# ClearPath
# System Design Document
## Version <1.0>
## 11/21/2024

# Document Control

## Distribution List

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## Change Summary

The following table details changes made between versions of this document:

| Version | Date | Modifier | Description |
| --- | --- | --- | --- |
| 1.0 | 10/24/2024 | SK, CN | Initial version of SDD document |
| 2.0 | 11/21/204 | IH, CN | Updated SDD – software processes |
| | | | |

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# 1. Introduction

## 1.1. Purpose and Scope

The purpose of this Software Design Document (SDD) is to provide a comprehensive design framework of the ClearPath system. Clear Path aims at integrating live traffic data and simulating runway and taxiway incursion scenarios within the XPlane environment. This document outlines the system architecture, software components, and interactions necessary to fulfill ClearPath's requirements.

The ClearPath system, is designed to interact with the XPlane simulator within LB131, enhances the simulation of air traffic scenarios by integrating real-time flight data and offering configurable incursion scenarios. It allows users to see live aircraft behavior, respond to incursion events, and simulate Air Traffic Control (ATC) and pilot responses. The system could be used to support academic training and operational research, providing a realistic platform for studying runway safety and aircraft movements.

**Project Summary:**

- **System Name**: ClearPath
- **Problem Addressed**: The need to improve training and research tools for runway safety through real-time data simulation and incursion scenario modeling.
- **System Scope**: ClearPath will offer live traffic integration, 3D visualization, and incursion alerting features but will not include broader air traffic control functionalities beyond the specific scope of incursion detection and alerting.

The ClearPath system arose from a needs analysis focused on enhancing real-world training and research on runway and taxiway incursions. The analysis highlighted gaps in current simulator capabilities regarding live traffic data use and accurate scenario modeling. ClearPath addresses these by providing **live traffic simulation** to reflect real-world aircraft movements. The system also allows for i**ncursion detection** and alerting for training in runway safety responses. The information within this document is currently the best idea we have of the design of ClearPath. All sections are subject to change.

## 1.2. Project Executive Summary

The ClearPath project is designed to provide training focused on enhancing runway and taxiway safety by integrating live traffic data and realistic incursion scenarios within the XPlane simulation environment. From a management perspective, ClearPath focuses on live data-driven outputs where users can practice response strategies for runway and taxiway incursions in a controlled, interactive setting. The project is structured around the following primary goals: integrating real-time traffic data into the simulator and offering a flexible and customizable incursion scenario simulation.

The conceptual design for ClearPath was developed through the needs of the customer, which included input from Dr. Masood Towhidnejad. Constraints include compatibility with the existing XPlane environment and some additional hardware setup. To address these requirements effectively, ClearPath will proceed through iterative development phases, which will align with team members academic schedules to facilitate development and refinement.

ClearPath's scope is defined around delivering a functional and accessible training tool. Its key deliverables include the integration of real-time flight data from FlightRadar24 or other live radar services, a module to detect and respond to simulated incursion events, and user interface enhancements that allow for scenario monitoring and alert management. Through this focused project framework, ClearPath will fulfill the requirements established in the System Requirements Specification, providing a valuable resource for training.

### 1.2.1. System Overview

At the core of the system is the ClearPath module, which processes commands, data, and simulation events to create a realistic and interactive training environment. Users interact with the system through a keyboard interface, which allows them to input commands and control various aspects of the simulation. ClearPath processes these commands to simulation parameters.

The system connects with external sources of live traffic data, which provides real-time information on aircraft positions and movements, ensuring that the simulated environment reflects current air traffic. This live data is essential for creating accurate and dynamic scenarios within the simulator. ClearPath also interacts with the flight control module of XPlane, issuing commands and sending data to simulate aircraft maneuvers and respond appropriately to potential incursions.

To enhance user engagement, ClearPath outputs data to a display module, which visualizes real-time information, alerts, and simulation feedback. This display allows users to monitor live traffic movements and any incursion alerts that may arise during a scenario. Additionally, the system interfaces with a 4D motion module, simulating realistic movements based on aircraft data, providing an added layer of immersion that allows users to experience the physical aspects of aircraft responses and movements in real-time.

Overall, the ClearPath system's architecture supports a continuous flow of information between user inputs, live traffic data, and display outputs, providing an interactive and high-fidelity platform for airfield safety training. Figure one shows ClearPath's concept diagram. This shows the intricate inputs and outputs and what data is being passed through the program.

