Electric/Hybrid Propulsion System (EHPS) Progress and roadmap to means of Compliance definition

EASA Webinar

13th December 2023

EASA
European Union Aviation Safety Agency

Opening

Frank Steffens

EASA Head of Department - Environment & Propulsion Systems • Department

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EHPS 2023 Webinar

EHPS-Industry view

Introduction

Herdrice HERESON

EASA Section Manager- GA&VTOL Propulsion &Powerplants systems

Javier CASTILLO

EASA Section Manager – LA Propulsion &Powerplants systems

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Morning Agenda

9:00-09:05: **Opening**

Frank STEFFENS-EASA Head of Department - Environment & Propulsion Systems

09:05-09:12: **Industry view**

Keynote (video), Jean Clair PRADIER- Head of Airworthiness at Safran Electrical & Power - Industry Standards working group representative (SAE E40& EUROCAE WG113)

09:12-09:20: **Introduction**

Herdrice HERESON-EASA Section Manager-GA&VTOL Propulsion &Powerplants systems &

Javier CASTILLO-EASA Section Manager-LA Propulsion &Powerplants systems &

09:20-09:50: EHPS A certification challenges on the road to sustainability

Regis ROSSOTTO-EASA Senior Expert – Powerplant GA/VTOL and Electric & Hybrid Propulsion Systems

- 09:50-10:00: *Session for selected questions submitted on Slido (www.slido.com code: #EHPS2023)*

10:00-10:20-: **Roadmap to SCE19-EHPS MOC &Guidance**

Arjan VAN DIJK-EASA Propulsion Project Certification Manager

- 10:20-10:30: *Session for selected questions submitted on Slido (www.slido.com code: #EHPS2023)*

Morning Agenda

10:30-10:50: **Certification of propulsion battery**

Carlos MUNOZ GARCIA-EASA New Electrical Technologies Expert

- 10:50-11:00-*Session for selected questions submitted on Slido (www.slido.com code: #EHPS2023)*

11:00-11:20: **Authorities cooperation -Certification Management Task (CMT) -Task Specific Team (TST)-**

Éric FLEURENT-WILSON, Powerplants & Emissions, Transport Canada /EHPS CMT-TST Representative

- 11:20-11:30: *Session for selected questions submitted on Slido (www.slido.com code: #EHPS2023)*

11:30-11:45: **Challenges of new design organizations**

Damian KOCJANCIC-EASA DOA Team Leader

- 11:45-11:55: *Session for selected questions submitted on Slido (www.slido.com code: #EHPS2023)*

11:55-12:00: **Conclusion**

Herdrice HERESON-EASA Section Manager GA&VTOL Propulsion &Powerplants systems

- End

Afternoon Agenda

15:00-15:05: **Opening**

Frank STEFFENS-EASA Head of Department - Environment & Propulsion Systems

15:05-15:12: **Industry view**

Keynote (video), Jean Clair PRADIER- Head of Airworthiness at Safran Electrical & Power - Industry Standards working group representative (SAE E40& EUROCAE WG113)

15:12-15:20: **Introduction**

Herdrice HERESON EASA Section Manager GA&VTOL Propulsion &Powerplants systems and

Javier CASTILLO EASA Section Manager -LA Propulsion General Aviation

15:20-15:50: **EHPS A certification challenges on the road to sustainability**

Regis ROSSOTTO-EASA Senior Expert – Powerplant GA/VTOL and Electric & Hybrid Propulsion Systems

- 15:50-16:00: *Session for selected questions submitted on Slido (www.slido.com code: #EHPS2023)*

16:00-16:20-: **Roadmap to SCE19-EHPS MOC &Guidance**

Arjan VAN DIJK-EASA Propulsion Project Certification Manager

- 16:20-16:30: *Session for selected questions submitted on Slido (www.slido.com code: #EHPS2023)*

Afternoon Agenda

16:30-16:50: **Certification of propulsion battery**
Carlos MUNOZ GARCIA-EASA New Electrical Technologies Expert

- 16:50-17:00-*Session for selected questions submitted on Slido (www.slido.com code: #EHPS2023)*

17:00-17:20: **Authorities cooperation -Certification Management Task (CMT) -Task Specific Team (TST)**
Éric FLEURENT-WILSON-Powerplants & Emissions, Transport Canada /EHPS CMT-TST Representative

- 17:20-17:30: *Session for selected questions submitted on Slido (www.slido.com code: #EHPS2023)*

17:30-17:45: **Challenges of new design organizations**
Javier CASTILLO-EASA Section Manager-LA Propulsion &Powerplants systems
on behalf of **Damian KOCJANCIC** EASA DOA Team Leader

- 17:45-17:55: *Session for selected questions submitted on Slido (www.slido.com code: #EHPS2023)*

17:55-18:00: **Conclusion**
Herdrice HERESON-EASA Section Manager-GA&VTOL Propulsion &Powerplants systems

- End

EHPS a certification challenges on the road to sustainability

Regis ROSSOTTO

EASA Powerplants GA&VTOL &EHPS Senior Expert

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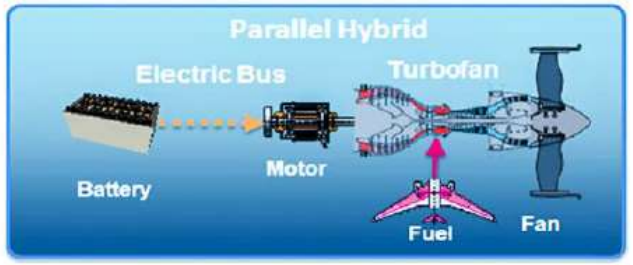
What is an EHPS?

Parallel hybrid

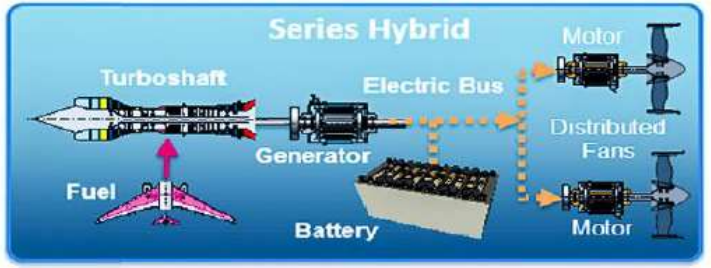


A system that uses a battery-powered motor and gas turbine engine both mounted on a shaft that drives fan, so one or both can provide propulsion at any given time

All electric

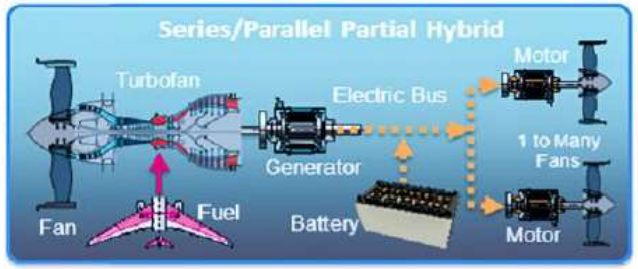
All-electric aircraft systems use batteries as the only source of propulsion power

Series hybrid



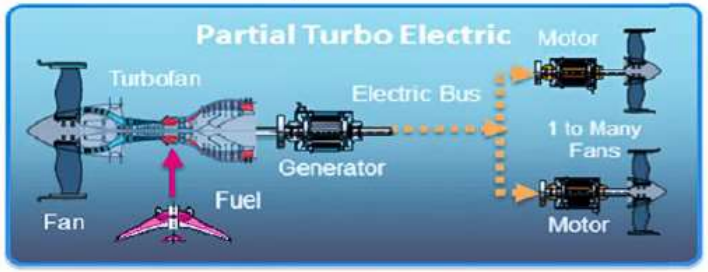
A system where only the electric motors are connected to the fans, and the gas turbine engine is used to drive an electrical generator which drives the motors and/or charges the batteries

Series/parallel partial hybrid



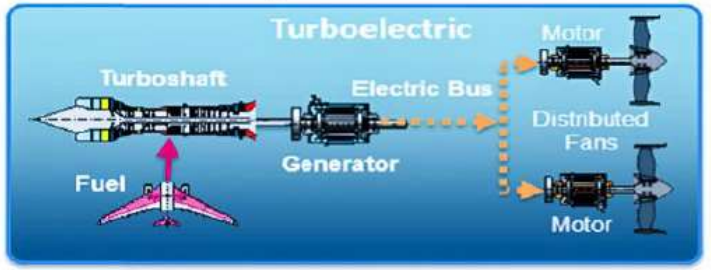
A system with one or more fans that can be driven directly by a gas turbine engine, and additional fans that are driven exclusively by electrical motors which can be powered by a battery or a turbine-driven generator

Partially turboelectric



A system that uses electric propulsion to provide part of the propulsive power, with the rest provided by a turbofan driven by a gas turbine

Fully turboelectric



A system that relies fully on gas turbines to drive electric generators which then power inverters and motors to drive disturbed fans

source: https://www1.grc.nasa.gov/aeronautics/eap/airplane-concepts/aircraft-configurations/

