Increasing Operational Flexibility: Mobile Web Applications for Flight Inspection

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ABSTRACT

Flight inspection requires precise execution and high situational awareness. Cockpit displays have evolved from analog gauges to integrated glass cockpits, yet fixed avionics sometimes lack the flexibility for displaying dynamic mission data. To address this, industry is shifting toward a "Bring Your Own Device" (BYOD) approach. This consolidates all data on a single personal device (like a laptop, tablet, or smartphone), reducing clutter and utilizing familiar hardware.

This paper presents a Mobile Web Application designed to improve mission awareness during flight inspections, which utilizes open mobile web standards for platform independence and high flexibility across different hardware. Its human-machine interface (HMI) provides a moving map with multiple selectable layers, mission procedures, and guidelines.

The design prioritizes usability through intuitive touch interactions, including pinch-to-zoom and quick panning gestures. This allows the crew to navigate through map overlays and procedure lists efficiently during flight.

The paper discusses the necessary operational constraints to ensure safe usage. By utilizing this technology, operators improve decision-making and streamline management, effectively connecting the flight crew with the flight inspection operator.

INTRODUCTION

During flight inspection missions, all crew involved (especially the pilots and operators) must maintain precise awareness of the aircraft's position relative to the defined nominal flight path as well as the next measurement procedures.

The Horizontal Situation Indicator (HSI) serves as the primary tactical reference for this task by providing real-time visualization of both lateral and vertical deviations from the intended trajectory. These deviations are derived directly from the measured navigation signals.

Additionally, a moving map provides the flight crew with an intuitive overview of the lateral flight path and the current mission status. It shows the aircraft's position in relation to the active inspection segment and the next planned flight segment. Guidance elements indicate the most efficient transition to the following procedure.

Meeting these operational requirements places specific demands on the cockpit display environment. The way mission data can be presented to the flight crew is strongly influenced by various factors like the cockpit layout and the degree of integration of the installed avionics systems. Additional displays or controls on top of the glareshield can affect the pilot's visibility and are subsequently inhibited. Otherwise, the pilot's capability to see and avoid other traffic might be degraded. The pilots need to access this information directly along their other indications.

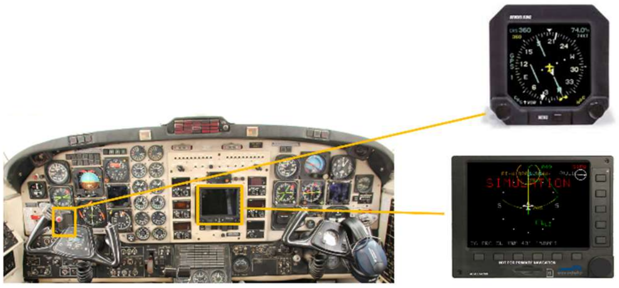


Figure 1: Legacy Flight Deck with Discrete Instruments for Flight Inspection Purposes

Older cockpit layouts like the flight deck of the Beechcraft 1900C provided enough physical space for the installation of additional gauges and mission-specific displays (ref. Figure 1). However, modern glass cockpit concepts have replaced traditional analog gauges with large, integrated displays that consume almost all available panel space.

Figure 2: Modern Flight Deck with External Interfaces

Some avionics vendors offer interfaces that allow displaying a moving map via an external video input stream (ref. Figure 2). This approach provides a seamless user interface for the flight crew.

Conversely, other vendors supply closed systems with very limited interfacing options (ref. Figure 3). In such closed systems, there is no possibility of injecting custom map elements or flight path deviation information.

Therefore, it becomes necessary to integrate additional devices into such cockpits to provide the flight crew with mission information.

Figure 3: Modern Flight Deck without External Interfaces

INDEPENDENT MISSION DISPLAY CONCEPT

If existing cockpit displays do not provide interfaces for mission data, additional devices must be used to compensate for the missing interfaces.

Of course, these devices must not interfere with any primary function of the aircraft and are thus subject to several constraints. These include certification constraints, electromagnetic compatibility, limited cockpit space, and the need for operational flexibility across different aircraft types. Based on these constraints, three hardware integration approaches can be considered for displaying information from an Automatic Flight Inspection System (AFIS) in the cockpit:

- **Interfaces to Proprietary Avionics:** Some avionics systems provide interfaces to display certain additional information. This allows for a seamless integration into the common cockpit workflow. The exact interfacing is neither standardized nor harmonized, so that it must be engineered for every aircraft type individually. In addition, some of these interfaces only allow to display information, but do not foresee any interaction. In this case, additional control inputs must be integrated into the cockpit.

