A CS-23 Compliant Light Aircraft with Integrated Garmin Avionics: Safety, Simplicity, and Sustainability

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Abstract: *The development of modern general aviation (GA) aircraft demands a balance between performance, safety, environmental responsibility, and regulatory compliance. This paper introduces a newly developed, single-engine, ELA1-category GA aircraft that complies with EASA CS-23 certification specifications for VFR and IFR, and is designed to set a new benchmark in safety, stability, and sustainability. Featuring advanced flight control systems, lightweight composite materials, and a fuel-efficient powertrain, this aircraft addresses current industry demands and future regulatory trends. This paper outlines the aircraft's design philosophy, key technical features, and the envisioned certification process, while also highlighting its role in the evolving ecosystem of eco-conscious general aviation.*

Key Words: *GA aircraft, ELA 1 aircraft, EASA CS-23, avionics architecture, Garmin, flight safety, light aircraft design*

1. INTRODUCTION

The evolution of general aviation (GA) aircraft design has increasingly focused on improving safety, reducing environmental impact, and meeting modern pilot expectations for intuitive, digital flight decks. In this context, the aircraft presented in this paper represents a forward-looking solution: a single-engine, ELA1-category [1] platform that combines advanced avionics, CS-23-compliant [2] safety engineering, and sustainable performance in a lightweight and versatile airframe. At the heart of this aircraft's capabilities lies a fully integrated Garmin G3X Touch avionics suite, tailored to maximize pilot situational awareness, minimize human error, and provide layered redundancy for critical flight data. The dual GDU1060 displays function as the primary flight and multifunction displays, interfacing with subsystems such as the GSU75 ADAHRS, GMU44B magnetometer, and GTN650Xi GPS/NAV/COMM unit. The architecture includes the GEA110 engine interface for real-time monitoring, a GTX345R transponder supporting ADS-B In/Out traffic awareness, and a GMA345 audio panel — all configured to maintain streamlined system interoperability. An integrated annunciator panel (AH500SD) and master warning push button (AH501) enhance pilot response time in abnormal situations, while the USB hub and backup systems, such as the GI275, ensure robustness and flight continuity in degraded modes.

This introduction sets the stage for a detailed exploration of the avionics logic, safetydriven design choices, and certification strategy underpinning the aircraft. By leveraging modern technology in an accessible and sustainable platform, this aircraft demonstrates how the next generation of GA can meet both regulatory demands and market needs.

The avionics system architecture was deliberately chosen to support flight training operations, offering a familiar interface to student pilots transitioning to higher-performance aircraft. The use of touchscreen interfaces, simplified menu hierarchies, and comprehensive engine and flight data visualization encourages early proficiency while maintaining low pilot workload. The system also supports customizable configuration modes tailored to flight schools, including data lockout, training overlays, and automated system alerts.

Also, in a GA aircraft design, the implementation of ATA 100 chapters [3] is integral to organizing technical data in manuals such as the *Aircraft Maintenance Manual (AMM)*, *Structural Repair Manual (SRM)*, *Illustrated Parts Catalog (IPC)* and *Component Maintenance Manual (CMM)*. These manuals, required for certification and ongoing airworthiness, rely on ATA numbering to categorize instructions, troubleshooting guides, repair procedures, and parts identification. By standardizing documentation formats and chapter references, ATA 100 enables maintenance personnel and engineers to quickly locate relevant information, reducing errors and downtime during inspections or repairs.

2. AVIONICS INTEGRATION AND SYSTEM ARCHITECTURE

The avionics suite of the aircraft was designed to deliver a high level of integration, functionality, and situational awareness while maintaining simplicity and redundancy for both training and operational safety. The avionics architecture (Figure 1.) centers around Garmin's modular G3X Touch ecosystem, offering seamless communication between systems and a scalable, certified platform compliant with EASA CS-23 requirements.

