Part 21 DOA Obligations Related to EWIS – Design Lifecycle: From Concept to Certification

The integration of Electrical Wiring Interconnection Systems (EWIS) into the aircraft design and certification process brings specific obligations to Design Organisations approved under EASA Part 21 Subpart J (DOA).

These obligations span the full EWIS lifecycle—from conceptual design through certification and into continued airworthiness.

Understanding the Regulatory Context: CS-25 and AMC 20-21

The foundation of DOA responsibilities related to EWIS stems from:

- **CS-25 Subpart H** – Covers airworthiness standards for EWIS for large aeroplanes.
- **AMC 20-21**– Provide acceptable means of compliance with EWIS safety objectives.
- **Part 21 Subpart J** – Outlines the privileges and responsibilities of EASA-approved Design Organisations.

CS-25 introduces detailed design and safety objectives related to EWIS, particularly in Sections **25.1701 through 25.1733**, which address:

- Function and installation:
- Systems and functions;
- System separation;
- System safety;
- Component identification;
- Fire protection;
- Electrical bonding and protection against static electricity;
- Circuit protection devices;
- Accessibility provisions;
- Protection of EWIS
- Flammable fluid protection;
- Powerplants;
- Flammable fluid shutoff means;

DOA Responsibilities Throughout the EWIS Lifecycle

Concept Phase

- **Hazard Identification**: DOAs must proactively identify hazards associated with EWIS installation, especially those that may lead to arcing, overcurrent, or electromagnetic interference.

Understanding the Nature of EWIS Hazards
EWIS hazards are often systemic and cumulative in nature. Key hazard types include:

- **Electrical Arcing** – Can occur from insulation breakdown, connector looseness, chafing, or incorrect routing.
- **Overcurrent / Overload** – Arises when circuit protection fails or current ratings are exceeded.
- **Electromagnetic Interference (EMI)** – Can be induced or conducted, affecting avionics or flight control systems.
- **Mechanical Degradation** – Vibration, abrasion, or fluid ingress can compromise wire integrity.
- **Fire Risk** – Poor protection or proximity to flammable fluids increases this hazard.
- **Cross-system Hazards** – Wiring failures affecting hydraulic, fuel, or oxygen systems.

Specific Practices for DOAs to Achieve Effective Hazard Identification

Structured Zonal Analysis

Practice: Implement a *Zonal Safety Analysis (ZSA)* for each aircraft section during the design review stage.

- **Purpose:** To identify EWIS routing exposures relative to flammable fluids, moving parts, or high-temperature zones.
- **Tool:** Use a standardized zonal hazard checklist derived from AMC 20-21.

Wiring Failure Mode and Effects Analysis (FMEA)
Practice: Conduct an EWIS-specific FMEA or integrate into System Safety Assessment (SSA).

- **Purpose:** To evaluate wiring failure consequences such as open circuits, shorts, arcing, and intermittent faults.
- **Documentation:** Link this analysis to AMC 25.1709 and CS 25.1309 compliance.

Proximity and Separation Assessment
Practice: Validate that wire separation meets CS 25.1707/AMC 25.1707 standards.

- **Method:** Overlay wire routing on 3D CAD models or DMU (Digital Mock-Up) and perform clash/interference checks.
- **Focus Areas:** Fuel tanks, flight control linkages, avionics zones.

Material Property Evaluation and Environment Suitability

Practice: Use material hazard analysis to review flammability, thermal resistance, and ageing.

- **Process:** Cross-check wire jacket material specs with zone environmental conditions (heat, moisture, chemical exposure).
- **Standard:** Refer to AMC 25.603 and AMC 25.869 for system fire/smoke protection.

Electromagnetic Compatibility (EMC) Assessment

Practice: Carry out EMC susceptibility testing and shielding effectiveness validation.

- **Tools:** Use HIRF (High-Intensity Radiated Fields) testing per CS 25.1317 and bonding checks per CS 25.899 / CS 25.1715.
- **Integration:** Include EMC in the EWIS compliance matrix to ensure awareness across disciplines.

Historic Data & In-Service Event Analysis

Practice: Integrate industry and internal historical data into hazard identification process.

- **Source:** EASA CAG/EWIS Working Group findings, FAA ADs, NTSB reports, industry databases.
- **Application:** Validate whether known failure scenarios are addressed in the design.

Interdisciplinary EWIS Safety Review Board

Practice: Establish a formal review board including electrical, systems, mechanical, safety, and certification engineers.