No H2

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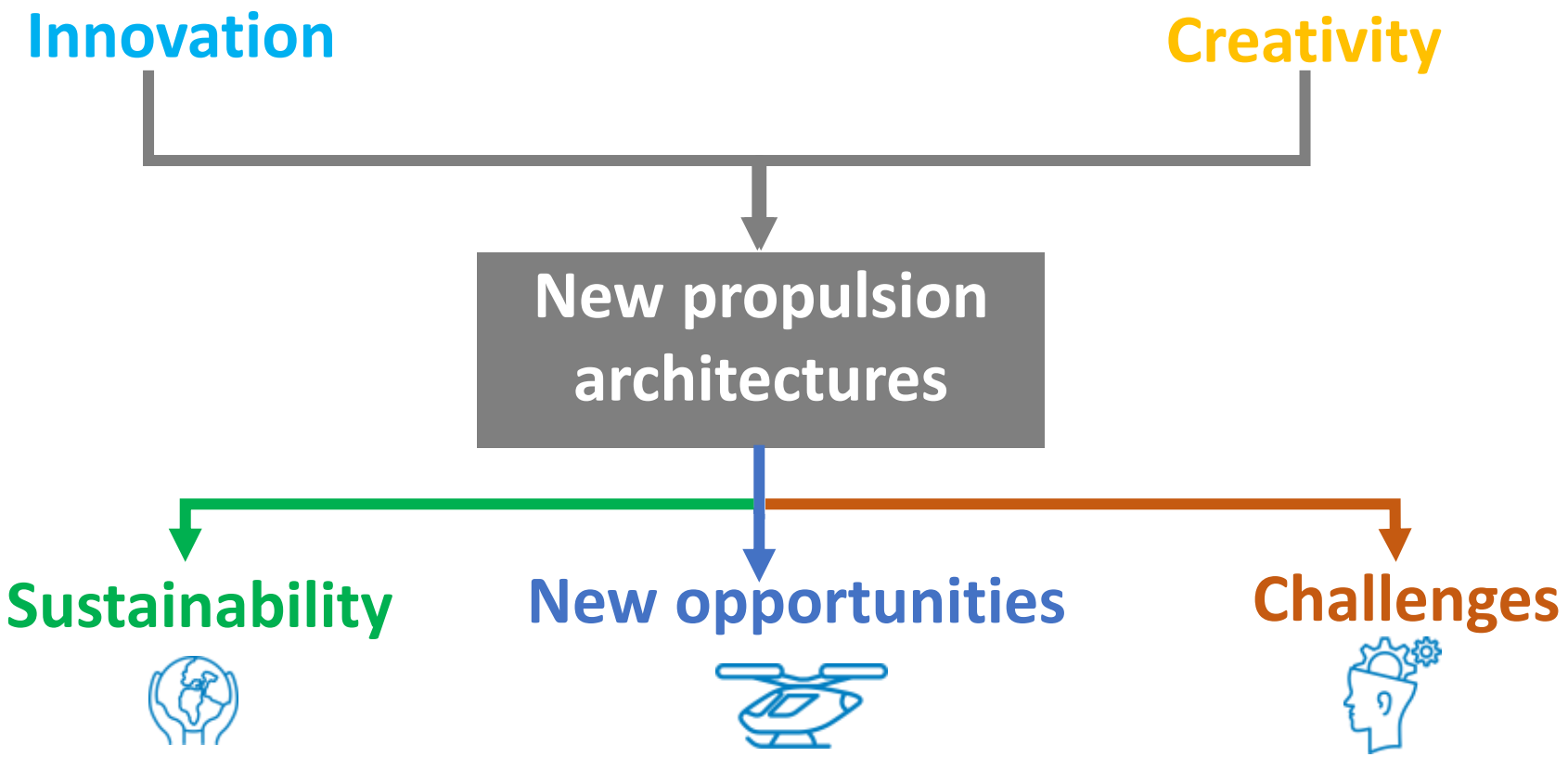
EHPS - enablers to aviation change

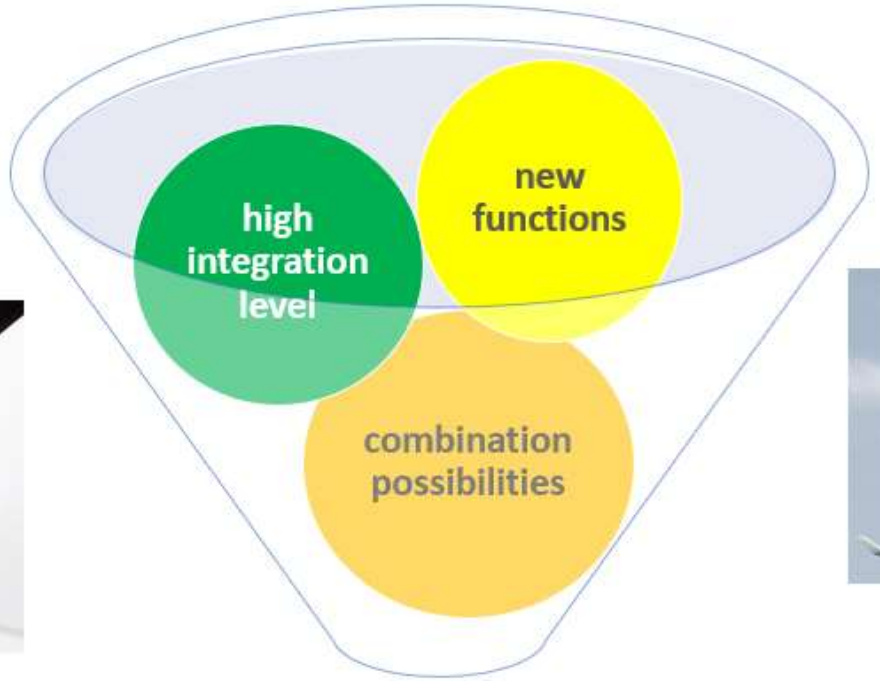


Current EHPS project Landscape

From single electric engine to complete hybrid and distributed propulsion systems

- 2 certified products
- 2 engine TC application for CS23 aircraft level 1&2
- Support as Engine &Powerplant experts on a CS25 Aircraft TC project using Electric propulsion systems
- Support as Engine &Powerplant experts on several e-VTOL TC projects
- Support as Engine &Powerplant experts on several CS23 Aircraft TC & STC projects using Electric propulsion systems
- Support as Engine &Powerplant experts on several Balloon and Airship TC projects using Electric propulsion systems
- Support as Engine &Powerplant experts on IPC (Innovation Partnership Contracts), TAC (Technical Advice Contracts), Clean Aviation, Research projects,
- Expected future involvement on US Validation projects of Engine TC and eVTOL

Challenges



~~PRESCRIPTIVE RULES~~

PERFORMANCE BASED RULES

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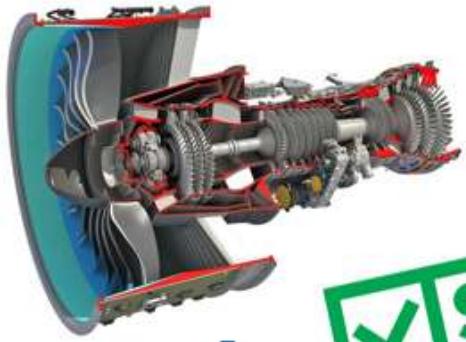
Supporting safe EHPS market entry

TODAY

60 years of aviation experience → Prescriptive regulations →  → SAFE

Imposing the same safety records

TOMORROW?

Step by step: from small to large products → Performance Based Rules + Industry Standards →  → SAFE

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EASA SC Available - Safety continuum

Certification Challenge- Performance based rule

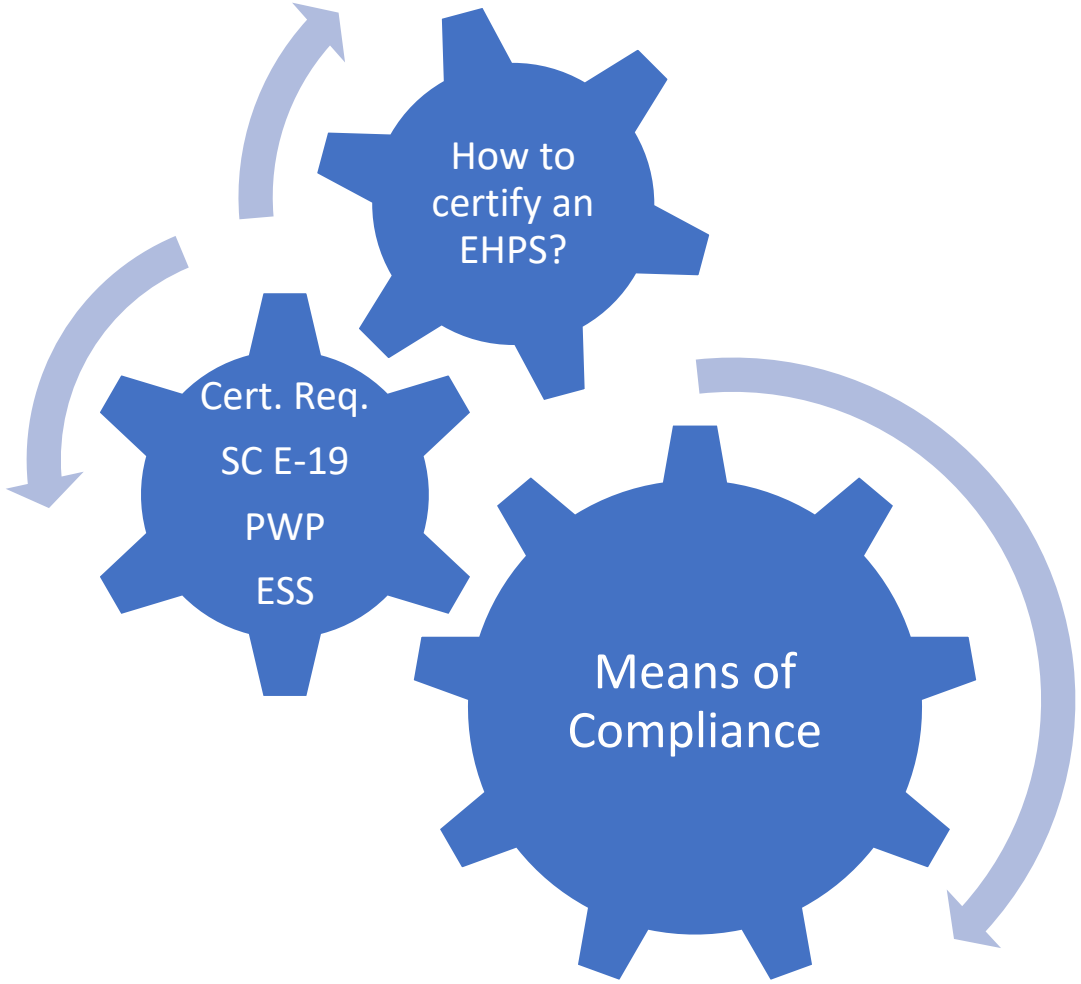
- SC E-01: Airworthiness standard for CS-22H Electrical retractable engine to be operated in powered sailplanes
- SC-22.2014-01 issue 2: Installation of electric propulsion units in powered sailplanes

