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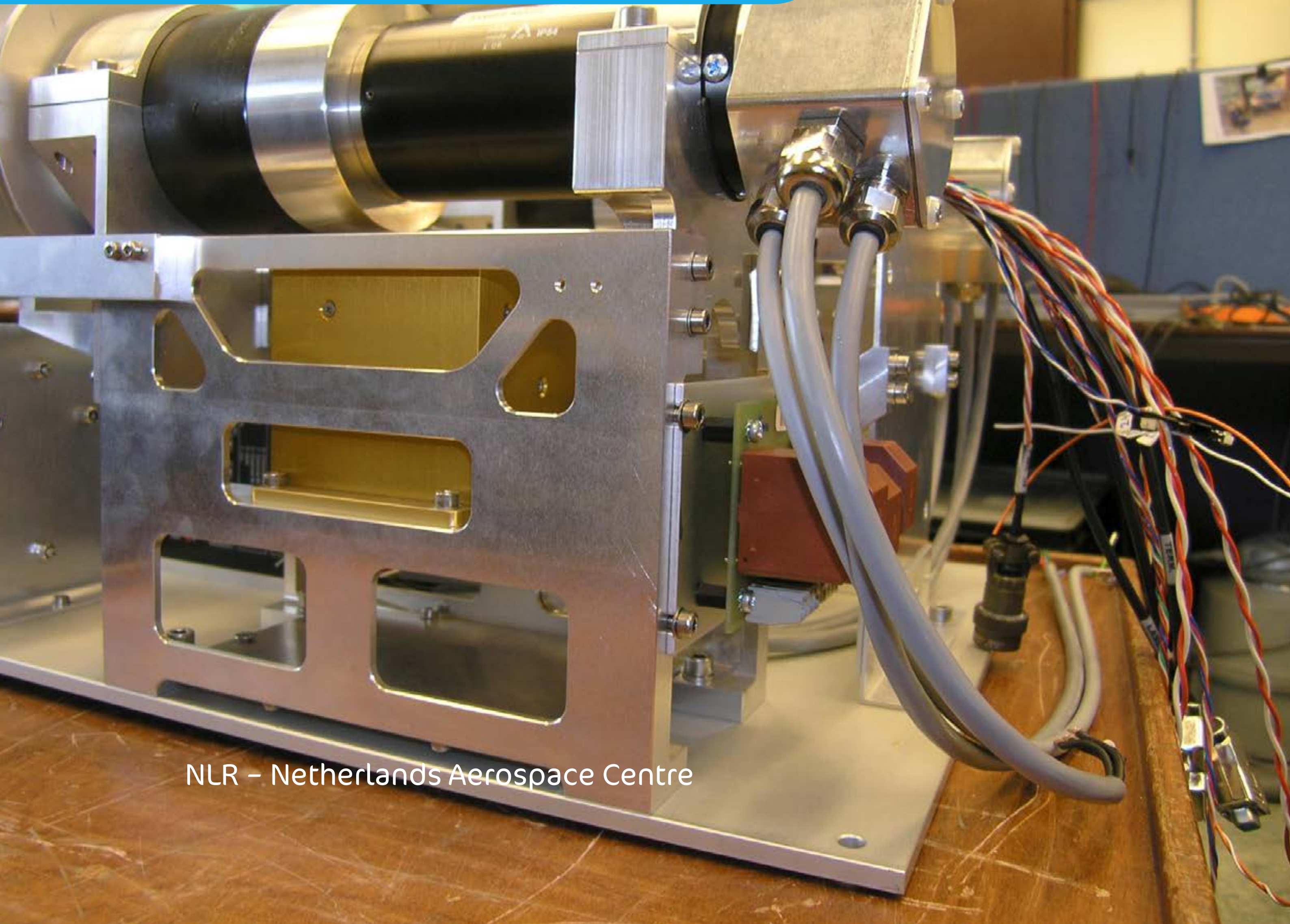
Exploitation of ACTUATION2015 Pre-Standardisation Activities on Power-By-Wire

CUSTOMER: European Commission



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EXECUTIVE SUMMARY

UNCLASSIFIED

Exploitation of ACTUATION2015 Pre-Standardisation Activities on Power-By-Wire

Problem area

Standardisation of Electro-Mechanical Actuators (EMAs) for aircraft and the components of actuators promises significant benefits for actuator suppliers and aircraft manufactures. The most important benefits are compatibility of actuator components and the interoperability induced by it. Reuse of components is thereby promoted, potentially leading to reduced overall cost. There are, however, also some drawbacks, including the limited possibilities to design the actuator as light as possible and with the reliability required for its specific application. In general, any standardisation of products is faced with benefits and drawbacks and a certain level of standardisation is the optimum. The benefits and drawbacks for hydraulic actuators and for Power-By-Wire actuators, the EMA and Electro-Hydrostatic Actuator (EHA) are addressed in this paper.