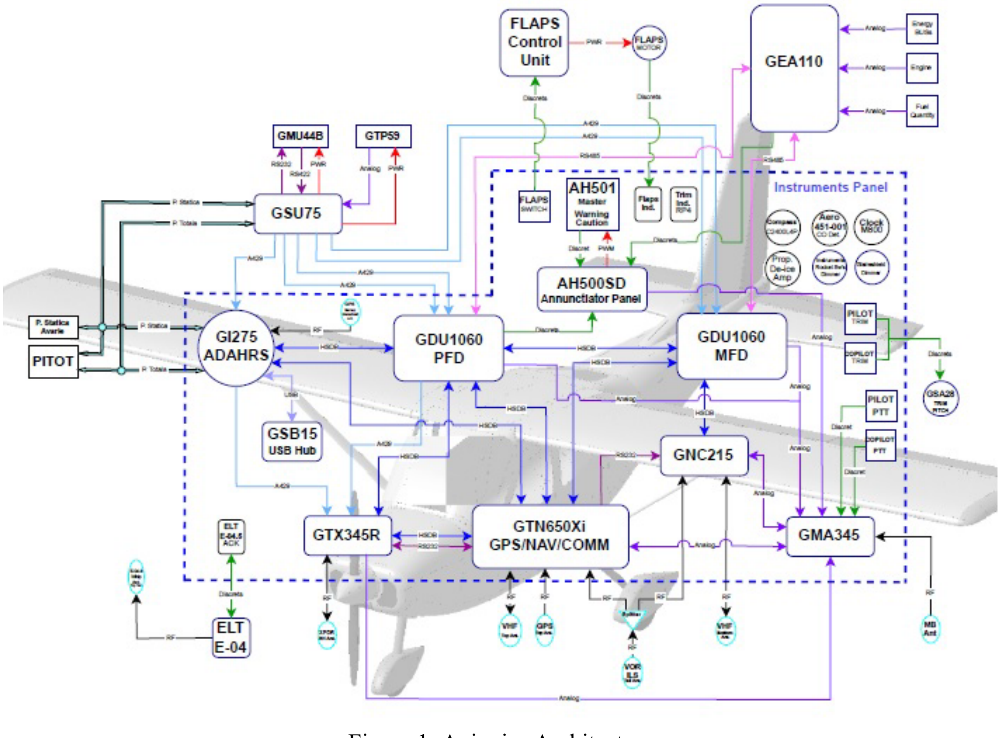

Figure 1. Avionics Architecture

2.1 Centralized Flight Display System

The primary flight instrumentation is managed through dual GDU1060 touchscreen displays - configured as a Primary Flight Display (PFD) and a Multifunction Display (MFD). The PFD presents flight-critical data including attitude, airspeed, altitude, and navigation cues, while the MFD consolidates engine performance metrics, system alerts, and moving map navigation. The use of high-resolution displays enhances situational awareness and reduces the likelihood of pilot misinterpretation.

2.2 Redundancy and Sensor Fusion

Redundant sensing and data processing form the backbone of the system's safety philosophy. Flight data is sourced through the GSU75 ADAHRS and GMU44B magnetometer, with GPS position derived from the GTN650Xi and an external GTPS9 antenna. This multi-source approach ensures robust data fusion and cross-checking for increased integrity.

In the event of partial panel or display failure, essential flight information remains available on the second GDU1060.

Furthermore, a backup GI275 instrument provides independent attitude and air data in a completely separate power and sensor chain—ensuring continuity during total PFD loss scenarios.

2.3 Communication and Navigation Subsystems

The GTN650Xi acts as the central navigation and communication unit, offering GPS, VOR/ILS, and COM functionality in a single touchscreen interface. Paired with the GNC215 NAV/COM and GMA345 audio panel, the system supports dual radio operation and clear, prioritized audio management - essential in busy airspace or training environments.
Traffic awareness is enhanced through the GTX345R transponder, which supports ADS-B In and Out, enabling real-time traffic visualization on the MFD and EFBs via Bluetooth.

2.4 Engine Monitoring and Safety Alerts

Engine performance and health data are collected via the GEA110 engine interface unit, which transmits information to the MFD for pilot reference. Critical parameters such as oil pressure, cylinder head temperature, EGT, and fuel flow are monitored continuously. The AH500SD annunciator panel and AH501 master warning system provide clear, immediate alerts in the event of limit exceedances, ensuring rapid response to abnormal conditions.

2.5 Data Logging and Maintenance Support

Flight and engine data are logged automatically by the GDU displays and can be exported via the GSB15 USB hub or wirelessly, depending on configuration. These logs support post-flight debriefing, maintenance diagnostics, and predictive analytics - an essential feature for flight schools or operators managing a small fleet. Integration with Garmin's cloud services allows centralized tracking of aircraft health and utilization trends.