- CS-LSA → ASTM F2840-11: Standard Practice for Design and Manufacture of Electric Propulsion Units for Light Sport Aircraft
- SC LSA-15-01 – Light Sport Aircraft – Electric Propulsion Powerplant

- SC E-18 issue 2 - Electric Propulsion Units for CS-23 Normal-Category Aeroplanes up to Level 1 (aim to make use of ASTM F3338-18 to have a joined approach with the FAA)

- SC E-19 – Electric / Hybrid Propulsion System (EHPS)- A performance based SC
  for all products categories except low end products such as UAS, sailplanes, LSA

EASA focuses



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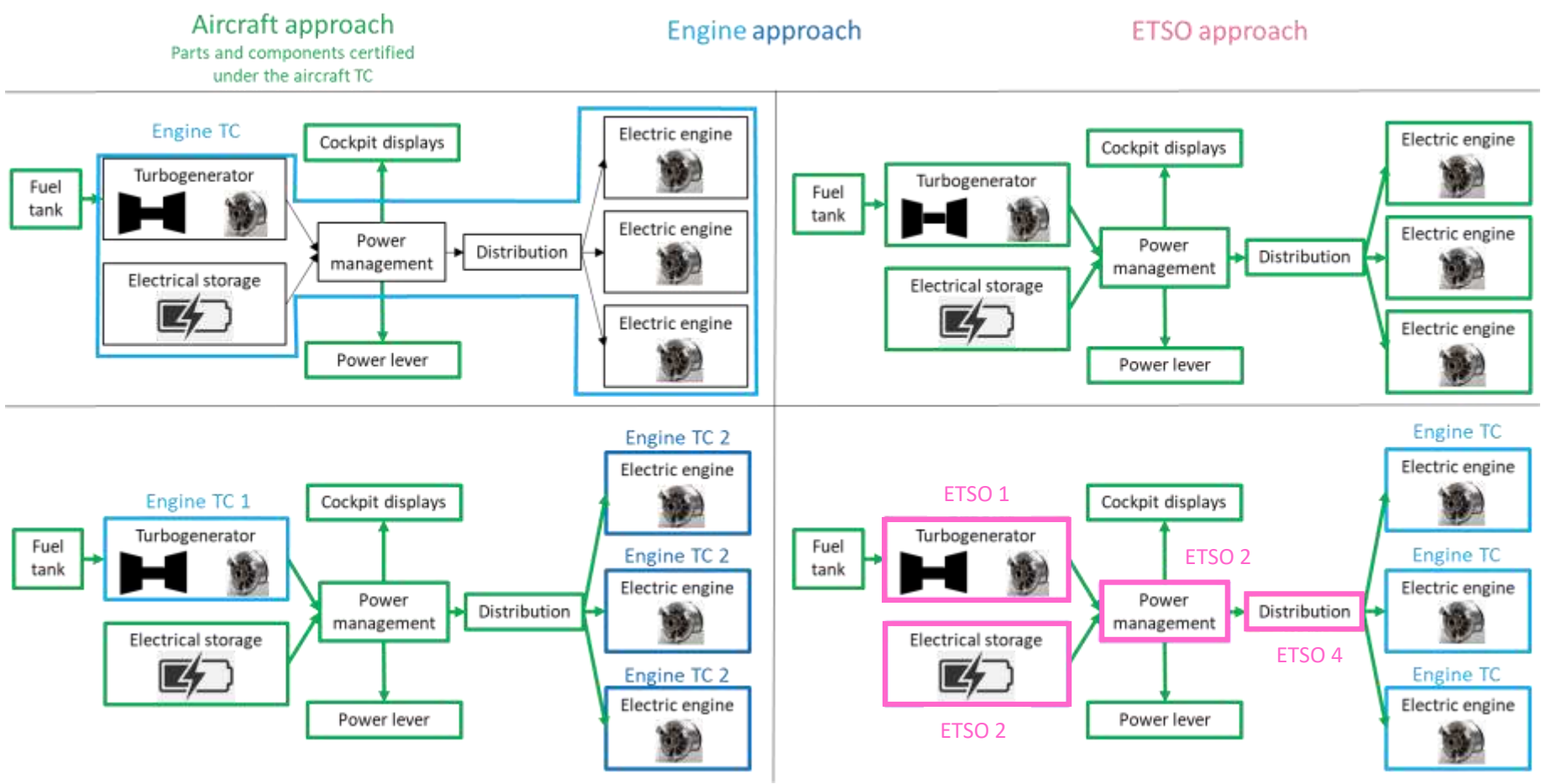
HARMONIZATION WITH FOREIGN AUTHORITIES

How to certify EHPS?



Shared with FAA and TCCA

Cert Memo to Part 21 under finalization – Q1 2024 for public consultation

SCE-19

First projects making use of SC E-19

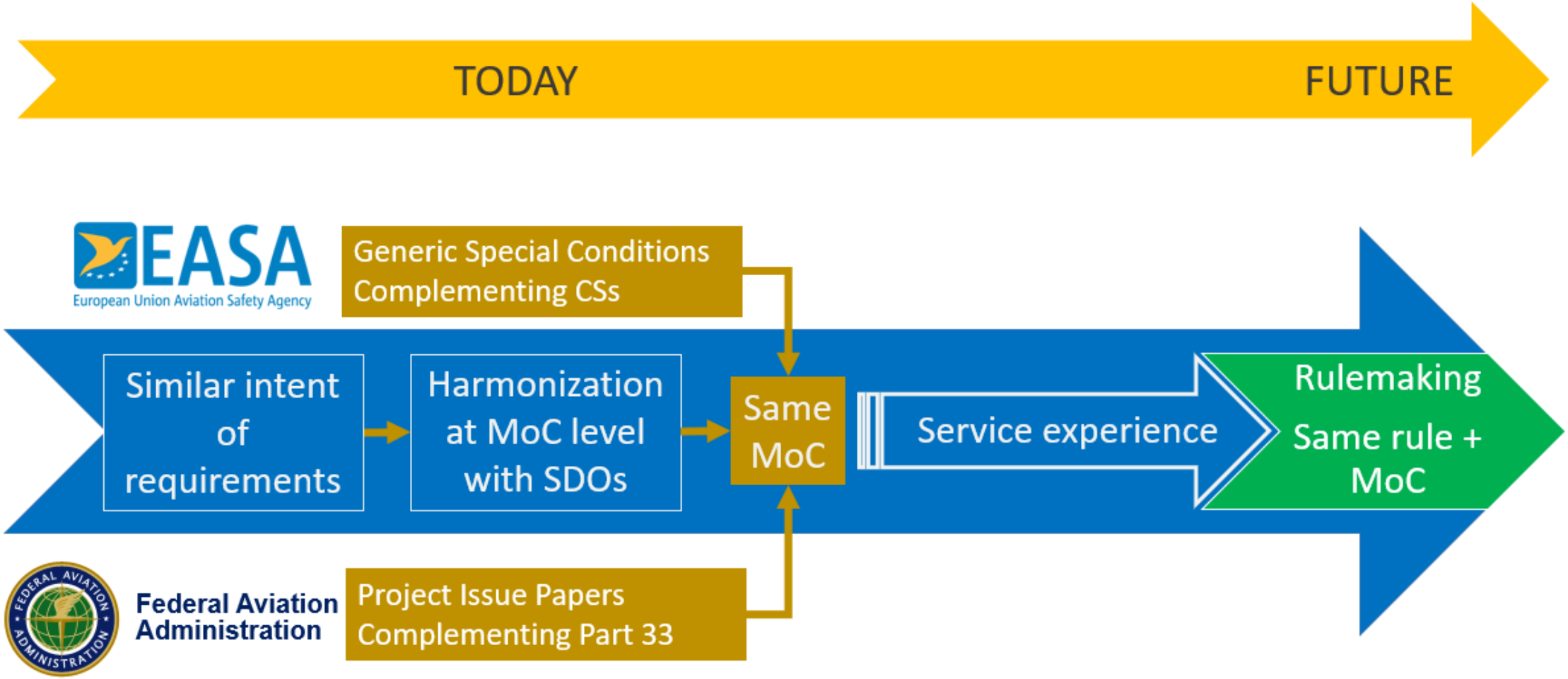
Identified improvements – clarifications only!

Update to come (2025)

EHPS integration (Powerplant)

LSA Sailplanes	Material available and used for several cert projects
GA	Intent of EASA to reuse FAA MOC for EHPS integration as they are running ahead of EASA (WiP with FAA Powerplant team) + ASTM standards
VTOL	MOC published by EASA + EUROCAE WG 112 standards
Other	TBD

Harmonization efforts



Harmonization efforts

CMT (Certification Management Team)
TST (task Specific Team) EHPS

Collaboration workshops / exchanges

Projects

Thank you!

