



# REAL-TIME SYNCHRONIZATION OF FLIGHT SIMULATION AND PHYSIOLOGICAL DATA USING LAB STREAMING LAYER: A CUSTOM X-PLANE APPROACH

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## Abstract

Poor synchronization of physiological and flight data hinders human factors research by obscuring cause-effect relationships and requiring laborious manual alignment. We developed a custom X-Plane plugin using Lab Streaming Layer (LSL) for real-time synchronization to integrate flight data with simultaneously streamed ECG and eye-tracking signals. Our setup simplifies data collection, ensures precise synchronization without manual intervention, reduces error, and minimizes preprocessing time.

This approach enables accurate correlation between physiological responses and in-flight events, offering deeper insights into pilot performance and workload. It provides a practical, reproducible method for simplifying multimodal data collection, making research in aviation human factors more accessible and efficient.

## Introduction

**Challenge:** Integrating multiple human performance measures (flight data, biometrics) in flight simulation is crucial for aviation psychology and human factors research.

**Problem:** Poor data synchronization obscures cause-effect relationships and requires extensive manual alignment, leading to potential errors and increased preprocessing time.

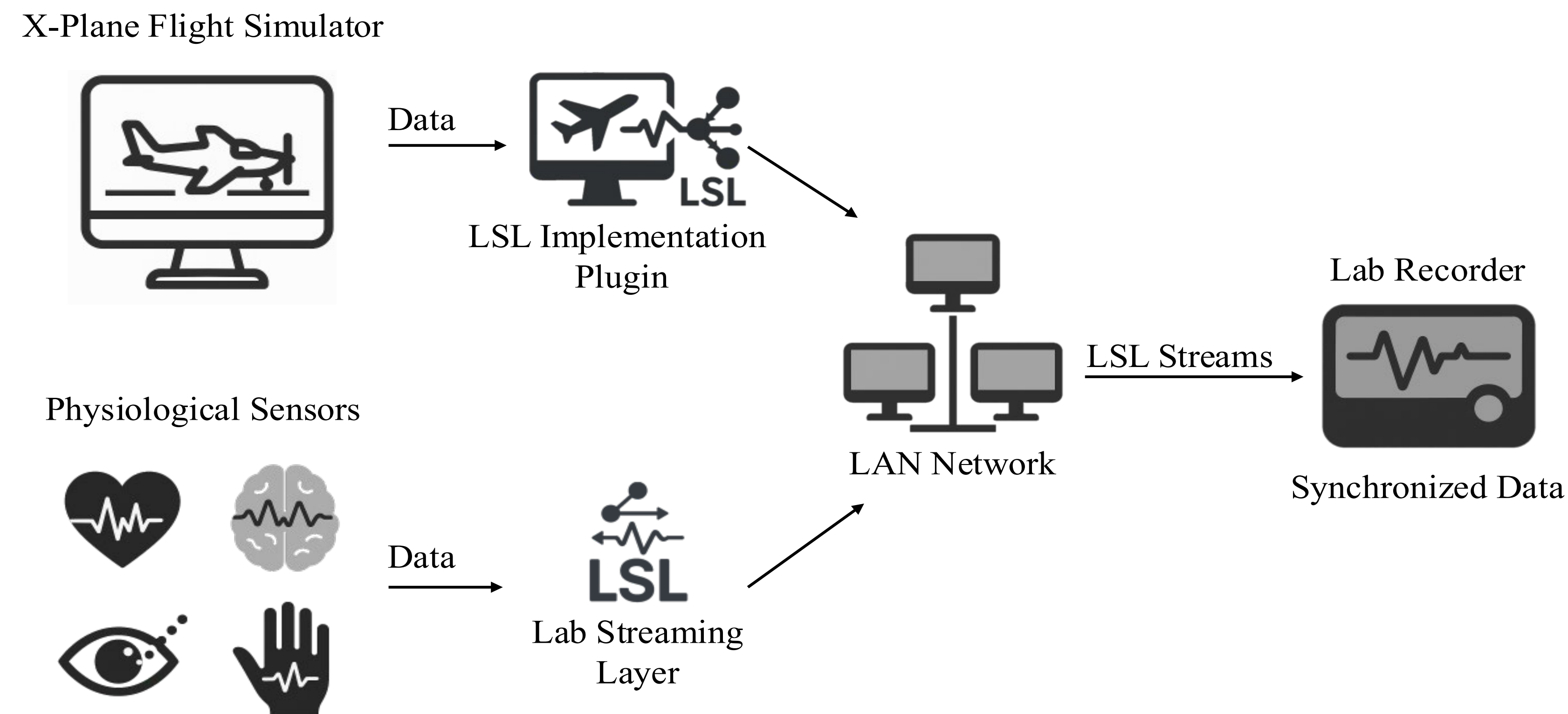
### Existing Solutions & Gaps:

While multimodal data collection is used (e.g., eye tracking, EEG, ECG in simulators), precise and effortless synchronization remains a hurdle.

**Our Solution:** A custom X-Plane plugin leveraging Lab Streaming Layer (LSL) for real-time, unified, and time-synchronized streaming of flight simulator data, ECG, and eye-tracking data.

## System Architecture and Methods

Our system integrates X-Plane, physiological sensors, and eye-tracking within a unified LSL framework on a single high-performance PC.



### Key Components:

1. **X-Plane Flight Simulator:** Varjo XR-4 headset.
2. **Physiological Sensors:** ECG (Polar H10), Eye-Tracking (Varjo XR-4 integrated).
3. **Lab Streaming Layer (LSL):** Open-source framework for synchronized streaming/recording (XDF).
4. **Data Streams:** Flight data, Physiological data (ECG), Eye-tracking data.

## Results and Benefits

**Successful Integration & Synchronization:** Reliably recorded aircraft state, control inputs, ECG, and gaze data via LSL without discernible loss or latency. LSL provided temporal precision.

**Enhanced Behavioral Insight:** High-quality HRV metrics from ECG. Synchronized gaze replay visualized attentional allocation.

- Positive correlation: maneuvering intensity & heart rate.
- Correlation: gaze patterns & cognitive workload.

### Key Advantages:

- Validated Sensor Integration
- Precise Synchronization (sub-millisecond)
- Richer Insights
- Simplified Workflow

## Conclusion

We introduced an integrated system for synchronized multimodal data acquisition in a VR flight simulation environment. The custom X-Plane LSL plugin achieves high-fidelity, real-time streaming of flight parameters precisely aligned with eye-tracking and ECG data.

- Overcomes Synchronization Challenges.
- Powerful Research Tool.
- Cost-Effective & Reproducible.

**Impact:** Deeper insights into pilot performance, supporting data-driven aviation training and system design.

## Future Work

Apply to traditional flight training devices. Develop LSL interfaces for proprietary simulators. Collaborate with training organizations.

## Plugin and Related Work

The X-Plane LSL Implementation Plugin is publicly available on GitHub :



[aub.ie/XPlaneLSL](http://aub.ie/XPlaneLSL)



[aub.ie/ISAP2025](http://aub.ie/ISAP2025)