2.6 Connectivity and EFB Integration

The avionics suite supports Bluetooth and optional Wi-Fi connectivity, enabling seamless integration with tablets and EFBs.

Pilots can transfer flight plans, update databases, and view real-time ADS-B traffic and weather on portable devices. This feature not only enhances cockpit ergonomics but also aligns with modern operational norms in digital GA.

2.7 Extended safety features

As a vital safety feature is the *Emergency Locator Transmitter (ELT)*[4]. Required on most registered aircraft, ELTs automatically transmit distress signals following a crash, guiding search and rescue teams to the aircraft's location. Modern ELTs, particularly 406 MHz models with GPS integration, offer highly accurate positioning and faster response times.

3. CERTIFICATION AND COMPLIANCE WITH EASA CS-23

Achieving compliance with the European Union Aviation Safety Agency's CS-23 specifications represents a constant process of both monitoring and design alignment, making it the ~~a~~ central pillar in the development of the aircraft. As an ELA1-category, single-engine, non-complex airplane, the aircraft benefits from streamlined regulatory processes, but it must still meet the stringent safety and airworthiness criteria defined under Part 21 of the EASA Basic Regulation and the latest performance-based amendments to CS-23.

3.1 Performance-Based Certification Philosophy

The aircraft certification process shall be conducted in accordance with the revised CS-23 framework, which emphasizes performance-based and risk-based requirements instead of prescriptive design mandates. This regulatory shift will enable innovation in both avionics integration and structural design, allowing the development team to apply safety-enhancing technologies —/ such as touchscreen displays, envelope protection, and integrated alerts, without being limited by legacy system definitions.
Using the certification categories under CS-23 Subpart B (Flight), Subpart C (Structures), Subpart D (Design and Construction), and Subpart E (Powerplant), the aircraft prototype shall be seeking validation for–operation across all normal conditions, including stall behavior, climb performance, and flight handling.

3.2 Avionics Compliance and Testing

The envisioned avionics suite, composed entirely of TSO'd Garmin components or non-TSO'd systems accepted under CS-STAN guidelines, is meant to be tested in accordance with EASA-approved methods for electromagnetic compatibility, environmental robustness (DO-160), and software assurance (DO-178C). Key subsystems such as the GTN650Xi, GTX345R, and GEA110; underwent compliance checks for ADS-B standards (ED-102A), RF performance, and interoperability.
System integration verification included:

- Display redundancy testing (GDU1060 PFD/MFD cross-failover),
- Power failure simulations with backup instrument continuity,
- Failure cascade analysis for alert systems (AH501, AH500SD),
- Human factors evaluations under simulated IMC and training scenarios.

3.3 Airworthiness and Structural Certification

The aircraft structure / likely made of lightweight metallic materials is planned to be tested in order to meet the load limits, fatigue margins, and flutter criteria of CS-23 Subpart C. Particular attention is paid to load propagation around avionics mounts, control surfaces, and the firewall, ensuring that avionics system integrity would be preserved under crash-impact scenarios. The fireproofing of wire routing, redundancy of power supplies, and EMI shielding are to be validated as part of the electrical system safety case.

3.4 Pilot Interface and Safety Assessment

CS-23 requires that aircraft systems support safe and intuitive operation by a typical GA pilot. The aircraft's avionics interface shall be tested using pilot-in-the-loop evaluations, focusing on:

- Readability and interpretability of alerts and displays,
- Ergonomics of touchscreen vs. knob-based input during turbulence,
- Cognitive load under VFR-into-IMC scenarios,
- Pilot response time to failure indications and annunciations.

The inclusion of synthetic vision, real-time traffic display, and automated voice alerts is targeting on reducing the pilot workload and increasing situational awareness, particularly beneficial for low-time pilots or training environments.

4. SUSTAINABILITY AND LIFECYCLE EFFICIENCY

4.1 Efficient Power Management

The electrical system integrates load-shedding logic, USB charging hubs, and solid-state devices to reduce electrical draw and maximize alternator efficiency. Avionics components such as the GTX345R and GDU1060 were selected for their low power consumption, helping reduce waste heat and extend electrical system lifespan.

These efficiencies allow for optional integration of small-scale solar panels or auxiliary batteries for powering avionics while on the ground, especially valuable in remote or off-grid environments.