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Progress and Roadmap to Means of Compliance definition

Arjan Van DIJK

EASA Propulsion Project Certification Manager

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Accessing SC E-19 MoC “under-construction” material

SC E-19 MoC- 3 Levels approach

Level 1 “**A la Carte**” **Tool** for guidance identification according to design specificities

Level 2 **Level 2** EASA **Means Of Compliance for** each requirement

- Guidance material & link to level 3 –#Subpart per Aircraft application

Explanation on Level 2: is the Main Webinar focus

Level 3 **Level 3** “**Methods of Compliance**”

- Published standards, CS-E or Certification Memo’s...

→ See next slide for example

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Level 1: MoC to SC E-19

→« A la carte » concept

	…	EHPS.230 Vibration Survey	EHPS.240 Overspeed and rotor integrity	…	EHPS.290 Bird, hail strike and impact of foreign matter	…
Adjacent engines		N/A	N/A		X	
Fan		X	X		X	
Electric engine		X	X		X	
Turbine		X	X		X	
High voltage						
…						

Requirements

Specific technical aspects

Inputs:
CS-E, AMC CS-E,CM, CRI, appropriate Standards (ASTM, SAE, EUROCAE…)

Agile and adaptable to innovation: can be quickly updated

MoC Level 2 and 3:

Example for EHPS.80

SC E.19 REQ	Level 2	Level 3	Name	Priority
EHPS.80	MOC.EHPS.80		Safety Assessment	1
		CS-E 850	Compressor, Fan and Turbine Shafts	
		AMC E850	Compressor, Fan and Turbine Shafts	
		CM -PIFS-017	Turbine engine HPT shaft loss of load and rotor integrity	
		CMT-XXX	LOPC Definition	
		AIR-XXX	Single Fault Tolerance	
		AIR-XX2	Reliability Database	
		IEC	Reliability Database	
		CS-E 510	Safety Analysis	
		CS-E 210	Failure Analysis	
		ARP4761	Safety Analysis Guidelines and Methods for conducting safety assessment process on civil airborne systems and equipment	
		ARP 4754A-ED-79A	Guidelines for the development of civil aircraft and systems	

i.e. **LOPC** and **Single Fault** explained as result of the exercise "GAP identification" in the existing MoCs (*see next slide*)

Rely on Industry to propose standards or methods of compliance to be accepted by EASA

MoC to explain how to use the Methods of Compliance and clarify its applicability

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MoCs GAP analysis

SC E-19 EHPS

Inventory for Electric Hybrid Propulsion Projects

Inventory of available Material

Missing Level 2,3 to develop

....

New Technologies – enable new architectures and vehicles designs –> new certification specification material

Guidance from EASA projects landscape

- More than 20 TC applications

-> review of proposed MoCs/ CRIs

- IPCs/TACs/PACs
- Research projects
- Working Groups

Existing published material

- CS-E- AMC's
- SC-VTOL MOC
- Certification Memos
- Industry Standards
- Others

Adaptation:

- Many existing material can be adapted.
- Explanation necessary of how to use the material to the EHPS technology.

New MoC or Standards:

- To be developed, i.e. by EUROCAE, SAE

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MoCs GAP analysis: An iterative process

Gap analysis conclusion ->
> 40 MOC (Level 2) to be developed-adapted by EASA
> 100 Level 3 documents to be developed mostly by Industry for the EHPS technologies identified.

New applicants bringing new concepts and new needs ->
Matching synergies of technical topics with available standards.

Iterative process to publish the right MoCs involving Industry and EASA bilateral pertness as soon as possible.
Safety as a common goal.

Need of Prioritization!

Priorisation MOC development for EASA

Group 1
Mature Projects
Electric Engines with Propulsion Batteries

Focus on Level 2 documents needed for mature Engine TC , Aircraft TC and VTOL projects for which certification is expected in the coming years

Group 2
Less mature designs

Common Core EHPS “Technical Aspects” treated in Group 1 will address already most of group 2 items.

Group 2 will focus on specific design needs of less mature projects

Industry Contribution to EUROCAE/SAE working-groups essential to address design specificities

Priority 1 in MOC for Req's

SC E-19	MoC	Title	Notes / Higlights
EHPS.15	MOC.EHPS.15	Terminology	• SAE E-40 : ARP8676
EHPS.40	MOC.EHPS.40	Ratings and Operating Limitations	• EUROCAE WG-113: ED-321 covers part of the Ratings/limitations • SAE E-40
EHPS.80	MOC.EHPS.80	Safety Assessment	• SAE E-40: Single Fault tolerance • CMT: LOPC definition • SAE AE-10 High Voltage Committee: Reliability data and acceleration factor
EHPS.100	MOC.EHPS.100	Fire Protection	• MOC.VTOL.2330 • ASTM F3338-18 Ch 5.5.1 • EUROCAE WG-112/113 Fire qualification of electric engine • Windmilling conditions after shortcut
EHPS.240	MOC.EHPS.240	Overspeed and Rotor Integrity	• MOC drafted, under review
EHPS.250	MOC.EHPS.250	Rotating Parts Containment	
EHPS.350	MOC.EHPS.350	EHPS Control System	• MOC to be developed, lot of material/standards available
EHPS.370	MOC.EHPS.370	Electrical Power Generation, Distribution and Wirings	• EUROCAE WG-112 + SAE E-40 • EWIS proportionality • EUROCAE WG-116 High Voltage, (1 of 4 standards close to publication)
EHPS.380	MOC.EHPS.380	Propulsion Battery	
EHPS.420	MOC.EHPS.420	Endurance Demonstration	• EUROCAE WG-113: ED-321 GM for endurance substantiation of EHPS – final stage • SAE E-40: ARP8689 Endurance tests for Aircraft Electric engine • Alternatives to teardown inspection for electric engines
EHPS.430	MOC.EHPS.430	Durability Demonstration	
EHPS.450	MOC.EHPS.450	Teardown Inspection	
EHPS.460	MOC.EHPS.460	Operational Demonstration	• Power response, reference to CS-E paragraphs

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Priority 1 in MOC for Req's

Electric Engine – Safety Assessment

1. Power Loss Rates and LOPC Classification for GA Level 1&2
2. GA Aircraft Safety Assessment for electric Aircraft. *(coordination with ASTM F3230)*

Electric Engine

1. RATINGS
2. Safety Assessment for EE
3. Fire protection for EE
   (incl. windmilling conditions)
4. Vibration surveys
5. EWIS proportionality
6. Continuous Rotation / short circuit

Electric Engine

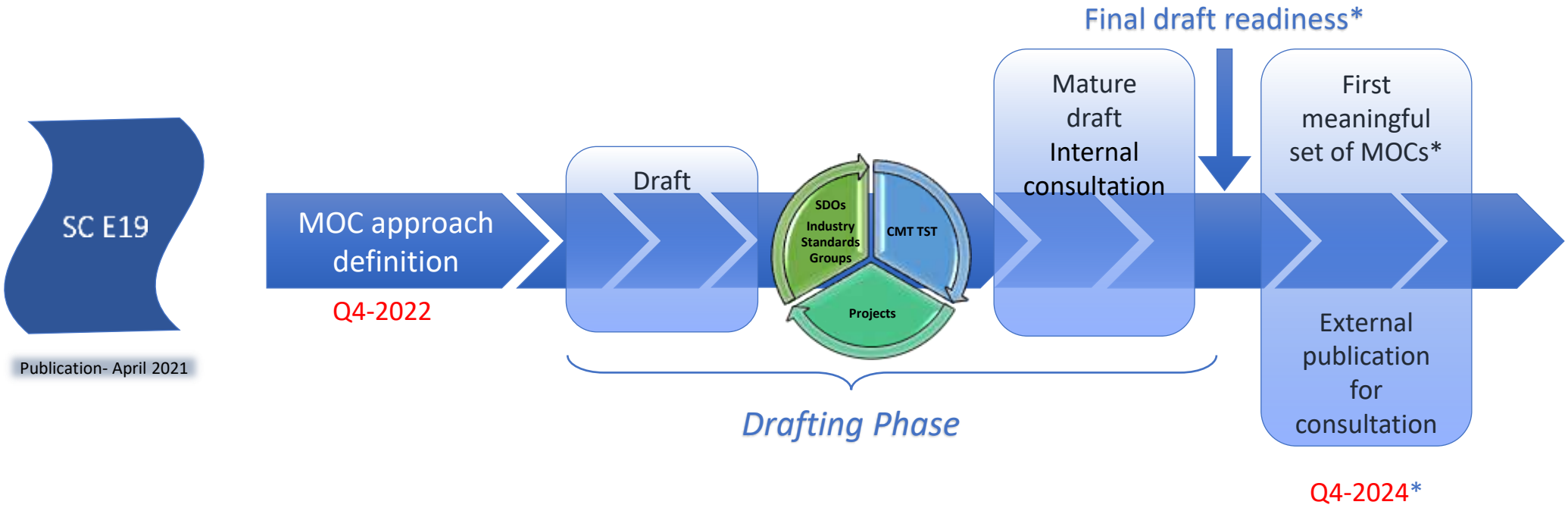
1.LOPC definition for single engine A/C
2. Single Fault Tolerance applicability to EE methodology: SAE E-40
3.Endurance test: EUROCAE WG-113 and SAE E-40.
4.Max speed to demonstrate containment

Electric Engine –

1. Control System Architecture VTOL<
2. Durability test EE
3. Containment demonstration for EE

Timeline

Priority 1 projects MOC level 2/3 (Set1, 2, 3, …)



Subject to evolution depending on priority and business needs*

Thank you!