- **Purpose:** To evaluate cross-functional hazard impacts during Preliminary Design Review (PDR) and Critical Design Review (CDR).
- **Outcome:** Review hazard logs and ensure that mitigations are traceable in compliance documentation.

Summary

A DOA's obligation to proactively identify EWIS hazards is not a tick-box exercise—it must be an embedded, auditable, and technically rigorous process that spans design, verification, and safety assurance.

Key enablers include:

- Use of formal safety analysis methods (ZSA, FMEA, SSA)
- Digital tools for layout validation
- Systematic engagement with past data and in-service trends

- Internal governance via Safety Review Boards

This level of proactive analysis supports CS-25 Subpart H compliance, enhances certification readiness, and ultimately contributes to improved operational safety and reduced post-delivery EWIS-related service disruptions.

- **Architecture Decisions**: Early decisions regarding wiring routing, segregation, and system redundancy must consider EWIS requirements (e.g., ensuring separation from flammable fluid lines or other systems).

Architectural Decisions in EWIS Design

Wiring Routing: Pathways Through the Aircraft

Wiring routing defines the physical paths through which bundles and looms pass between system components. Poor routing decisions can introduce unacceptable risks that are difficult (and expensive) to mitigate later.

Key Objectives:

- Minimise exposure to heat, vibration, moisture, and flammable fluids.
- Avoid proximity to mechanical systems and moving components.
- Enable accessibility for inspection and maintenance.

Specific Best Practices:

- **Use of Predefined "EWIS Zones"**: Establish designated routing corridors that avoid high-risk areas like hydraulic bays, fuel tanks, and landing gear assemblies.
- **Optimise Bend Radius & Support Spacing**: Adhere to AMC 25.1703 recommendations for minimum bend radius and clamp spacing (e.g., support every 24 inches).
- **Use of CAD/Digital Mock-Up Tools**: Simulate routing and identify early clashes with structure or systems.

Regulatory Reference:

CS 25.1703 & AMC 25.1703: "Function and installation of EWIS shall be such that it performs its intended function under all foreseeable operating conditions.

Segregation: Functional & Physical Isolation of EWIS Elements

Segregation ensures that electrical faults, such as arcing, do not propagate across systems and cause cascading failures. This is critical for flight safety, redundancy, and fire containment.

Categories of Segregation:

- **Physical**: Physical distance between wires or bundles to prevent contact or damage.
- **Functional**: Isolation between different systems (e.g., flight controls vs. entertainment).
- **Redundancy-based**: Separate routing of primary and backup power/control lines.

Specific Best Practices:

- **Minimum Separation Distance**: Maintain regulatory minimums (e.g., 50 mm between high-power and signal cables unless shielded).
- **Use of Barriers and Shields**: Where separation isn't possible, physical protection such as conduits or shield plates must be installed.
- **Avoiding Common Routing Channels**: Especially for redundant or safety-critical systems, routing should avoid common failure modes (e.g., through the same conduit or pylon).

High-Risk Zones:

- Underfloor areas with hydraulic lines.
- Engine pylon regions (exposed to vibration and fluids).
- Proximate routing to fuel and oxygen systems (flammability risk per CS 25.1723).

Regulatory Reference:

CS 25.1707 & AMC 25.1707: Requires EWIS to be designed with adequate separation to prevent damage from mechanical, electrical, or environmental causes.

System Redundancy: Assuring Continuity of Critical Functions
Redundancy is the architectural provision of alternate paths or circuits to ensure continued functionality following a failure. EWIS architecture must support this by enabling safe routing of primary and backup paths.

Key Considerations:

- **System Redundancy vs EWIS Independence**: It's not sufficient to duplicate systems—their supporting wiring must also be independently routed.

- **Protect Against Common Mode Failures**: Including impact, fire, flooding, or maintenance-related damage.

Specific Best Practices:

- **Redundant Circuit Isolation**: Ensure that control and power wires for dual systems (e.g., dual elevator controls) do not run in the same bundle or through the same physical conduit.
- **Use of Discrete Wiring**: Avoid bundling high-criticality redundant circuits with other lower-priority systems.
- **Route Audit Trails**: Maintain documentation of all EWIS paths and crossings, ensuring there's no unintentional proximity.

Interaction with Other Systems: Cross-Disciplinary Design Impact

EWIS architecture is interdependent with:

- **Structural Design**: Wire routing must not compromise structural access or violate fatigue-critical zones.
- **Mechanical Systems**: Interfaces with flammable fluids, rotating parts, and structural supports must be carefully coordinated.
- **Environmental Control Systems (ECS)**: High humidity and temperature zones require enhanced insulation and material choices.