4.2 Maintainability and Lifecycle Monitoring

Maintenance efficiency is enhanced through modular avionics architecture and digital diagnostics. Units such as the GEA110, GTN650Xi, and GDU1060 automatically log operating hours, failure events, and performance trends. These logs can be exported wirelessly or via the GSB15 USB hub and analyzed to support predictive maintenance, reducing unplanned downtime and part replacements.

This data-centric approach lowers total cost of ownership and extends aircraft service life while helping maintenance teams address anomalies before they become safety issues.

Additionally, use of standardized, certified components (e.g., Garmin TSO'd units, connectors, fasteners, etc.) ensures long-term supportability and spare part availability, essential for fleet operators and private owners alike.

4.3 End-of-Life Responsibility

While aircraft typically have long service lives, sustainability must account for eventual disposal or recycling. Composite structures have been designed for disassembly, and avionics modules use recyclable metals and plastics where feasible. Documentation and maintenance tracking facilitate aircraft resale and prevent premature obsolescence.

In the future, the currently carried out design aims for minimal modifications for powerplant upgrades or retrofitting to electric or hybrid propulsion systems, preserving the airframe's utility across multiple technological generations.

This chapter highlights the aircraft's forward-thinking design as not only a safe and modern platform but also a responsible choice for environmentally conscious aviation.

5. FLIGHT TRAINING AND OPERATIONAL USE CASE

This aircraft design relies on high adaptability for both personal and institutional use, and flight training emerged as a primary operational domain during its development. The combination of digital avionics, stable flight characteristics, and maintainability offers a comprehensive solution for aviation schools, instructors, and student pilots.

5.1 Training - Oriented Cockpit Design

The cockpit layout emphasizes symmetry, simplicity, and intuitive operation, which is critical for early-stage student pilots. The dual GDU1060 displays present a logical separation of primary flight and systems data, while touchscreen controls offer fast interaction with minimal tactile overload. Backup instrumentation using the GI275 or G5 further supports training in degraded systems scenarios.

Voice alerts, customizable checklist overlays, and dynamic alert annunciations enhance situational awareness and encourage proper pilot response behavior. These features help instructors guide students more efficiently while maintaining a safe learning environment.

5.2 Realistic Transition Platform

The avionics suite closely mirrors those found in larger GA and commercial training platforms, such as the Garmin G100 [5] or G5000, making this aircraft an ideal stepping stone toward more complex aircraft. The inclusion of ADS-B traffic, synthetic vision, and IFR-capable navigation systems ensures students by exposing them early to real-world flight management environments.

Simulated failures (via circuit breakers or system toggles) allow instructors to train for partial panel, loss of GPS, or engine anomalies, enabling practical scenario-based training aligned with EASA and ICAO flight training objectives.

5.3 Operational Versatility and Cost Control

The aircraft’s low fuel burn and digital maintenance logging significantly reduce operational costs; an essential factor for flight schools operating multiple sorties per day. Quick-access engine and system data simplify post-flight debriefs, while predictive maintenance minimizes downtime and enhances fleet reliability.

Additionally, the high dispatch rate supported by reliable avionics and power systems makes the aircraft suitable for both initial pilot training (PPL) and instrument rating (IR) modules. With its comfortable cabin and modern cockpit, it also serves well in time-building and cross-country training environments.

6. CONCLUSION AND OUTLOOK

This paper presented a modern, single-engine general aviation aircraft developed under EASA CS-23 certification and optimized for the ELA1 category. From its advanced Garmin G3X Touch avionics architecture to its sustainable materials and lifecycle-aware design, the aircraft exemplifies the convergence of safety, simplicity, and sustainability in modern GA.

By incorporating redundant systems, user-friendly interfaces, and real-time diagnostics, the aircraft not only enhances operational safety but also reduces the cognitive load for both seasoned pilots and trainees. Its performance-based certification under CS-23 allowed for the integration of innovative features without compromising regulatory compliance, highlighting the benefits of EASA’s modernized approach to light aircraft certification.

Operational use cases (especially in-flight training) demonstrate the aircraft's value in practical aviation contexts. Cost efficiency, maintainability, and training versatility ensure long-term relevance across private, instructional, and light commercial domains.

Looking ahead, the platform's modular structure, data connectivity, and fuel flexibility position it well for future enhancements, including partial electrification, integration with airspace modernization programs (e.g., U-space/UTM), and further emissions reductions. As such, the aircraft serves not only as a capable general aviation machine but also as a scalable foundation for the next generation of clean, connected, and pilot-centered aviation product.

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