- **Custom-Built Hardware:** To bypass closed avionics, organizations can engineer specialized hardware exclusively for the FIS use case. While this solves the data interface problem, custom-built devices introduce high development costs, complex aviation certification processes, and long lead times for spare parts.

- **Commercial Off-The-Shelf (COTS) Devices:** This approach utilizes standard consumer or enterprise hardware, such as off-the-shelf portable computing devices. COTS devices provide a flexible and cost-effective alternative to traditional aviation hardware. Commercial off the shelf

> (COTS) devices are widely used in airborne systems because they offer high performance, high integration, and reduced development effort. However, these devices are usually not developed according to aviation standards such as ED 80/DO 254, and detailed design data is normally not available to the applicant. As a result, COTS devices can introduce additional risks, especially due to their complexity, configurability, and potential design errors. For this reason, COTS devices used in functions with hardware DAL A, B, or C require specific development assurance activities, starting with an assessment of whether the device is considered complex.[6]

Among these options, Commercial Off-The-Shelf (COTS) devices provide the most suitable balance between flexibility, cost, and operational availability. By using COTS tablets as independent mission displays, the mission hardware remains physically decoupled from proprietary avionics systems. In addition, most pilots already use similar devices for flight planning, checklists or other tasks, so that it is ensured that the pilots can handle these well.

The other options presented have been implemented in the past and are not novel. For this reason, the remainder of this paper focuses on the use of portable COTS devices for displaying mission data in the cockpit.

The integration of such devices into an aircraft environment requires strict Electromagnetic Compatibility (EMC). The new hardware must not interfere with any of the functions of the aircraft. Electromagnetic interference (EMI) can influence the navigation or communication functions and must be checked accordingly. Furthermore, any physical data connection requires absolute electrical isolation (such as optical decouplers) to prevent ground loops from propagating into the certified avionics bus.

The use of USB-C Power Delivery simplifies the integration of portable mission displays by avoiding device-specific power adapters and converters. A single, standardized power interface supports different device types while reducing system complexity. A power limit of 60 W is well suited for aviation use, as it can be easily provided by typical 28 V DC aircraft power rails[2]. Since a standard tablet requires no more than approximately 20 W for charging and operation, USB-C PD provides sufficient power margin while maintaining a simple and robust integration[3].

SOFTWARE INTEGRATION

Using standard COTS devices requires a software approach that works seamlessly across different device types. A native application contradicts this goal because it requires development for specific platforms. In addition, mandatory app store certification processes make software updates unnecessarily complex.

Progressive Web Applications (PWA) offer a platform-independent solution. A PWA uses standard web technologies and can be accessed via a web browser or installed onto the home screen to function exactly like a native app with the possibility of hiding all browser typical user interface (UI) elements like the address bar. This approach completely decouples the software deployment from third-party app stores, while still maintaining a smooth user experience with various features.

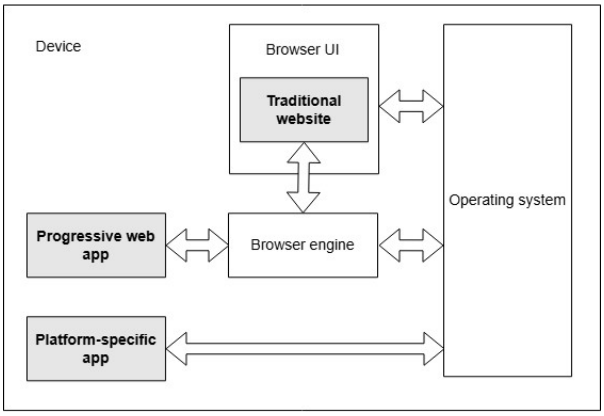


Figure 4: Different application types [4]

A key feature of PWAs is the ability to explicitly cache application resources on the device. This allows essential parts of the application to be loaded locally without requiring a continuous network connection[5]. Users can hardly distinguish between traditional and Progressive Web Applications.