Description of work

This paper discusses the existing standardisation applicable for hydraulic actuators and presents activities leading to standardisation of Power-By-Wire actuators. The standardisation of the EHA has interesting parallels with EMA standardisation efforts. A modular approach for the design of the actuators and especially for the EMAs contributes to the potential for standardization.

The modular EMA design and the standardisation are subject of the EC FP7 ACTUATION2015 project. Project results were input for pre-standardisation activities of CEN Workshop 77 on Modules for Electro-Mechanical Actuators in Aircraft. The current status and the future development of standardisation is presented.

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Electro-Hydrostatic Actuator
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Modular Design
Standardisation

Results and conclusions

Benefits and drawbacks of standardisation of aircraft actuators determine an optimum standardisation level. The standardisation of the electrical components of aircraft actuators appears to be beneficial at a higher level than the standardisation of mechanical components. This appears in more standardisation of the servovalve compared with the rest of the hydraulic actuator. For the EHA and especially for the EMA, standardisation is not yet mature. Also there, standardisation is progressing in particular for the electrical components and modules. The higher level of standardisation is attributed to the fact that electrical interfaces are with the data and power buses of the aircraft that have a large commonality.

The ACTUATION2015 project provided the material for the definition of standardised EMA modules in CWA77. This work is to be continued by the aircraft actuator development community towards a full standard, for instance a CEN European Standard (EN) or ISO standard.

Applicability

The scope of future Power-By-Wire actuator standards may cover EHA components and EMA modules. EHA components are not yet subject of CWA77 but show considerable commonalities with EMA modules described in the CWA.

GENERAL NOTE

This report is based on a presentation held at the 7th International Conference R3ASC 2016, Recent Advances in Aerospace Actuation Systems and Components, Toulouse, France, March 16-18, 2016.

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EXPLOITATION OF ACTUATION2015 PRE-STANDARDISATION ACTIVITIES ON POWER-BY-WIRE

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ABSTRACT

The modular EMA design and the standardisation are subject of the EC FP7 ACTUATION2015 project. Project results were input for pre-standardisation activities of CEN Workshop 77 on *Modules for Electro-Mechanical Actuators in Aircraft*. The current status and the future development of standardisation is presented.
Standardisation of Electro-Mechanical Actuators (EMAs) for aircraft and the components of actuators promises significant benefits for actuator suppliers and aircraft manufactures. The most important benefits are compatibility of actuator components and the interoperability induced by it. Reuse of components is thereby promoted, potentially leading to reduced overall cost. There are, however, also some drawbacks, including the limited possibilities to design the actuator as light as possible and with the reliability required for its specific application. In general, any standardisation of products is faced with benefits and drawbacks and a certain level of standardisation is the optimum.
This paper discusses the existing standardisation applicable for hydraulic actuators and presents activities leading to standardisation of Power-By-Wire actuators, the EMA and Electro-Hydrostatic Actuator (EHA). The standardisation of the EHA has interesting parallels with EMA standardisation efforts. A modular approach for the design of the actuators and especially for the EMAs contributes to the potential for standardisation. Standardisation of the more electric modules of the EMA appears more beneficial compared with the standardisation of more mechanical modules.