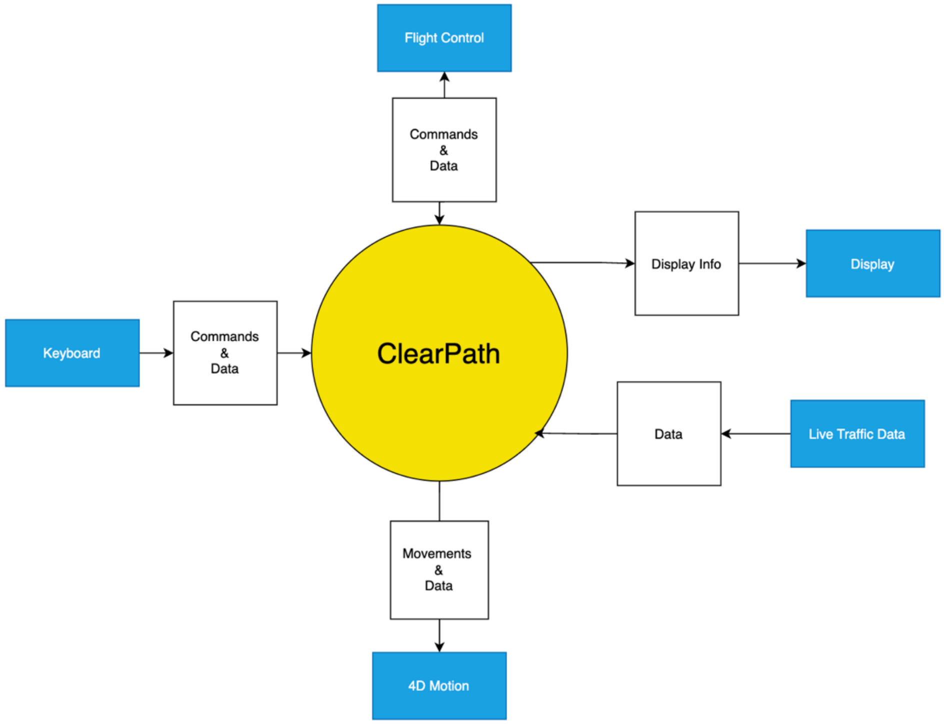


Figure 1. System context diagram

#### 1.2.2. Design Constraints

To date, the ClearPath project has progressed smoothly without encountering any constraints. The system's design and integration are set to be implemented as planned.

#### 1.2.3. Future Contingencies

ClearPath currently foresees the program to be developed without a hitch. However, we as a team have discussed some contingencies with the customer. We have discussed milestone steps, of having a plane appear on the 2D top-down view before it appears in 3D. We then will attempt to add live traffic data in the 2D and 3D environments. We have also discussed these milestones to be used as contingencies in the event we cannot make an aspect of the system work properly.

### 1.3. Document Organization

This document is organized into sections and subsections. The sections are: Introduction, System Architecture, Human-Machine Interface, Detailed Design, External Interfaces, and System Integrity Controls. These sections have appropriate subsections with paragraph explanations and diagrams as needed. The Table of Contents may be used to properly navigate this document.

### 1.4. Project References

There are no references used at the moment.

## 1.5. Definitions, Acronyms, and Abbreviations

### 1.5.1. Definitions

This section lists terms used in this document and their associated definitions.

**Table 1: <Caption>**

| Term | Definition |
|---|---|
| Game | Refers to XPlane 11 or 12 |
| | |
| | |

### 1.5.2. Acronyms

This section lists the acronyms used in this document and their associated definitions.

**Table 2: <Caption>**

| Term | Definition |
|---|---|
| | |
| | |
| | |

### 1.5.3. Abbreviations

This section lists the abbreviations used in this document and their associated definitions.

**Table 3: <Caption>**

| Term | Definition |
|---|---|
| | |
| | |
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# 2. System Architecture

## 2.1. System Hardware Architecture

The system hardware architecture includes a collection of hardware components that enable immersive training experiences by closely replicating real-world cockpit interactions. The architecture consists of the following key components:

