WANDA Wireless Anatomical Neuro-physiological Device for Aircrew for Physiological Monitoring of In-flight Aircrew

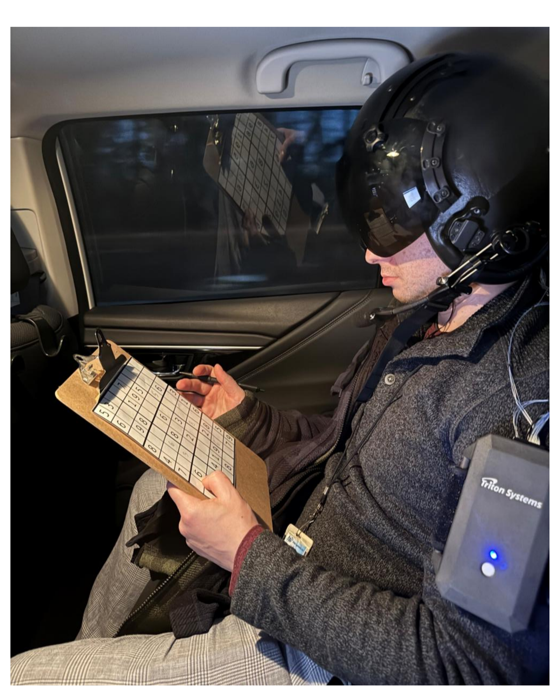
Triton Systems

Jason Lasser, Aaron Rios, Annie Geheran, Paul Fleming, James Saunders | PM: jsaunders@tritonsys.com

Motivation

There is currently insufficient operational data to inform decisions on integration of physiological metrics such as EEG-based cognitive monitoring into aircrew systems. The performance of EEG systems described in research is typically limited to controlled lab settings, without the application being integrated into current flight helmets; as a result, current research cannot strongly account for the impacts of real flight conditions (i.e., high G-load, vibration, motion, thermal load, and helmet form factor). This produces a dual bottleneck: too little operationally relevant research exists to inform use, and the same constraints that limit that use (motion artifact, poor helmet integration, unreliable signal in-flight) limit research efforts. Closing this gap requires building a system that proves a reliable EEG signal can be acquired in-flight.

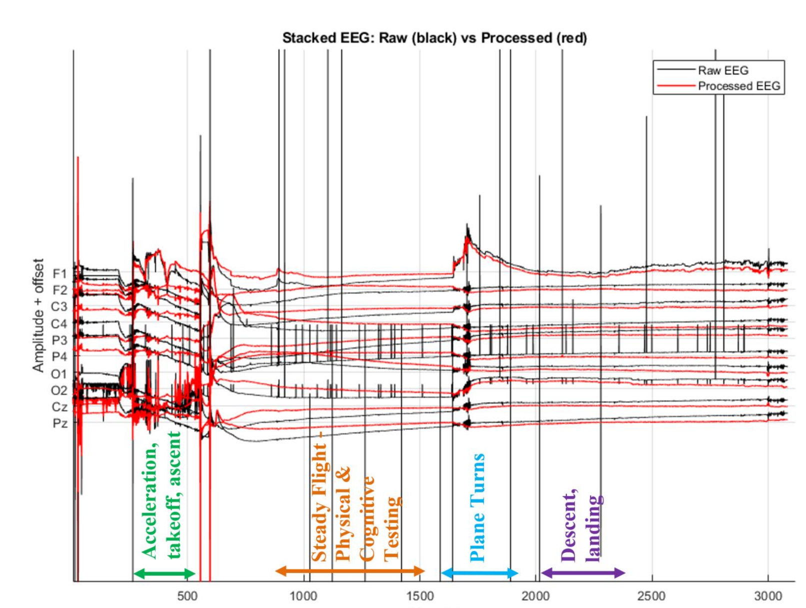
Methods

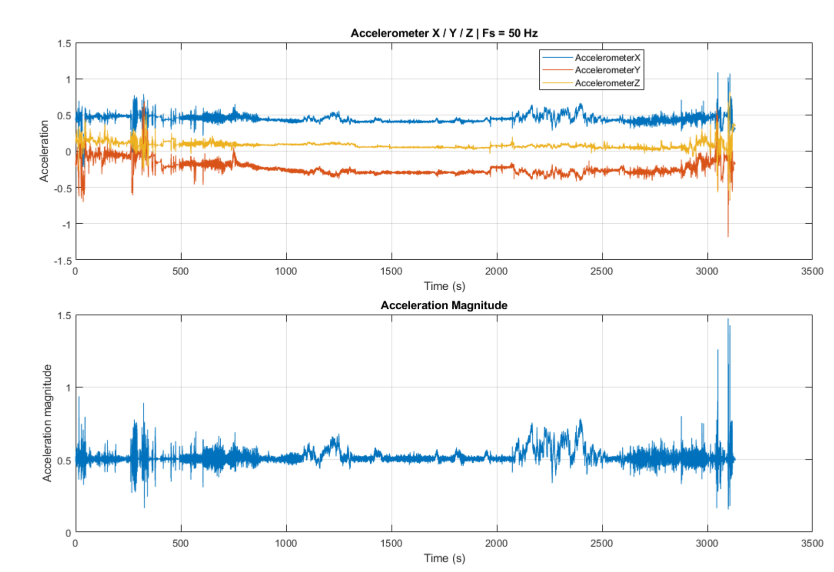


To address this gap, we designed, developed, and tested a custom 10-channel dry-electrode EEG system integrated into a standard fixed-wing flight helmet (HGU-68/P), with electrodes placed per the 10-20 system in place of the stock comfort liner. The system was evaluated across simulated, ground-based, and in-flight conditions aboard a civilian six-seat propeller aircraft, using an SSVEP paradigm to assess signal acquisition and subjective comparisons to conventional systems for comfort and usability. The system acquired a discernible 12 Hz spectral peak consistent with an SSVEP response.

Results

Real-time data acquisition and signal quality monitoring interface used during testing. Six electrodes were not populated for this use case (red). The left panel (Galea GUI) displays live time-series data and per-channel signal quality metrics with scalp topography; right panel shows the custom 10-channel EEG viewer with real-time smoothing used for continuous monitoring during ground and in-flight sessions.





Stacked EEG traces (10 channels, raw in black, artifact-processed in red) across a full in-flight recording, annotated by flight phase. High-amplitude artifacts are visible during acceleration, takeoff, and ascent, with signal stabilizing during steady flight and cognitive/physical testing. Plane turns and descent/landing reintroduce transient artifacts, which are attenuated in the processed signal, demonstrating usable signal recovery across dynamic flight conditions.

- Integrated electrode actuation improves donning, electrode contact consistency, and signal reliability
- Modular lattice / electrode design enables customization across head sizes and hair types without performance loss
- Real-time signal processing algorithms filter and remove noise and artifacts for reliable data acquisition and live marker detection

Discussion

Results demonstrated dry electrode EEG can be reliably acquired from within a flight helmet without compromising fit, comfort, or function, addressing a key barrier that has historically confined EEG research to the lab. The consistent 12 Hz SSVEP response indicates the system captures physiologically meaningful signal. This sets a foundational benchmark: reliable signal acquisition is achievable in an operationally relevant environment. These findings are limited by a small sample size, a single airframe, and the absence of validated measures for operationally relevant states such as fatigue and hypoxia, and further testing is needed across diverse aircraft and larger cohorts to establish generalizability.

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