance-, generalization-, stability-, and/or robustness requirements and should be agreed with the competent authority

The functions described in (a) may be implemented in a distributed or single function or system.

System Monitoring in this context can be interpreted as the monitoring part of a Run-Time Assurance (RTA). This is a method to bound the subsystem/item containing the HCS at a higher level than the subsystem/item itself and provides therefore an additional safety layer.

The ASTM Standard F3269, "Standard Practice for Methods to Safely Bound Flight Behaviour of Unmanned Aircraft Systems Containing Complex Functions" can be used as guidance to implement a Run-Time Assurance into the system.

GM C-UAS.8 Interface requirements

(a) With increased automated functions the human interaction and intervention possibilities may change and so are no longer possible on the lower HCS level. This may be valid as well for functions ensuring the continued safe flight and landing in case of abnormal and emergency conditions. Therefore, in general, a higher level of automation for safety critical functions requires additional, more stringent airworthiness requirements for these automated functions.

(b) Where a system or subsystem provides information to humans, this information should enable the humans:

   (1) To perform oversight on the system functions, and
   (2) To interact where appropriate with the system, when required.

(c) Where the HCS output data has a probabilistic "character", additional information associated to this data may be required to fulfil the requirements in CS-UAS.2605 and/or CS-UAS.2500 to CS-UAS.2510.

GM C-UAS.9 HCS Control and Explainability

The target audience of the explanation drives the different needs for explainability. The level of explanation is dependent on the domain and expertise of the target audience.

(a) The data generated from the HCS may not allow a direct evaluation if the HCS operates as intended. Therefore, the content, amount, quality and format of the data should fulfill the requirements of the agents performing the evaluation. These agents can be humans or an interconnected system.

(b) In the context of this Annex C it is assumed that the HCS performs specific functions in a system. Other functions of the same system may be performed by traditional software and hardware. The content, amount, quality and format of the data in (b) are therefore a requirement set to the HCS during the processes to show compliance to the system safety as per CS-UAS.2500 to 2510.

(c) Where humans are involved in the safe management of the flight operation based on data obtained from the HCS, it is expected that sufficient information is provided on:

   (1) To support the interpretation of this data, and

   (2) How the HCS reached the output if it is needed in case of doubts on the correctnes of the output and the interpretation.

(d) Refer to GM C1-UAS.10 Recording for occurrences, incidents and accidents investigation.

Further information concerning AI explainability can be found in the guidance published by the FAA and EASA

- EASA Artificial Intelligence Concept Paper Issue 2 - Guidance for Level 1 & 2 machine-learning applications | EASA (europa.eu)
- FAA Roadmap for Artificial Intelligence Safety Assurance, Version I

GM C-UAS.10 Recording for occurrences, incidents and accidents investigation

(a) The recording should ensure, that the input data used by the HCS and the output data based on these inputs and which led to the occurrence can be followed in the investigation. The recorded data must be stored as a minimum until correct function of the HCS is checked.

(b) Although sometimes HCS are referred to as "black-box" functions (i.e. the mapping from input to output is obscured from view), it must still be possible to investigate the occurrence. All relevant parameters used in a HCS that can be recorded for investigative purposes should be recorded in the event that an accident occurs such that experts can analyse the case.

GM C-UAS.11 HCS Continued Safety

(a) The assumptions specifying the ODD during the design of the HCS forms the basis for the selection of the data used for design and certification. The selection and quality of the data in each part/section of the ODD should encompass the reality of all the operations. A mismatch between the assumptions specifying the ODD and the actual operation may lead to unanticipated behavior of the HCS. The safety impact of this mismatch needs to be properly analyzed and addressed.

(b) Reserved

(c) One of the basic assumptions is that the HCS uses novel technology with limited experience in operation. The effects of a mismatch as described in (a) may challenge the safety compliance demonstration or identify safety issues not considered during the design and certification. Therefore, the effects of this mismatch should be addressed depending on their criticality to ensure the safety of the ongoing operations. Details on information to be recorded and analyzed should be agreed with the certifying authority.

GM C-UAS.12 Configuration management for Data used in HCS

In AI applications as e.g. ML the final behavior of the AI-Model which is implemented depends on the data used for training and validation as well as on the selected architecture of the soft- and hardware. With the final data used for testing the AI-Model, compliance is shown, that the output of the AI-Model is within the required limits.

If compliance to the certified limits must be demonstrated by CAW or other reasons, the AI-Model output must be within the certified limits, provided the data used for the initial compliance demonstration will be reused. This data is therefore part of the UAS configuration and Configuration Management applies.

The existing standards for Data Management (e.g. DO-200C/ED-76B) can be applied.

Depending the criticality of the function supported by the HCS, the level of rigor applied to the Configuration Management may be different.