Design Documentation & Change Control
Early architecture decisions must be documented in:

- **EWIS Design Drawings and Installation Schematics**
- **Zonal Hazard Analysis**
- **EWIS Safety Assessment Reports**
- **Installation Manuals & Maintenance Documentation**

Design changes that affect routing, segregation, or redundancy must be tracked via DOA configuration control processes, with re-assessment of EWIS hazard and safety implications.

Design and Development Phase - Design Organisations should:

- Apply a lifecycle safety perspective from the conceptual layout stage.
- Validate architectural choices against CS-25 Subpart H and AMC 20-21.

- Use digital tools and cross-functional reviews to proactively identify and mitigate hazards.

These actions collectively form the basis for a compliant and resilient EWIS design—essential not only for certification success but also for the long-term airworthiness and reliability of the aircraft.

- **Compliance with CS-25 Subpart H**: The DOA must ensure EWIS components (connectors, wiring bundles, protective materials) meet the applicable certification specifications.

Testing and Verification

- **Material Flammability and Smoke Testing**: Verifying that wiring materials pass flame propagation and smoke density requirements.
- **Installation Validation**: Ensuring design data translates effectively into manufacturing/installation drawings and production specifications, including compliance with bend radii, clamp spacing, and protective sleeving.
- **Verification of Design Data**: Using analysis, inspection, and testing methods, DOAs must verify that all EWIS elements conform to the specified performance and safety requirements.

Purpose of Verification in EWIS Design - Verification ensures that all EWIS design elements:

- Perform their intended function under all operating conditions (CS 25.1703),
- Are free from unacceptable risks of failure, degradation, or interaction with other systems (CS 25.1709),
- Comply with environmental, electrical, mechanical, and safety performance criteria,
- Meet the requirements for airworthiness approval and continued airworthiness.

Verification of EWIS design data is accomplished using a triad of methods:

1. **Analysis**
2. **Inspection**

3. **Testing**

Types of Analysis:

- **Electrical Load Analysis (ELA)**: Ensures that wiring size, length, and protective devices are adequate for current-carrying needs.
- **Thermal Analysis**: Evaluates heat dissipation, particularly in densely packed bundles or near heat sources.
- **Voltage Drop and Signal Integrity Analysis**: Important for avionics and low-voltage communication systems.
- **Zonal Safety Analysis (ZSA)**: Reviews each aircraft zone for hazards like fluid ingress, EMI, or physical damage risks.
- **Failure Modes and Effects Analysis (FMEA)**: Identifies potential wiring failure scenarios and mitigations.

Inspection - To confirm that EWIS components are correctly specified, installed, routed, secured, and protected according to approved design data and that no latent non-compliances are introduced during manufacturing or integration.

Types of Inspection:

- **Design Data Review**: Verifying that design drawings, installation manuals, and electrical schematics are consistent, accurate, and validated.
- **Digital Mock-Up (DMU) and 3D Model Reviews**: Checking clearances, bundle separations, accessibility, and proximity to other systems.
- **Installation Inspection**: On the production line or prototype—checking wire routing, clamp spacing, bend radius, shield terminations, and markings.
- **Visual Verification of Compliance**: Ensuring physical separation per CS 25.1707 and proper environmental protection per CS 25.1721.

- Use of borescopes, fiber-optic cameras, or smart inspection tools for hard-to-reach installations

Testing To validate the performance and safety of EWIS components and systems under simulated or actual conditions.

Component-Level Testing

- **Flammability and Flame Propagation Tests** (CS 25.1713):

- Assess the ability of wire insulation to resist ignition and prevent fire spread.
- **Insulation Resistance and Dielectric Strength**:
  - Verify compliance with design voltage and leakage limits.
- **Mechanical Tests**:
  - Flexure, abrasion resistance, and connector engagement/disengagement force.

System-Level Testing

- **Functional Continuity Tests**:
  - Confirm electrical paths, correct pin assignments, and resistance levels.
- **Shielding and EMI Testing**:
  - Validate system immunity to electromagnetic interference (CS 25.1317).
- **Bonding and Grounding Tests**:
  - Check that resistance to aircraft ground meets regulatory limits (typically $<2.5\ m\Omega$).

Environmental Testing

- **Temperature Cycling** (e.g., –55°C to +125°C)
- **Fluid Susceptibility**: Fuel, hydraulic fluid, de-icing agents
- **Humidity and Corrosion Exposure**: Especially important for connectors and terminations

- **Application of AMC Guidance**: AMC 20-21 offers DOAs best practices and checklists for systematic EWIS evaluation.