KEYWORDS

Electro-Mechanical Actuator, Electro-Hydrostatic Actuator, Hydraulic Actuators, Modular Design, Standardisation, ACTUATION2015

I INTRODUCTION

Standardisation is a process that enhances compatibility and interoperability of products. Standardisation has benefits, but there are also drawbacks. The benefits and drawbacks for hydraulic actuators and EMAs for aircraft are addressed in this paper.
The standardisation of hydraulic actuators for aircraft is limited. Important standards have been developed for the specification of parameters, such as [SAE ARP 1281] and [SAE ARP 4058]. For testing actuators, standards are also available, such as [SAE ARP 5724] and [SAE ARP 1383]. This facilitates the aerospace community to communicate better as the terminology and understanding of the characteristics of the product will be the same for the most important features.
Further standardisation of architectures or interfaces of the hydraulic actuator only exists for the servovalves, a component commonly applied in aircraft actuators. [SAE ARP 490F] describes the electrohydraulic servovalve. The compatibility of components of actuators or actuators themselves is however limited and not covered by standards. This is the status whereas the market for hydraulic actuators for aircraft can be considered as mature and the balance

between gaining benefits and drawbacks due to standardisation of the actuators or actuator components apparently is optimal at a low level. The electrohydraulic servovalve is a component with a larger degree of standardisation and the paper will consider the standardisation of this component in more detail.
The EMA is a system that is expected to play a major role in the aircraft of the future. Future aircraft are expected to be far more electric, without or virtually without hydraulics. The EMA will have benefits of highly efficient power to actuation conversion. The market for EMAs is currently very small but is expected to grow rapidly. The ACTUATION2015 project has the objective to prepare the industry for the introduction of the EMAs. Several EMAs are developed in the project for different applications on different types of aircraft. A modular approach is applied for the design of the actuators. Standardisation of modules is an option that is investigated through the development and test of the modules and the actuators. The project delivered experiences with this process and experience with finding the level of standardisation of modules. An initial effort towards developing a standard for some of the modules resulted from the project. The experience gained with the standardisation process and the process of developing the standard for modules is addressed in the paper.
The EHA has been applied in several aircraft for some time. Therefore the product is more mature than the EMA, but has not the long track record of the hydraulic actuator in aircraft applications. Standardisation of terminology and specifications has also been addressed, for instance in [ISO 22072]. Further standardisation efforts are ongoing in [SAE ARP 6154] – design, performance and test requirements for an Electro-Hydrostatic Module (EHM). The standardisation process is reviewed to find parallels with the standardisation efforts of hydraulic actuators and EMAs.
Section II of this paper addresses standardisation aspects in general. Section III addresses the standardisation of servovalves for hydraulic actuators and Section IV summarizes the experience and results of the standardisation of modules of EMAs in the ACTUATION2015 project and the CEN Workshop 77 – *Aerospace series – Modules for Electro-Mechanical Actuators in Aircraft*. Section V presents an overview of the standardisation processes of actuators in aircraft also taking into account the EHA standardisation.

II Standardisation and ACTUATION2015

The most tangible result of a standardisation process is the release of a written standard, such as practiced by CEN, ISO, SAE and other standardisation bodies as a result of deliberate work of and discussions between experts. The consequences for the product are however much more important. Standardisation leads to commonalities between products which is an advantage if different products for the same purpose are applied. The level of standardisation can differ. Roughly the following levels can be distinguished for products such as an aerospace actuator:

- Standardised terminology. In specifying and describing the relevant parameters of a product, the wording and the parameters are standardised. This improves the communication about the product. For instance, if an industry invites suppliers to quote components for an actuator, unambiguous terminology should be used to describe the component.
- Tests of the product. The qualification of products is determined by applying standardised tests, procedures and reporting of test results. This also improves the communication about a product such as described in the example above.
- Interfaces. Interfaces for integrating the product in its intended operational environment are standardised.
- Performance and interfaces. The product can be replaced by a different product conforming to the same standard, or at least the standard will give guidance to verify interchangeability.

Standardisation obviously has advantages such as improved communication preventing that a supplier delivers a product that does not comply with the intended application for the lower levels and the replacement of a product of one supplier by the product of another supplier for the higher levels. The optimisation of a product for a specific application is however endangered by standardisation. Specific engineering of a product will result in a product with the best weight, size, reliability, cost, environmental qualifications, etc. The balance between standardisation and optimisation for a specific application leads to choices on the level of standardisation. In this paper the standardisation of actuators for aircraft is addressed.
However, before addressing the standardisation of aircraft actuators, the standardisation of screws is shortly discussed as it demonstrates advantages and drawbacks of standardisation clearly and appeals to what every engineer experiences “daily”.
Threads of screws are standardised in [ISO 261]. The standard is widely applied and terminology as M1, M2, M3, M4, etc. is what every young engineer and mechanic learns quickly. The standard describes amongst others diameters, pitches and profiles. Except for the integer number of diameters (M1, M2, ..), also intermediate numbers are standardised (M1.2, M1.6, ..). Furthermore, [ISO 261] describes a coarse and a fine pitch. The surprising fact is that in a mechanical shop a common stock is kept for integer diameter and coarse pitch screws and that it fulfils the daily usage requirements.
Many shapes of the heads of screws are in use. The pan head, flat head, round head, oval head and a myriad of other shapes exist. Furthermore, heads interface with different screw drivers or wrenches. The slotted head, cross head, Phillips head, Allen head, square head, hexagonal head and many others. Standards probably exist that describe all these heads.
An interesting conclusion can be made from the standardisation of screws. The “market” pushes the application of a limited number of threads on screws (M1, M2, …, coarse pitch). This is apparently beneficial for the market (at least in Europe), while written standards exist for