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Certification of Propulsion Batteries Systems

Carlos Munoz Garcia

EASA New Electrical Technologies Expert

EASA
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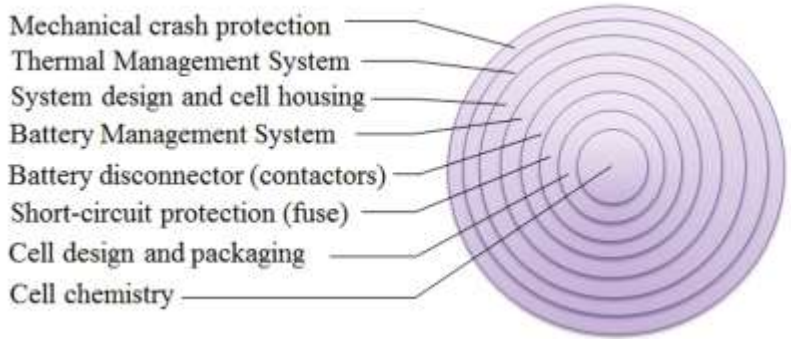
EASA SAFETY STRATEGY FOR PROPULSION BATTERIES

- **Particularities of Propulsion Batteries:**
  - Higher Capacity, size and weight (≈25% of the weight of the aircraft)
  - Higher Voltages (300V-1000V) → Risk of electroshock and corona effects
  - High specific energy/power needed → Lower safety profile (i.e. NMC)
  - New critical function as “fuel”



- **Protection Layers from cell to aircraft installation level**
- **Guidelines for proper design, manufacturing, installation, operation and maintenance (based on “MOPS for Rechargeable Lithium Batteries and Battery Systems” RTCA DO-311A)**
- **Proportionality between different products (from sailplanes to eVTOLs and large airplanes)**
- **Lesson learnt and knowledge acquired during the last decade in aviation and other industries**
- **Based on these EASA is developing/contributing to new requirements and means of compliance**

Several initiatives are on going to harmonize with FAA and other authorities

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EASA SAFETY STRATEGY FOR PROPULSION BATTERIES

CELL LEVEL	BATTERY LEVEL	INSTALLATION LEVEL
Quality cells from robust suppliers (Under POA) **Cell Incoming Inspection and testing** (↑Uniformity, ↓ manufacturing issues) **Proper Mechanical layout of cells** (Cell clearance and venting orientation) **Proper electrical insulation** (avoid cell shorting and between cells) **Proper thermal isolation of cells** (avoid/minimize propagation of Thermal runaway between cells) **Full characterization of thermal runaway behaviour at cell level** (Trigger methods, SOC, heating rates)	**Manufacturing, design, operation and maintenance guidelines in DO-311A** **Thermal runaway (TR) containment test** **TR criticality not relaxed due to tests** (>2 cells CAT) **BMS with the highest DAL** (Protection and warning system) **Proper routing practices to protect internal battery wiring and conductors** • **Short-circuits and corona discharge** • **Heat and chemical damage** **HV Isolation Monitor** (to detect any decrease/loss on isolation)	**Accurate estimation of the available / accessible energy** (Calculation of the maximum error) **Available / accessible energy shall be clearly displayed to the pilot** **Aircraft installation location shall consider guidelines in DO-311A:** • **Max. Temperatures in any failure** • **External threats** (mechanical. and thermal) • **Venting and draining provisions** **VTOL: Drop test from 15m for the battery system** (Similar to Rotorcraft fuel tank drop test)

Protection Layers

Proportionality

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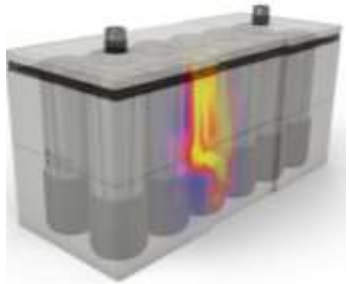
Global Approach for MOC " Thermal Runaway"

- **eVTOL enhanced → MOC-3, Published in June 2023**
  - Non-propagation (1 cell) AND Containment tests (20%)
  - Highest level of DAL and Cell reliability imposed.
  - Environmental degradation and aging considered.

Same approach for (TBC):

- CS-25 Large Airplanes
- CS-29 and CS-27 Cat. A
- CS-23 certification level 3&4



- **CS-23 level 1 and 2, CS27 non Cat. A and eVTOL basic (TBC):**
  - Non-propagation (2 cells) OR Containment test (According to EASA MOC or DO-311A)
  - Safety level increased to CS23 assessment level 2 for both categories.
  - Environmental degradation and aging considered.
- **Electrical Light Sport Aircrafts (LSA):**
  - 2 Cells in thermal runaway → Non-propagation OR Containment (DO-311A containment test also accepted).
  - Safety level increased to CS23 assessment level 1 (no 1309 requirement for conventional non-electric LSA).
- **Electrical Sailplanes:**
  - 1 cell in thermal runaway → Non-propagation OR containment (DO-311A containment test also accepted)

Several initiatives are on going to harmonize with FAA and other authorities

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CERTIFICATION MATERIAL, MOCs AND STANDARDS

- **Electric Sailplanes**
  - Special Condition SC-22.2014-01 "Installation of Electric Propulsion Units in Powered Sailplanes" include Guidance Material in the appendix C for the "Qualification of the Battery" → Tests from DO-311A applicable and adapted to Sailplanes
- **Light Sport Aircrafts:**
  - CS-LSA amdt. 1 already include provisions for Propulsion Batteries through ASTM standard F2840-11 "Design and Manufacture of Electric Propulsion Units" as requirements.
  - Special Condition SC-LSA-F2480-01 "LSA Propulsion Lithium Batteries" to complement CS-LSA admt. 1 requirements.
- **CS-23 Aeroplanes:**
  - CS-23 admt. 5&6 include requirements for Energy Storage Devices for Propulsion (eVTOLs MOCs to be tailored, ASTM standards)
- **SC E-18 Electric Propulsion Units for CS-23 Normal-Category Aeroplanes up to Level 1:**
  - SC E-22 for Propulsion Batteries and Electrical Systems to complement SC E-18.
- **SC E-19 - Electric / Hybrid Propulsion System (CS-23, CS-27, CS-29 and CS-25)**
  - Special Condition E-19 EHPS already include requirements for the Electrical System and Wirings (EHPS.370) and Propulsion Battery (EHPS.380)

Requirements at aircraft level for CS-27, CS-29 & CS-25 to be developed

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CERTIFICATION MATERIAL, MOCs AND STANDARDS

- **Propulsion Batteries - EUROCAE WG 112 VTOL SG-1 Electrical:**
  - ED-289 “Guidance on determination of accessible Energy in Battery Systems”
  - ED-309 “Guidance on VTOL Energy Level Information Provided to the Crew”
  - ED-308 “Guidance on VTOL Charging Infrastructure”
  - ED-312 “Guidance on Determining Failure Modes in Lithium-Ion Cells”
  - DP001 “Process Standard for Crashworthiness Test of Battery Systems” (consultation)
  - DP003 “Testing and Qualification of a Lithium-Ion Battery” (consultation)

https://www.eurocae.net/about-us/working-groups/

- **High Voltage - EUROCAE WG 112 VTOL SG-1 Electrical:**
  - ED-290 “Guidance on High Voltage Definition and Consideration for Personal Safety”
  - ED-296 “Guidance on Design Assurance for High Voltage Standards and Power Quality”

- **High Voltage - EUROCAE WG 116 “High Voltage Systems and Components in Aviation”:**
  - ED-320 “Aging Mechanisms of Electrical Insulation Materials in a High Energy System” (Together with SAE AE-11) (consultation)
  - DP006 “Test Guidelines for Electrical Insulation Materials and Components for a High Voltage System” (consultation)
  - DP001 “Guidance for Aircraft High Voltage Power Quality” (2024)
  - DP004 “Guidance for High Voltage Risk Mitigation at EWIS and Human Safety Level” (2024)

CERTIFICATION MATERIAL, MOCs AND STANDARDS

- **VTOL Means of Compliance developed in EASA:**
  - MOC VTOL.2430(a)(3) and (a)(4) Accessible energy in electrical energy storage systems
  - EASA MOC VTOL.2440 Propulsion Batteries Thermal Runaway
  - EASA MOC VTOL.2325(a)(4) Fire Protection - Energy storage crash resistance
  - EASA MOC VTOL.2330 Fire Protection in designated fire zones (Including Battery Explosive Fire Zone)
  - MOC VTOL.2400 (c)(3) Hazards to Crew, Passengers and Ground Personnel by HV Electromagnetic Fields (consultation)
  - MOC VTOL.2525 System power generation, energy storage, and distribution (consultation)

- **New EU Regulation on Batteries and waste batteries (July 2023)**
  - Harmonized regulatory framework to deal with the entire life cycle of batteries in a sustainable and safe way→ Applicable to Aviation (industrial category)
  - Some requirements only applicable for batteries > 2 kWh → Impacting aviation propulsion batteries:
    - Carbon footprint declaration (label, classes, max. threshold limit) from 2025.
    - Minimum percentage of recovery and use of active materials (95%→26% Cobalt, 80%→12% Lithium, 95%→15% Nickel)
    - Minimum values of electrochemical performance and durability requirements (capacity/power fade, efficiency, lifetime…)
    - Battery passport from 2027 → Electronic record accessible to the general public.

