Human Factors in Electrical Wiring Interconnection Systems (EWIS) Design Integration

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Introduction

The integration of Human Factors (HF) into Electrical Wiring Interconnection Systems (EWIS) design is critical to ensuring system usability, maintainability, and operational safety across the aviation industry. Drawing from decades of lessons learned, this paper explores the evolution of HF in EWIS, with a focus on certification products under CS-25 (Large Aeroplanes) and CS-23 (Small Aeroplanes). Although CS-23 aircraft are not currently subject to the same regulatory EWIS obligations as CS-25, the application of HF principles remains essential for ensuring optimal safety and performance.

This paper offers a historical overview, addresses current design challenges, and outlines future developments. Special emphasis is placed on the role of communication, ergonomic and usability improvements, maintenance optimization, and global best practices.

Historical Perspective: The Catalyst for Change

EWIS design was historically overlooked, often considered secondary to structural and avionics systems. This led to complex, poorly accessible installations, increasing the likelihood of human error and maintenance difficulties.

Two major accidents fundamentally changed this perception:

- **TWA Flight 800 (1996)** and **Swissair Flight 111 (1998)** exposed critical vulnerabilities in wiring systems, where latent failures and flammable materials led to catastrophic outcomes.
- These events drove regulatory reform, culminating in the **FAA's Enhanced Airworthiness Program for Airplane Systems (EAPAS)** in 2008 and parallel developments by **EASA**.

Regulatory Framework: FAA EAPAS and EASA Implementation

FAA EAPAS

Federal Register Vol. 72, No. 79 (April 25, 2007)
Docket No.: FAA–2005–22449
Effective from December 10, 2007, EAPAS introduced key amendments:

- **14 CFR Part 25** – New certification requirements for EWIS in large transport category aircraft
- **Part 26** – Continued airworthiness for aging systems

- **Part 121** – Operational and maintenance mandates, including EWIS training

Supporting Advisory Circulars:

- *AC 25.1701-1* – Certification of EWIS
- *AC 25.1709-1* – Functional Hazard Assessment
- *AC 120-94* – Aircraft EWIS Training Program

Together with ATSRAC recommendations, these form the backbone of FAA's EWIS regulatory strategy.

EASA Implementation

- **CS-25 Amendment 5** introduced EWIS design mandates.
- **AMC 20-21 and AMC 20-22** extended these to continued airworthiness.
- Key focuses included wire separation, routing clarity, and environmental protection—anchored in proactive HF design.

Current Challenges in EWIS HF Design

Despite regulatory advances, systemic challenges persist:

- **Maintenance Complexity:** Wiring routed through inaccessible areas, sharp bends, and tight compartments creates inspection and repair difficulties.
- **Labeling Confusion:** Inconsistent or unclear wire and connector labeling contributes to errors.
- **Communication Gaps:** Insufficient feedback loops between design, production, and maintenance teams undermine HF effectiveness.

To mitigate these risks, HF must be embedded early in the design process, enabling error-preventive configurations and maintenance-friendly layouts.

Core Ergonomic & Human Factors Considerations

Ergonomics & Accessibility

- Easy access to harnesses/connectors
- Adequate space for hand tools and technician movement
- Simplified routing to avoid unnecessary bends
- Visual clarity: color-coded wiring, standardized labels, logical grouping

Physical Usability

- Connectors should be easily operable, even with gloved hands
- Placement should support one-hand access and minimize physical strain
- Tool compatibility and minimized need for specialized equipment

Cognitive Factors

- Reduce technician workload with intuitive layouts
- Use keyed connectors to prevent mismatching
- Design for familiarity to minimize retraining

Environmental Resilience

- Designs must withstand temperature, vibration, and noise stresses
- Use durable components that are easy to replace
- Allow for quick inspections and low-fatigue servicing

Proactive Design for Maintenance Error Prevention

- **Error-tolerant design:** Fail-safe connectors, unique keying, and reinforced zones
- **Standardization:** Repeatable, predictable layouts aligned with documentation
- **Real-world testing:** Include simulated maintenance scenarios to identify error-prone configurations early in development

The Critical Role of Communication

Effective HF integration relies on continuous dialogue between designers, certifiers, technicians, and regulators. Communication lapses often lead to inaccessible systems and latent hazards. A feedback-driven design culture improves not only ergonomics but long-term airworthiness.

Lessons from Modern Programs

Boeing 787 Dreamliner: Simulation and Predictive HF Integration

- **3D modeling and virtual prototyping** enabled risk identification before physical builds
- High-risk access areas were redesigned proactively
- Zone separation for power/signal routing improved safety and maintainability
- Improved color-coding and routing logic directly supported EWIS certification and minimized misconnection risk

Airbus A350 XWB: Feedback-Driven Maintainability

- **Technician feedback loops** from A330/A340/A380 programs improved accessibility and connector placement
- Simplified wiring routes and **compartmentalized zoning** facilitated troubleshooting and minimized cross-connection risk
- **Tool compatibility** and ergonomic placement were central design priorities

Both aircraft exemplify the value of HF as a systems-level design function—not just a checklist item. These programs set new benchmarks for incorporating simulation, technician input, and design standardization.

Conclusion: The Future of HF in EWIS Design

Human Factors must be regarded as a foundational element of EWIS design, particularly for CS-25 aircraft, and as a best-practice model for CS-23. Although the regulatory obligation may differ, the safety imperative does not.

The future of EWIS HF integration lies in:

- **Sustained stakeholder communication**
- **Continual ergonomic innovation**
- **Leveraging simulation and emerging technologies**

By embracing a human-centered design philosophy, the aviation industry can substantially reduce EWIS-related maintenance risks, enhance system performance, and uphold the highest safety standards.