various threads. On the other hand, the "market" apparently considers a large number of screw heads beneficial. Different applications require different heads.
As the "market" for screws can be considered as mature, the weighing of benefits and drawbacks of standardisation resulted in the standardisation level described above. The paper will further address the standardisation of actuators for aircraft and the level of standardisation for different market maturities:

- The market for hydraulic actuators may be considered as mature as they are on the market for a long time.
- The market for EMAs is new and the standardisation of the product is in its infancy. Benefits and drawbacks are largely unknown. The ACTUATION2015 project aims to speed up the standardisation process for EMAs by having many European stakeholders working together on the development of standardised modules and experiencing the benefits and drawbacks in its early development.
- The market for EHAs is new compared with the market for hydraulic actuators, but more mature than the market for EMAs, as EHAs are applied in military aircraft for decades and also in large passenger aircraft such as the Airbus A380.

An attempt will be made to understand what the level of standardisation is for the existing markets and what the optimum level will be for the emerging markets.

III Servovalve standardisation

Standardisation is developed for the electrohydraulic flow control servovalves, or in short, the servovalve, in [SAE ARP 490]. The servovalve is the commonly applied component in a fly-by-wire hydraulic actuator configuration to convert an electric control signal into a hydraulic fluid flow to and from a hydraulic actuator of a moving aircraft surface or part. The dynamic behaviour of movables such as the primary flight control surfaces is of crucial importance for the aircraft and the characteristics of the servovalve are therefore of crucial importance.
The standardisation of the servovalve in ARP 490 leaves considerable freedom for the designer to optimise the servovalve for an application. The standardisation comprises recommended practices with respect to the development of a procurement specification, recommended test methods and quality assurance and reliability considerations. The first version of the ARP was published in 1958, which indicates that this level of standardisation may be considered as appropriate for this component.
The standard does provide recommendations with respect to the architecture of the component, including detailed descriptions of the hydraulic and electric connections to the component and the identification of connections. This allows the definition and evaluation of parameters of the servovalve. Numerical values are provided for different sizes of the servovalve, but also many parameters are not specified to allow flexibility to the valve designers to apply optimal designs for specific applications with their specific requirements.
The servovalves applied in hydraulic actuators in ground equipment have a slightly higher level of standardisation. "General purpose" servovalves are for instance Moog type 30 series servovalves. For these ground applications some additional standardisation is applicable for the interfaces such as [ISO 10372] and [ISO 4401]. The market for ground applications is apparently different, probably because the balance between weight, reliability and cost, combined with the size of the market developed to another optimum in the standardisation level.