- 4D Motion Platform: This component provides the physical movement that simulates the aircraft’s position and orientation changes. It is responsible for creating motion feedback based on the pilot's interactions with the simulator controls and the simulated aircraft's behavior.
- Computer: Serves as the central processing unit of the incursion system, coordinating inputs from the user and the 4D motion platform and generating corresponding outputs. The computer calculates responses to user input in real-time, producing motion feedback and updating the display to reflect the current scenario.
- Display: Provides the visual interface for the incursion system, showing real-time simulations of the runway environment, aircraft status, and external surroundings. This display helps users remain immersed in the simulated environment by providing a realistic view of the cockpit perspective and external conditions.
- User Input Controls: The pilot interacts with the incursion system using various control inputs, which include:
- Yoke: Represents the primary flight control, used by the pilot to manage the aircraft’s pitch and roll.
- Throttle/Mix/Flaps/Gear Controls: Control the power, fuel mixture, flaps, and landing gear, respectively, allowing the pilot to adjust various flight parameters as needed.
- Pedals: Control the aircraft’s yaw, simulating rudder control for directional adjustments during ground operations.
- Emergency Stop (E-Stop): Two E-Stop buttons are integrated into the system for safety. One E-Stop is positioned near the 4D motion platform to halt motion immediately if necessary. A second E-Stop is connected to the user input control panel, allowing the pilot or instructor to stop all interactions and outputs instantly in the event of a malfunction or unsafe scenario.

The figure below provides an image of how the hardware interacts with the other physical components as well as interacts with the user.

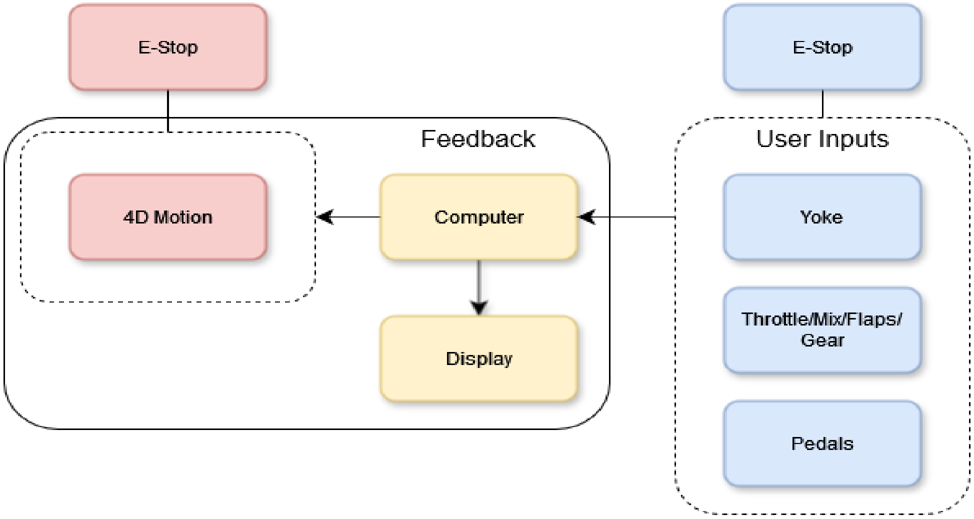


Figure 2. ClearPath Hardware Architecture

## 2.2. System Software Architecture

Clear Path does not currently have any software developed. Once we start developing and integrating additional software, we will update this section.

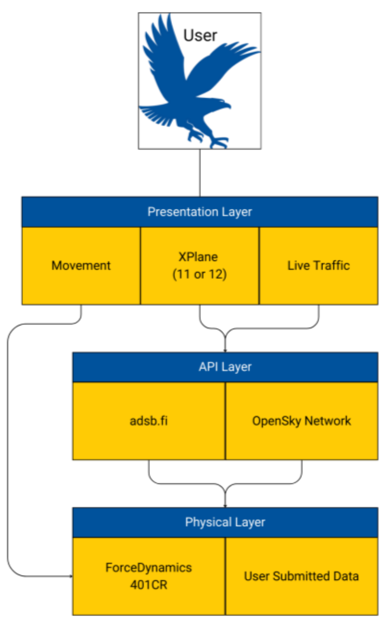


Figure 3. Software Architecture

## 2.3. Internal Communications Architecture

Clear Paths internal software communication can be best found in Sections 4.3 & 5.4, where it is explained how the game is able to read the live traffic data through the plugins.

# 3. Human-Machine Interface

ClearPath System's Human-Machine Interface (HMI) is designed to facilitate seamless interaction between users and the Force Dynamics 401CR simulation setup integrated with XPlane. This section outlines the specific input and output mechanisms for both Basic Users and Administrators, ensuring that interactions are user-friendly, intuitive, and secure.

## 3.1. Inputs

This subsection describes the user inputs for operating the ClearPath System, focusing on configuration, control, and safety.