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Authorities cooperation
Certification Management Task (CMT)
Task Specific Team (TST)

Éric FLEURENT-WILSON

Powerplants & Emissions, Transport Canada/ EHPS CMT-TST Representative

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Backgound

- CMT TST EHPS created to address high priority certification issues related to electric engines.
- Authorities intend to develop harmonized approach on these topics.
- Two issues identified:
  1. Single Fault Requirement for Electric Engines
  2. Energy Storage integration and interactions with the EHPS and the Aircraft

Initial taskings

1. Electric engine control system architecture and reliability
   - ★ a. Definition of LOPC (Loss of Power Control) for electric engine
   - b. Methodology to define the applicable components falling under the requirement
     - Covered by the Industry in SAE E40/36 (AIR 7130)→ TST EHPS coordination ensured
   - c. Reliability demonstration for components of electric engine electrical system
     - Covered by the Industry in e.g. IEC and SAE AE10 → TST EHPS coordination ensured

★2. Energy Storage integration and its interactions with the EHPS and the Aircraft

Membership

ANAC:

- Marcelo Saito – Propulsion System & Environmental Protection
- Sergio Roberto Ferreira Machado – Electroelectronics Systems and Software Eng'g

EASA:

- Carlos Munoz - Panel 5 new technologies expert
- Ralph Menzel – Powerplant expert
- **Regis Rossotto (co-chair)** - Powerplant GA/VTOL and Electric & Hybrid Propulsion Systems

FAA:

- **Gary Horan (co-chair)** – Electric/Hybrid-Electric Propulsion Focal
- Mark Bouyer – Electric/Hybrid-Electric Propulsion Focal
- Deepak Kamath – Engines and Propulsion controls and A/C integration
- Michael Walz – Propulsion battery and electric engine expert

TCCA:

- Eric Fleurent-Wilson – Powerplants and Emissions
- Daniel Kenji Nishimaru – Electrical Systems

ALL: Internal coordination with various groups

Membership

1st F2F: Cologne (Nov 2022)

2nd F2F: Boston (Sept 2023)

- Very good cooperation
- High involvement of all members

Deliverables: Task 1 (Single Fault Requirement)

- Document 1: LOPC-E for single engine GA Level 1 and 2
  - Issue 1: Single Fault Ratings and LOPC-E Definition
    - PUBLISHED ON EASA CMT TST WEBPAGE* (DEC 10, 2023)
  - Issue 2: Defined associated Safety Objectives
    - First draft produced at 2nd F2F meeting (Boston, Oct 2023)
    - Target: Submit to CMT in MAY 2024
- Document 2: LOPC-E for other applications
  - Produce a first mature draft to address other A/C applications (Q2 2024):
  - Target: Submit to CMT by end of 2024

* www.easa.europa.eu > Home > Document > Library > International Cooperation > Bilateral agreements > CMTS TST

Deliverables: Task 2 (Energy Storage Integration)

Document 3: Energy Storage and engine/aircraft integration topic

- CMT tasking verbiage: *Energy Storage integration and its interactions with the engine and potentially the aircraft.*
- Began draft at 2nd F2F meeting (Boston, Oct 2023)
- Target: Mature draft by May 2024

Document 1 (Issue 1):
LOPC-E for single engine GA Level 1 and 2

Issue 1: LOPC-E for single engine GA Level 1 and 2

STATUS: APPROVED (DEC 2023)

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Document 1 (issue1) LOPC-E

Overview of Decision Document 1 – Issue 1 (LOPC-E)

- **IN ENGINE CERTIFICATION:** Current regulations call for the engine control system to be essentially single fault tolerant of electrical and electronic failures leading to a LOPC/LOTC event. Equivalent requirement is included in the cert basis of all electric engine applicants.

- **For electric engines, most electrical organisations electronic components need to be included (not just the ECU + sensors + valves, as with turbines).**

- **The intent**: to achieve the same safety record on electric engine powered aircraft as today's reciprocating engine powered aircraft.

- **The purpose**: to provide the power required for the pilot to safely land the aircraft following a single fault that results in the use of SFR power.

Document 1 (issue1) LOPC-E

- Applicable regulatory text:

CS-E 50:

(c) *Engine Control System Failures.* The Engine Control System must be designed and constructed so that:

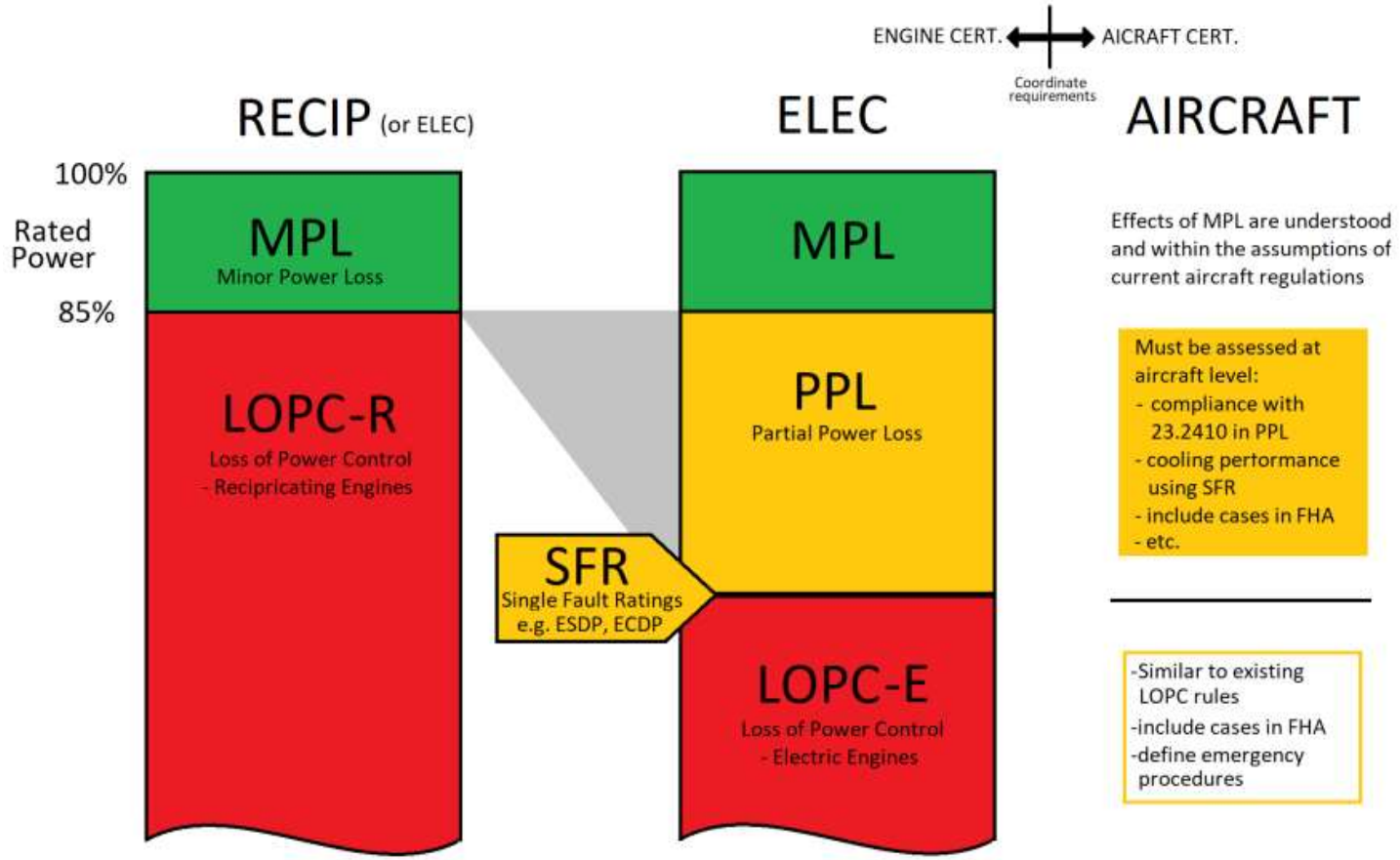
(1) …

(2) **In the Full-up Configuration, the system is essentially single Fault tolerant for electrical and electronic failures with respect to LOTC/LOPC events.**

(3)…

Document 1 (issue1) LOPC-E

- Overview of accepted approach:



Document 1 (issue1) LOPC-E

➢ Example of Single Fault Ratings (SFR)

SFR

Declared ratings	Duration	Power	Temperature limitation	
MCP	unlimited	80%	130°C	Typical ratings
MTOP	5min	100%	130°C	
ESDP	3min	80%	200°C	Only available during identified single fault cases. Must declare an occurrence rate.
ECDP	unlimited	50%	200°C	
*Values given are for illustrative purposes only				

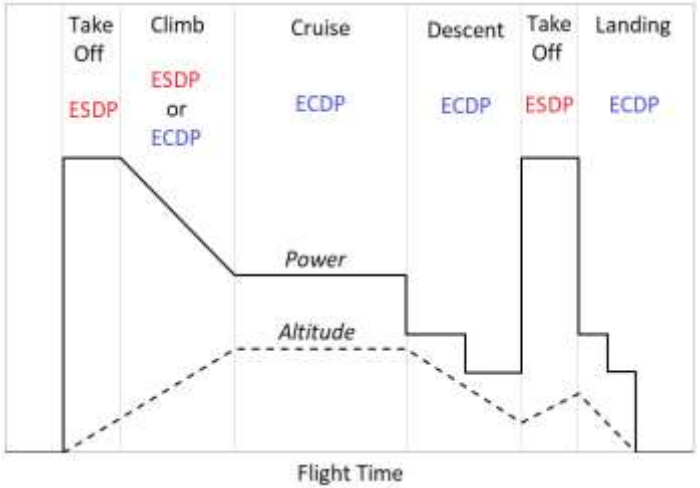


Figure 3 - Example flight profile with SFR allocations

For illustrative purposes only

Deliverables: Document 1 (issue1) LOPC-E

➢ LOPC definition for electric engines (LOPC-E)