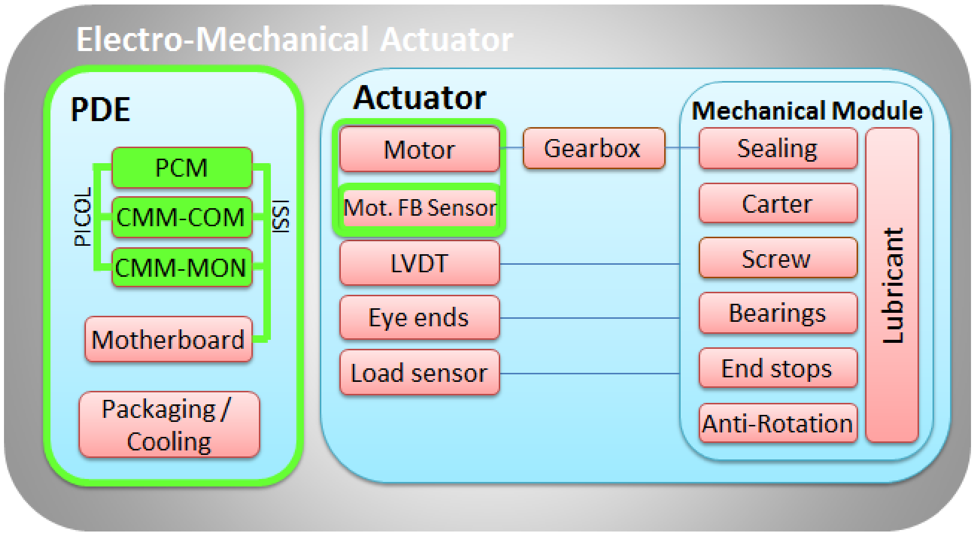
IV EMA standardisation and ACTUATION2015

4.1 Modular EMA design

The EC supported project ACTUATION2015 took up the challenge to make significant steps in the EMA standardisation process. The project took an approach for the design and standardisation in which the functionality of the EMAs is assigned to different modules. As such, ACTUATION2015 aims to develop and validate a common set of standardised, modular and scalable Electro Mechanical Actuator (EMA) resources for all actuators (flight control, high lift, landing gear, door, thrust reverser) and all types of aircraft (business/regional/commercial airplanes and helicopters).
Providing modular EMAs will address current aircraft manufacturers' requirements regarding the variety reduction, compatibility and interchangeability and allow these aircraft manufacturers to adopt the technology. ACTUATION2015 innovates through:

- Modularity: move from custom made actuators to actuators made from standard off-the-shelves modules and implemented using a standardised design process and a common validation method and tools.
- Module sharing: design electric actuation functions as parts of a global aircraft electrical architecture and not as single and independent functions to shared modules, support redundancy and save weight addressing actuation functions at an aircraft level and not at an equipment level.
- Standardisation: identify and specify a set of EMA building blocks (modules) that can be standardised and thereby facilitate multiple sources of module supply and lower EMA certification and acquisition cost.

The EMA modules identified in the ACTUATION2015 project are shown in Figure 1.



PDE	Power Drive Electronics	**PCM**	Power Core Module
Mot. FB Sensor	Motor Feedback Sensor	**CMM-COM**	Control and Monitoring Module – Control
LVDT	Linear Variable Differential Transformer	**CMM-MON**	Control and Monitoring Module – Monitor
PICOL	Protocol for Inverter Control Over LVDS	**ISSI**	Internal Standardized Supply Interface

Figure 1 EMA modules.

4.2 Standardisation activities

A CEN Workshop developed an agreement [CEN CWA77] on how EMA modules are to be described in a future standard. The ACTUATION2015 provided important input for the workshop as participants brought their experience in the design of standardised modules to the workshop.

Not all modules appeared to be suitable for a standardisation effort. The modules and interfaces with a green outline in Figure 1 are dealt with in the CWA:

- Power Drive Electronics (PDE), including the Internal Standardized Supply Interface (ISSI).
- Power Core Module (PCM).
- Control & Monitoring Module (CMM).
- Protocol for Inverter Control Over LVDS (PICOL).
- Motor interface, including the motor position feedback sensor (Motor interface).

The CWA provides terminology, functional descriptions, interfaces and requirements, both environmental requirements and detailed technical requirements for the EMA components. Detailed interfaces, such as connector types and pin allocations, are described. The EMA standardisation effort should be continued after the release of the CWA as the CWA should serve as the first step towards the release of a full standard. A CWA is just valid for 3 years, with a possibility to extend for another 3 years if a full standard release is intended but not available yet.

The standardisation scope for EMA modules may be extended. The current components subject to standardisation are a subset of all the modules. Also mechanical modules should be considered for standardisation, perhaps not at the same (high) level as the electrical components, but terminology, tests (for as far not in general aircraft actuator tests), architecture and interface descriptions.

The aircraft actuator development community is encouraged to find the right levels for standardisation of the EMA and its modules because proper standardisation levels will provide the largest benefits for the supplier of actuators (large market) and for the aircraft manufacturers (cost reductions for logistics, spares, amongst others).