IMPLEMENTATION OF A WEB APP FOR MISSION AWARENESS

The Mission Awareness application consists of two primary functional components: the Electronic Horizontal Situation Indicator (EHSI) and the Moving Map. Both components are integrated into a single Web Application and can be displayed simultaneously or individually, depending on the operational needs of the flight crew.

The application is designed to run on standard Commercial Off-The-Shelf (COTS) devices. Any device capable of rendering a WebGL 2 context and supporting modern web standards can be used to operate the application. This ensures broad compatibility across different hardware platforms while maintaining the graphical performance required for real-time flight inspection data visualization.

System Architecture

The PWA is provided by a server which is independent from the avionics. The application is delivered to the client device via standard Hypertext Transfer Protocol (HTTP) requests, comparable to a conventional web server.

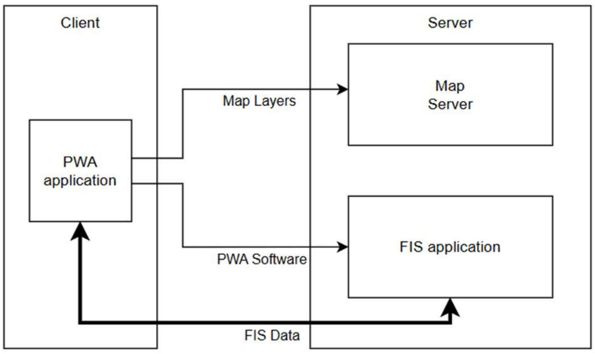


Figure 5: System architecture for a FIS PWA application

After the PWA has been loaded on the client device, a persistent WebSocket connection is established between the application and the server. This connection is used for the continuous exchange of real-time Flight Inspection System (FIS) data. The WebSocket connection operates as a bidirectional communication link as shown in Figure 5. In addition to transmitting Flight Inspection System (FIS) data to the cockpit, it allows the client application to send information and trigger mission-related events from the flight deck back to the server.

A dedicated map server provides map data via standard HTTP interfaces. Offloading map data delivery to a separate service reduces the processing load on the Flight Inspection System (FIS) application and enables a standardized and scalable way to provide multiple map layers to clients.

Communication Continuity and Integrity Control

Reliable communication between the client application and the onboard server is essential for safe and effective flight operations. Due to the dynamic nature of the operational environment, network interruptions may occur at various points in the communication chain and are not always immediately visible at the application level. To mitigate the risks associated with such failures, the application implements proactive monitoring, user feedback, and automated recovery mechanisms. These measures ensure data integrity, user awareness, and continued operation with the correct software version.

To ensure early detection of connectivity issues, the application continuously supervises the WebSocket connection using an automated heartbeat mechanism. This mechanism periodically verifies end-to-end connectivity between the client and the server. A failed heartbeat or an unexpected WebSocket disconnection is interpreted as a loss of communication.

When a connection issue is detected, the application immediately informs the user through a dedicated status indicator in the user interface. This visual feedback enables users to quickly assess the validity and currency of the displayed data, thereby maintaining trust in the system during degraded network conditions.

In parallel with user notification, a background reconnection routine is initiated. This routine attempts to re-establish the connection at predefined intervals without requiring user interaction. Once the connection is successfully restored, the application automatically synchronizes the mission data and clears the warning indicator to reflect the recovered system state.

After the connection has been successfully established, the application performs an explicit software version check. This step ensures compatibility between the client and server and prevents continued operation with an outdated application version, such as when a PWA remains active after a newer version has been deployed. If a version mismatch is detected, the application automatically reloads to ensure that the correct and approved software version is in use.

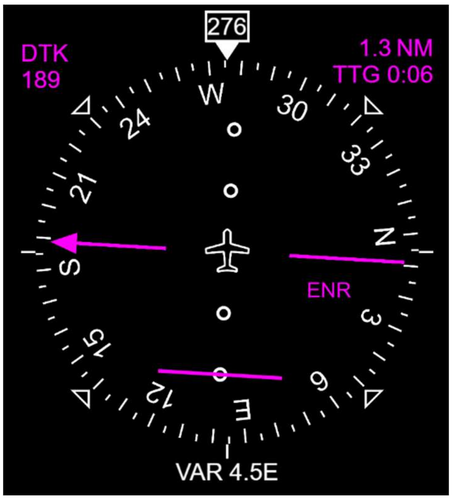


Figure 6: HSI component of PWA application

HSI for Tactical Guidance

The Horizontal Situation Indicator (HSI) is the primary instrument for monitoring the aircraft's deviation from the defined nominal flight path during flight inspection missions. It provides high-frequency visual feedback that is essential for the calibration of navigation aids and the validation of flight procedures.