	Electric engine
LOPC-E definition	An LOPC-E event is defined as an event where: • **an electric engine has lost the capability of modulating power above Single Fault Ratings* (e.g. ESDP and ECDP)** at applicable operating conditions,** or • an electric engine suffers a Fault which results in unacceptable power oscillations, or • has lost the capability to govern the Engine in a manner which allows compliance with its operability specifications
Safety objectives	***--- to be addressed in Issue 2 ---*** For Electric Engines: A PPL*** rate of ____. A LOP rate of ____, including LOPC-E rate, total power loss and other mechanical failures.
*** Single Fault Ratings (SFR)** are emergency ratings that specify the power available following a single electronic or electrical fault **** Emergency Short Duration Power (ESDP)** and **Emergency Continuous Duration Power (ECDP)** ***** Partial Power Loss:** includes failures leading the engine to deliver partial power equal to or greater than the SFR but lower than 85% of the rated powers	

THANK YOU

Back-up slides…

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Document 1 (Issue 2):
LOPC-E for single engine GA Level 1 and 2

Issue 1: LOPC-E for single engine GA Level 1 and 2

STATUS: APPROVED (DEC 2023)

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Document 1 (Issue 2) :
LOPC-E for single engine GA Level 1 and 2

Issue 2: Safety objectives associated with LOPC-E

STATUS: DRAFT

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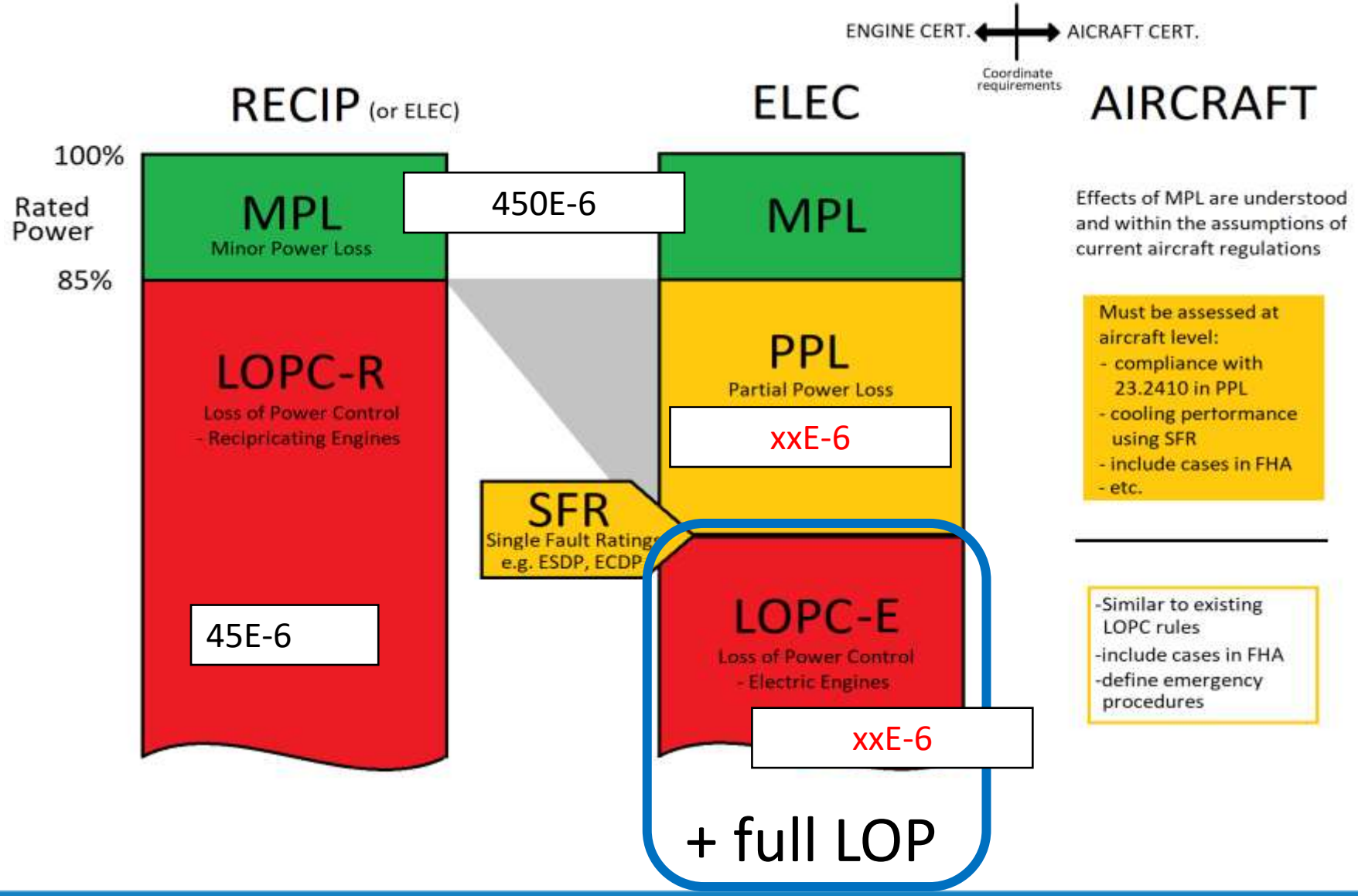
Document 1 (issue2) : Safety Objectives

➢ Safety target rates for LOPC-E

	Electric engine
LOPC-E definition	An LOPC-E event is defined as an event where: • **an electric engine has lost the capability of modulating power above Single Fault Ratings* (e.g. ESDP and ECDP)** at applicable operating conditions**, or • an electric engine suffers a Fault which results in unacceptable power oscillations, or • has lost the capability to govern the Engine in a manner which allows compliance with its operability specifications
Safety objectives	***--- to be addressed in Issue 2 ---*** For Electric Engines: A PPL*** rate of ____. A LOP rate of ____, including LOPC-E rate, total power loss and other mechanical failures.
*** Single Fault Ratings (SFR)** are emergency ratings that specify the power available following a single electronic or electrical fault **** Emergency Short Duration Power (ESDP)** and **Emergency Continuous Duration Power (ECDP)** ***** Partial Power Loss:** includes failures leading the engine to deliver partial power equal to or greater than the SFR but lower than 85% of the rated powers	

Document 1 (issue2) : Safety Objectives



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Document 2:
LOPC-E for GA Level 3, eVTOL, et al

STATUS: DRAFT

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Document 2: Single Fault LOPC – Higher Levels

- Assess and adapt Document 1 approach for higher level aircraft

- Consider novel designs and aircraft architectures, and their impact on the intent of essentially single fault tolerance of EHPS control systems requirement

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Document 3: Energy Storage integration and its interactions with the EHPS and the Aircraft

STATUS: DRAFT

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Document 3: Energy Storage Integration

- The CMT task team have defined a set of objectives to identify gaps on current aerospace guidance/specs and find alternative standards to cover them.

- Issue overview: There are gaps in known aerospace standards (e.g.: DO-311A) for electrical propulsion system.

- Topics under discussion:
  1. ESS requirements identification and harmonization
  2. Endurance and durability of battery propulsion system
  3. Useful Energy
  4. Power and Energy reserve

Document 1: Document 1 (Issue 1) : LOPC-E

➢ BACKGROUND (cont'd)

Table 1: Existing LOPC/LOTC definition and safety objectives for reciprocating and turbine engines

	Reciprocating engines	Turbine engines
LOPC /LOTC definition	An LOPC event is defined as an event where the Engine Control System: • has lost the capability of modulating power between idle and 85% of maximum rated power at all operating conditions, or • suffers a Fault which results in a power oscillation greater than the levels given in paragraph (7)(c) of this AMC, or • has lost the capability to govern the Engine in a manner which allows compliance with the operability specifications given in CS-E 390.	7(b)(iii) A LOTC/LOPC event is defined as an event where the Engine Control System: • has lost the capability of modulating thrust or power between idle and 90% of maximum rated power or thrust, or • suffers a Fault which results in a thrust or power oscillation that would impact controllability in the intended installation, or • has lost the capability to govern the Engine in a manner which allows compliance with the operability specifications given in CS-E 500(a) and CS-E 745, as appropriate.
Safety objectives	7(d)(ii) For piston Engines: An LOPC rate of 45 per million engine flight hours (or 1 per 22,222 engine flight hours) has been shown to represent an acceptable level for the most complex EECS.	7(d)(i) For turbine Engines: The EECS should not cause more than one LOTC/LOPC event per 100 000 engine flight hours.

The existing definitions of LOPC/LOTC is provided in guidance material, wherein AMC 20-3B (Section 7(d)(ii)) and AC 33.28-3 (Section 6-2(d)) state:

Document 1 (issue1) LOPC-E

Document Highlights:

- Old Approach: Applicants may choose to use the existing reciprocating engine LOPC definition.

- New approach:
  - Declare emergency engine ratings and limitations that define capability of operating with a single fault. These are called Single Fault Ratings (SFR). Example of which are the ESDP (Emergency Short Duration Power) and ECDP (Emergency Continuous Duration Power), presented at last EASA Webinar.

  - Results in new range of power loss: Partial Power Loss (PPL)
    - Worse than Minor Power Loss (MPL, 85% rated power), but better than LOPC

  - the concept of Single Fault Ratings, such as ESDP and ECDP, is used in the proposed LOPC definition for electric engines.