Within the airworthiness regulations, modular certification is currently not supported, so ACTUATION2015 partners have proposed an approach that should provide the evidence needed for modular certification of EMAs. The method is similar to the one applied for Integrated Modular Avionics (IMA) [EUROCAE ED-124]. The modular qualification and certification of EMAs will benefit largely from a standardised approach. This will reduce the substantiation of specific qualification and certification processes largely. Describing such an approach in a standard equivalent to the [EASA ETSO-2C153] standard available for IMA qualification and certification is recommended.

V Considerations on aircraft actuator standardisation

Standardisation of the hydraulic actuator as a product exists for terminology and for testing. Further standardisation is available for the servovalve. The standardisation up to this level is apparently profitable as the market and the associated standardisation should be considered as mature. This may be understood by the specific requirements for the hydraulic actuators in aircraft. The space for installation is limited and not uniform, the weight of the actuator is to be minimized as this determines the efficiency of the aircraft, the reliability objective is dependent on the aircraft FHA and the environment in which the actuator is operated is dependent on its location on the aircraft. All these variables make that designs optimised for specific applications are more beneficial than the profits from commonality of actuators, which may probably be mostly towards lower purchase and logistics costs of the actuator.

From the ACTUATION2015 experience of developing EMA modules, it appears that the standardisation of the electrical modules can be chosen at a higher level relative to the more mechanical modules. The modules described in the CWA are the more electrical parts of the EMA. This can be related to the similarity of interfaces for electrical modules. All electrical modules interface with the same aircraft busses for data and for power supplies. In the CWA some versions for lower power and higher power are defined, for instance for the PCM, but with that variation of, in this case, 4 sizes of the PCM, standardisation is feasible.

For the hydraulic actuator also the more electrical component, the servovalve, is the component of higher standardisation. Also here the more uniform electrical interface, in contrast with the many optimisation possibilities for the mechanical solution may provide the optimum in standardisation level.

The EHA can be placed in a middle position between the hydraulic actuator and the EMA with respect to maturity. EHA standardisation follows a similar track as the hydraulic actuator and the associated servovalve standardisation. The more electric component of the EHA, the EHM is again subject to a higher level of standardisation. The standard developed for the EHA contains however much more technical details than the standard for the servovalve.

The EMA electrical modules standardisation and EHA standardisation show a potential for mutual fertilisation. The interfacing of the actuator with the aircraft buses is very similar and modules as the CMM and interface protocols may be applicable for both types of actuators.

This applicability of modules for EMAs and EHAs, together with the continuation of the EMA standardisation effort bringing the CWA towards a definite new standard, offers a nice challenge for the aircraft actuation community.

CONCLUSION

Benefits and drawbacks of standardisation of aircraft actuators will determine an optimum standardisation level. The standardisation of the electrical components of aircraft actuators appears to be beneficial at a higher level than the standardisation of mechanical components. This appears in more standardisation of the servovalve compared with the rest of the hydraulic actuator. For the EHA and especially for the EMA, standardisation is not yet mature. Also there, standardisation is progressing in particular for the electrical components and modules. The higher level of standardisation is attributed to the fact that electrical interfaces are with the data and power buses of the aircraft that have a large commonality.

The ACTUATION2015 project provided the material for the definition of standardised EMA modules in CWA77. This work is to be continued by the aircraft actuator development community towards a full standard, for instance a CEN European Standard (EN) or ISO standard. The scope of such standards may be extended to cover commonalities with EHA components as the EHM and the other EMA modules not yet subject of CWA77.

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NOTATIONS

Abbreviations

ACARE	Advisory Council for Aeronautics Research in Europe (EU)
ARP	Aerospace Recommended Practice
CEN	European Committee for Standardization
CMM	Control & Monitoring Module
CWA	CEN Workshop Agreement
EASA	European Aviation Safety Agency
EC	European Commission
EHA	Electro-Hydrostatic Actuator
EHM	Electro-Hydrostatic Module

EMA	Electro-Mechanical Actuator
EN	European Standard
ETSO	European Technical Standard Order
FHA	Functional Hazard Analysis
FP	Framework Programme
IMA	Integrated Modular Avionics
ISO	International Organization for Standardization
ISSI	Internal Standardized Supply Interface
LVDS	Low Voltage Differential Signaling
PCM	Power Core Module
PDE	Power Drive Electronics
PICOL	Protocol for Inverter Control Over LVDS
WG	Working Group

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