Operational Modes

- **Angular Mode (APPR):**
  This mode is used for approach and receiver guidance, such as ILS or VOR inspections. Lateral

and vertical deviations are displayed representing the measured navigation signal behavior.

- **Linear Mode (ENR):**
  This mode is used for enroute segments or RNAV transitions. Deviations are displayed as cross-track distance in nautical miles (NM), typically using a 0.5 NM full-scale deflection to support standardized evaluation.

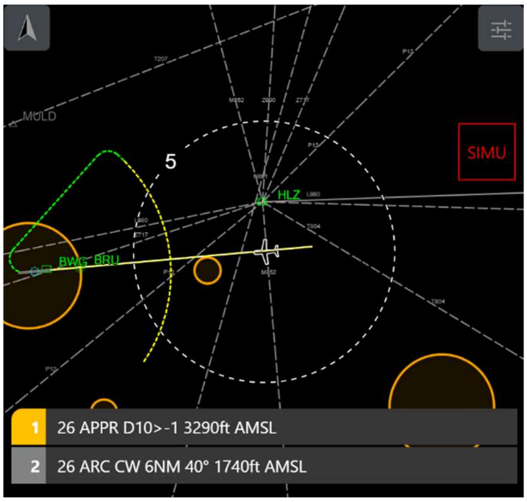
Technical Performance

To avoid control-loop instability and pilot-induced oscillations (PIO), the system is designed to achieve very low latency between data reception and visual update. Hardware-accelerated rendering ensures a stable and jitter-free display of the compass rose and deviation indicators, maintaining readability under high-workload cockpit conditions.

Moving Map for Strategic Guidance

The Moving Map provides strategic situational awareness by placing the aircraft's position within its geographic and operational context. It allows the operator to monitor mission progress and assess the aircraft's position relative to terrain, airspace, and mission-specific constraints.

Depending on the user's preferences, the moving map can be oriented North-Up or Track-Up. While Track-Up supports short-term orientation, North-Up is more suitable for the medium- or long-term orientation throughout different profiles.



1 26 APPR D10>-1 3290ft AMSL

2 26 ARC CW 6NM 40° 1740ft AMSL

Figure 7: Moving Map component of PWA application

Data Integration

- Raster Assets:
  The system supports standardized raster imagery, such as sectional charts for visual flight rules (VFR) and topographic background maps. A backend server can be used as data source for different data types like map tiles or GeoTIFF images.
- Vector Assets:
  Mission-specific elements, including nominal flight tracks, waypoints, and protected signal volumes, are rendered dynamically using standardized vector formats (e.g. GeoJSON). Custom map layers and site-specific obstacle databases can be integrated as required.

Geospatial Configuration

The Moving Map supports multiple map projections to match the operational use case. Standard Web Mercator projection is used for general navigation, while local Universal Transverse Mercator (UTM) projections can be applied for high-precision survey and inspection tasks. Coordinate processing ensures that transformations between GNSS input data and map display maintain the accuracy required for flight inspection reporting.

HUMAN FACTORS

The hardware setup and operational use of the mission guidance display are comparable to a portable or mounted Electronic Flight Bag (EFB Type 1 or Type 2) [1]. As a result, established aviation human-factors guidelines for EFBs are applicable to the design and operation of this application.

Applying these guidelines ensures that the Human-Machine Interface (HMI) meets the specific requirements of the cockpit environment and supports safe and efficient flight inspection operations. The most relevant design considerations are outlined below.

Visual Readability

The display is designed to remain clearly readable under varying ambient lighting conditions. Adaptable color schemes are implemented to ensure sufficient contrast and avoid glare or loss of information in bright sunlight or low-light conditions. [AC 120-76C 13.c].

Interaction Design

Touch interaction elements are sized and spaced to allow reliable operation during all flight phases. Buttons and touch targets are scaled appropriately to support precise inputs even under aircraft vibration or turbulence.