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Challenge for new design organizations

Part 21 Design Organisation Approval (DOA) – An Introduction

Morning Session:

Damian KOCJANCIC

EASA DOA Team Leader

Afternoon Session:

Javier CASTILLO

Section Manager – LA Propulsion &Powerplants systems

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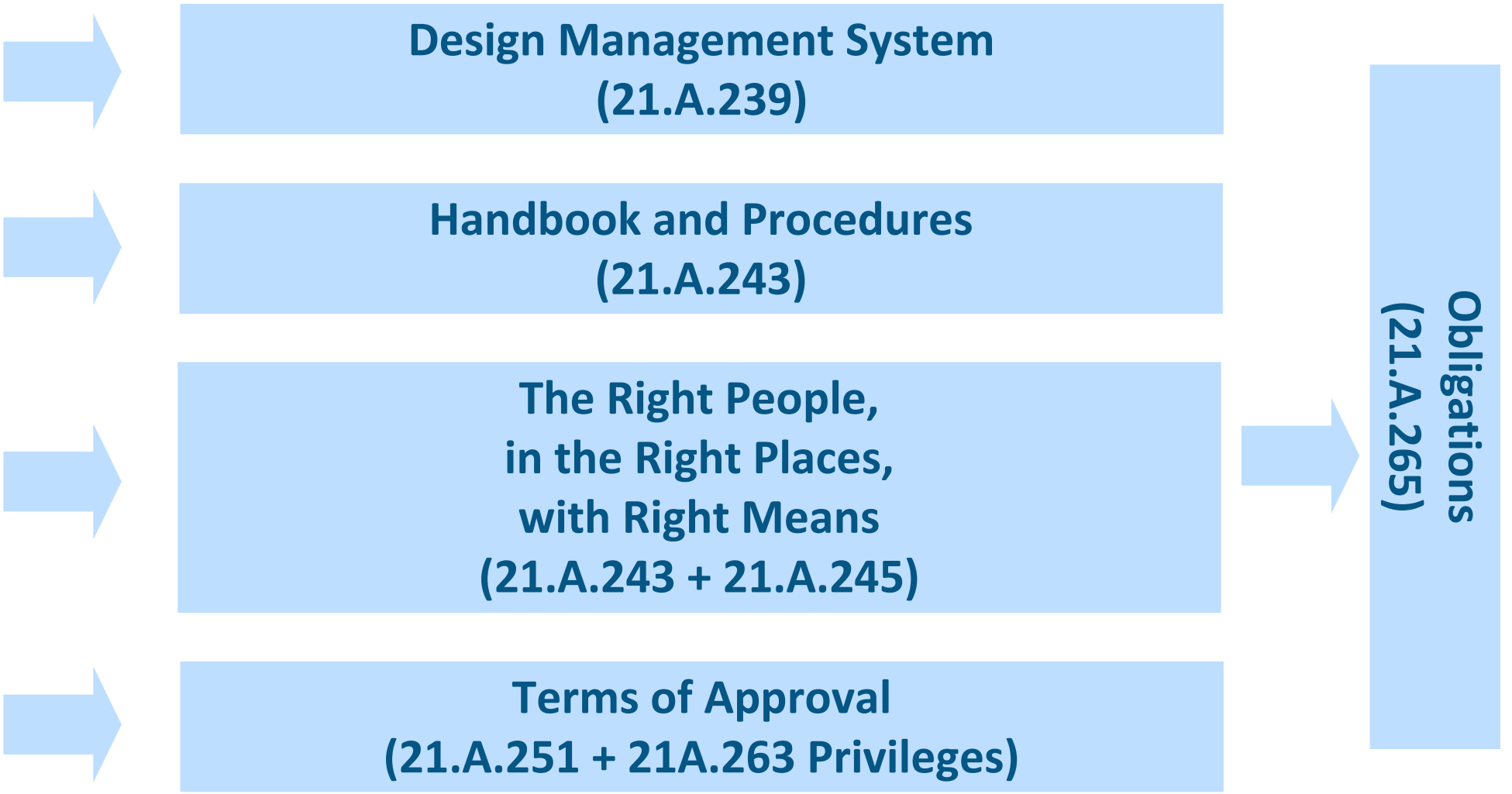
Requirement for DOA

21.A.14 An applicant for a type-certificate...shall demonstrate its capability by holding a design organisation approval, issued by the Agency.

Design Organization concept



DOA Investigation Process

The DOA investigation is performed to confirm that the applicant's design organisation is fulfilling all applicable Part 21 requirements:

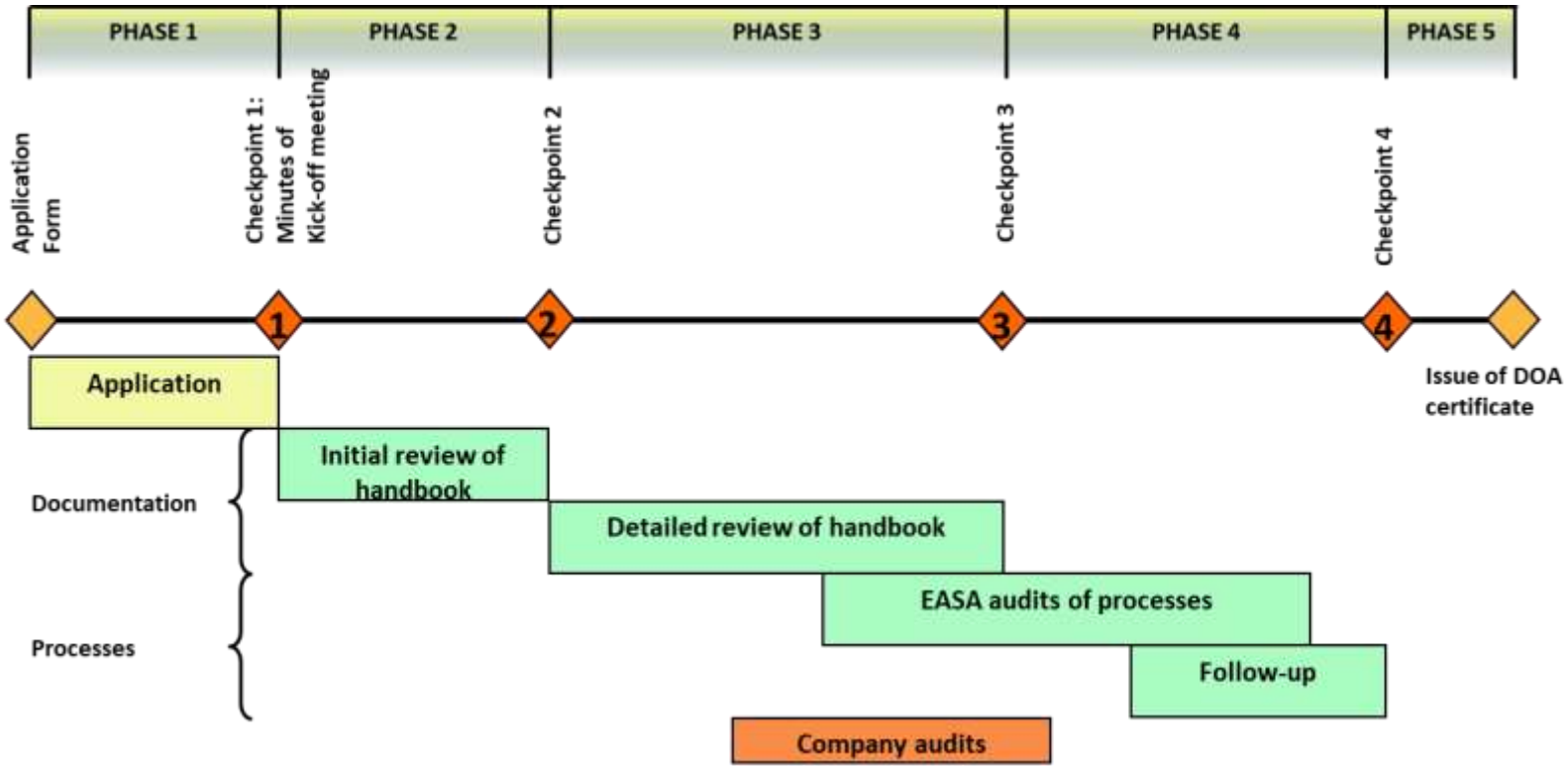
Part 21/
AMC/GM

Compliance
Checklist

Practices

Audits

DOA Investigation Process



Terms of Approval

Design Organisation Approval Certificate

EASA.21J.000

1 Scope

This Design Organisation Approval is applicable for the scope defined in Annex A for design work with regard to the airworthiness, operational suitability and environmental characteristics of the products.

2 Privileges

a) (Reserved)

b) (Reserved)

c) The holder of this design organisation approval shall be entitled, within the scope of this terms of approval, and under the relevant procedures of the design assurance system:

1. (Reserved);
2. (Reserved);
3. (Reserved);
4. (Reserved);
5. (Not applicable);
6. (Not applicable);
7. (Not applicable);
8. (Not applicable);
9. (Not applicable).

3 Obligations

The holder of this design organisation approval shall, within the scope of this terms of approval:

a) maintain the handbook required under point 21.A.243 in conformity with the design assurance system;
b) ensure that this handbook or the relevant procedures included by cross-reference are used as a basic working document within the organisation;
c) determine that the design of products, or changes or repairs thereto comply with the applicable specifications and requirements and have no unsafe features;
d) (Not applicable);
e) (Not applicable);
f) (Not applicable);
g) (Not applicable);

h) (Reserved).

Date of issue: XX/XX/20XX

John SMITH
Senior DOA Team Leader

Annex A

Scope of work

Legend:

	Title for product
	Title for scope
■	Within scope
	Outside scope

	TC	STC	major changes	minor changes	major repairs	minor repairs	flight conditions	permit to fly
Electric Engine								
All scope (TCH)								
All areas	■							

List of products

Product	Design Activity	Types
Electric Engine	TC	Applicant for ABC123

Limitations

Limitations common to all products and activities
[Not applicable]

Product	Limitations particular to each product
Electric Engine	For TCH activity: [Not applicable]

Further information

https://www.easa.europa.eu/en/domains/aircraft-products/design-organisations/design-organisations-approvals

- **DOA Initial Investigation Information Package**

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Thank you!

EHPS Webinar conclusion

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