Safety Assessment

- **Functional Hazard Assessment (FHA)** and **Zonal Safety Analysis (ZSA)** must consider EWIS as a standalone system and as part of integrated systems (e.g., electrical power distribution, avionics).

- DOAs must analyze failure modes such as insulation degradation, arc tracking, and connector failure—ensuring compliance with the intent of AMC 25.1709 and AMC 20-21

Certification Phase

- **Certification Programme Oversight**: DOAs must integrate EWIS compliance documentation into the Certification Programme and demonstrate conformity during technical review by the EASA PCM (Project Certification Manager).
- **Means of Compliance Documentation**: Demonstrate the applied AMC or alternative means of compliance for each CS-25 EWIS paragraph.

Continued Airworthiness

- **Instructions for Continued Airworthiness (ICA)**: EWIS-specific ICAs must be developed, including inspection intervals, cleaning procedures, aging/degradation mitigation, and connector servicing.
- **Configuration Control**: DOAs must ensure that post-certification design changes involving EWIS are assessed and approved through the appropriate Minor or Major Change process under Part 21.

Integrating SMS Principles into EWIS Design

Part 21 Amendment 2022/201 covers the integration of Safety Management Systems (SMS) into design processes. DOAs are now obligated to include EWIS-specific risks within their Design Risk Assessments (DRAs) and show that safety data from service experience, incidents, or OEM advisories is captured and managed proactively.

This includes:

- Collecting in-service data on EWIS degradation.
- Engaging in safety promotion and training activities specific to wiring safety.
- Regular design reviews to integrate lessons learned.

Key Elements of SMS Integration into EWIS Design **Design Risk Assessment (DRA) with EWIS Focus** To formally identify, assess, and document EWIS-related safety risks during the design phase. **Actions:** • Integrate EWIS-specific failure modes into the DRA process (e.g., chafing, arc tracking, EMI susceptibility).

- Link DRA outcomes with **CS 25.1709** and **AMC 20-21** requirements for system safety assessments.
- Apply a **graded risk approach**—e.g., different levels of scrutiny for critical flight control wiring vs. cabin service systems.

Output:
A risk register or matrix that explicitly identifies EWIS hazards and defines mitigation actions, safety objectives, and verification methods.

In-Service Data Collection & Analysis

To use real-world operational data to inform ongoing safety and design decisions.

Sources of Data:

- EASA Safety Information Bulletins (SIBs) and Airworthiness Directives (ADs)
- OEM Service Bulletins (SBs) and Reliability Reports
- Airline feedback and maintenance findings
- Incident investigations (e.g., wire shorting, burned connectors, failed circuit protection)

Practices:

- Establish a **closed-loop feedback system** where in-service data is reviewed and linked to specific EWIS design elements.
- Update DRAs and ICA (Instructions for Continued Airworthiness) based on real-world degradation trends.

Safety Promotion and Wiring-Specific Competence Development
To build and maintain a strong organisational culture of wiring safety awareness.

Activities:

- Conduct internal EWIS-specific training for design, certification, and compliance staff.
- Use real-world case studies (e.g., Swissair 111) to highlight latent wiring risks and lessons learned.
- Promote cross-functional knowledge sharing between DOA, POA, and CAMO teams.

Tools:

- Safety newsletters, wiring hazard bulletins, design awareness briefings.
- EWIS-focused "safety moments" during design reviews or team meetings.

Ongoing Design Review and Lessons Learned Integration

Objective:

To ensure that past failures and field experience continuously inform future designs.

Implementation:

- Establish regular EWIS Design Safety Reviews, at PDR (Preliminary Design Review), CDR (Critical Design Review), and final approval phases.
- Maintain a central Lessons Learned Repository, tagging EWIS-related risks and mitigations across aircraft programs.
- Use post-certification changes (e.g. STCs or major mods) as opportunities to update hazard assessments and design best practices.

Practical Integration Tools and Processes

DOAs should use the following methods to embed SMS principles into EWIS design:

- **EWIS-specific safety performance indicators (SPIs)**, such as defect rate per 10,000 flight hours or incident reports per fleet segment.
- **SMS-aligned configuration control**, ensuring that changes to routing, materials, or bundle segregation are assessed for safety impact.
- **Safety Risk Management (SRM) workflow** embedded into engineering change requests (ECRs) and design updates.
- **Audit trails linking EWIS hazards to mitigations**, supported by documentation (checklists, testing results, and compliance matrices).

Next Steps

www.sassofia.com and www.sofemaonline.com provide classroom, webinar and online training covering all aspects of EWIS. Please see the websites or email: team@sassofia.com