For example, zoom interactions can be performed using minimal user input. Gesture recognition determines the intended zoom direction and automatically selects the nearest predefined zoom level based on the final gesture position, reducing the need for fine pinch gesture interactions during flight. [AC 120-76C 13.f(6)].

Information Architecture

The information layout prioritizes mission-relevant data to support efficient decision-making by the flight inspection crew. Visual clutter is minimized to reduce cognitive workload and enable rapid interpretation of displayed information. Map element labels are managed dynamically to prevent overlap and are shown or hidden based on the current zoom level. [AC 120-76C, 13.l].

Position Awareness and Integrity Monitoring

To prevent misleading position information, the application continuously monitors the health of the GNSS data stream. If position updates are interrupted, the own-ship symbol is removed from the display to avoid a "frozen" own-ship condition caused by signal loss or power interruption of the GNSS source. For systems updating at 1 Hz, the own-ship symbol is removed after three consecutive missing position updates, in accordance with [AC 120-76C 13.f(4)].

The application also implements limitations on map zoom levels. Maximum zoom is restricted to ensure that the displayed own-ship position is not interpreted as suitable for direct aircraft maneuvering. The permitted zoom range is aligned with the positional accuracy of the GNSS data, providing supplemental situational awareness only [AC 120-76C, 13.f(6)].

Interface Consistency

Wherever possible, the user interface follows established flight deck design philosophies. While not required to be identical to certified avionics displays, the interface is designed to be consistent in terms of symbology, terminology, color usage, and interaction patterns [AC 120-76C, 14.d(3)(a)].

Consistency is also maintained across different application views and functions. Data entry methods, color-coding concepts, and symbols are applied uniformly to support intuitive operation and reduce training effort [AC 120-76C, 13.b].

OUTLOOK

Progressive Web Applications provide a flexible approach for cockpit software used in Flight Inspection. Based on standardized web technologies, they allow software to be adapted, extended, and maintained efficiently over long system lifecycles. This flexibility supports continuous improvement while reducing dependency on rigid, platform-specific solutions.

PWAs are particularly suitable for smaller supporting applications. Additional observer tools or modules for training purposes can be developed as independent modules and distributed reliably as PWAs. This modular approach simplifies software management and supports the use of purpose-built tools without affecting core cockpit systems.

A further advantage is the simplified integration of new and more capable hardware. As performance and available interfaces improve, PWA-based software can utilize these capabilities with minimal architectural changes. This enables faster adoption of modern hardware while preserving existing software solutions.

Platform independence also ensures long-term availability. PWAs can operate across different operating systems and device types, reducing reliance on specific vendors or technologies. Even if certain platforms disappear from the market, PWA-based solutions can be transferred more easily, supporting sustainability and continuity in Flight Inspection cockpit systems.

CONCLUSIONS

This paper presented a mobile, web-based Mission Awareness Application designed to enhance situational awareness during flight inspection missions. By combining an Horizontal Situation Indicator for tactical guidance with a Moving Map for strategic context, the system supports precise flight path control while maintaining a comprehensive overview of mission progress and environmental constraints.

A decoupled system architecture was introduced to enable the integration of mission-specific functionality without interfering with certified aircraft avionics. The use of Commercial Off-The-Shelf (COTS) devices and standardized interfaces allows flexible deployment across different aircraft types while avoiding costly custom hardware and lengthy certification cycles. Key integration aspects, including electromagnetic compatibility, power supply via certified USB-C Power Delivery, and robust network handling, were addressed to ensure safe and reliable operation in the cockpit environment.

On the software side, the implementation of a Progressive Web Application enables platform-independent deployment and efficient lifecycle management. Features such as controlled caching, active version checking, bidirectional WebSocket communication, and automated reconnection mechanisms ensure consistent operation and timely delivery of mission data, even under intermittent network conditions.

Human-factors considerations based on established EFB guidance were applied to the design of the Human-Machine Interface. These measures ensure readability, intuitive interaction, and protection against misleading information, supporting safe operation under high workload and dynamic flight conditions.

Overall, the presented approach demonstrates that modern web technologies, when combined with a carefully designed system architecture and aviation-specific human-factors principles, provide a viable and flexible solution for mission awareness in flight inspection operations.

DISCLOSURE

Microsoft Copilot was used as AI-based language tool solely to improve readability and language quality. All technical content, interpretations, and conclusions are the responsibility of the author.

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