### 3.1.1. Simulation Controls and Input Mechanisms

This interface enables users to start, stop, and adjust simulation parameters and controls the initial setup and launch sequence required to activate the Force Dynamics 401CR and XPlane 11.

**Startup Sequence**:

1. **Turn on all power switches**: Ensure all necessary power switches on the Force Dynamics 401CR are switched on.
2. **Reset all emergency stops**: Confirm that all emergency-stop buttons are released.
3. **Boot into BIOS**: Start the system by accessing the BIOS.
4. **Press F1 to save changes in BIOS**: Press F1 to enter the BIOS, save any necessary changes, and then exit.
5. **Normal PC startup**: After exiting BIOS, the PC will boot up normally.
6. **Auto-launch Force Control Program**: The system will automatically open the Force Control program used to manage motion.
7. **Enable Motion**: Within the Force Control program, activate the motion by selecting "Enable Motion."
8. **Press "Park Up"**: Prepare the simulator for operation by pressing "Park Up."
9. **Launch XPlane 11**: Open and run XPlane 11 to begin the simulation

**Inputs**:

- **Start Simulation Button**: Initiates the real-time simulation environment within XPlane.
- **Stop Simulation Button**: Ends the current simulation session.
- **Proximity Threshold Slider**: Allows users to adjust the minimum distance for detecting incursions on runways and taxiways.

**Data Validation:**

- **Proximity Threshold:** Restricts values to a range of 0.1 to 5.0 nautical miles, ensuring that incursion detection operates within realistic parameters.
- **Mandatory Fields:** Start and Stop buttons are required actions to initialize and end the simulation session.

## 3.2. Outputs

This section describes the system outputs displayed to the user, including both real-time data visualizations and event logs.

### 3.2.1. Output Displays and Data Elements

**Real-Time Simulation Display**

The main visualization screen shows a dynamic 3D view of the simulated airspace on the Force Dynamics 401CR, updating in real-time with data from XPlane and live tracking.

**Outputs:**

- **Aircraft Icons:** Displays real-time positions, heading, and altitude of aircraft in the simulation.
- **Incursion Alerts:** Highlights potential incursions on the display using flashing red indicators and includes detailed data on the screen sidebar.

**Purpose:** Allows Basic Users to observe aircraft behavior and alerts in real-time, enhancing situational awareness during training.

**Access Restrictions:** All users have view-only access to the real-time simulation display.

**Incursion Event Log**

Provides a record of all incursions detected during the simulation, accessible via a pop-up window.

**Outputs:**

- **Event ID:** A unique identifier for each incursion.
- **Timestamp:** The exact date and time when each incursion was detected.
- **Aircraft Details:** Displays aircraft ID, position, and speed for both aircraft involved.

**Purpose:** Enables Administrators to analyze and review specific incursion events for training and improvement purposes.

**Access Restrictions:** Only Administrators have the ability to export the event log data for further analysis.

### 3.2.2. Output Screen Layout and Security Considerations

**GUI Layout**: The primary real-time display occupies the majority of the screen, with an incursion alert sidebar to the right. The event log window is accessible through a button on the main display, opening as an overlay for convenience.

**Data Integrity and Security**:

- **Event Log Protection**: Only Administrator-level users can export or manipulate event log data to prevent unauthorized data access.
- **Temporary Data Retention**: Real-time alerts and event logs are cleared at the end of each session to prevent data retention issues and maintain privacy.

# 4. Detailed Design

## 4.1. Hardware Detailed Design

The ClearPath system operates on a 4D simulation platform with specific hardware components to create an immersive flight simulation experience. Below are the detailed specifications for each primary component:

- Power Input Requirements: The ClearPath simulator, including the yoke, throttle, mixture, RPM sliders, and monitors, requires a stable AC power supply. Each component is powered independently, and the power distribution system should be capable of supporting the entire setup without fluctuations.
- Signal Impedances and Logic States: The control inputs, such as the yoke and throttle, use standard signal levels compatible with the simulation software. The system components require updated drivers for the GPU and motion.
- Connector Specifications: The yoke, throttle, mixture, and RPM sliders are connected to the main computer, likely through USB connectors. Each of the three monitors is connected via HDMI or display cables to support high-definition video output.
- Memory and Storage Space Requirements: To achieve smooth performance at 120 frames per second (fps) on XPlane, the computer should be equipped with at least 16GB of RAM, though 32GB is recommended for optimal performance. Storage should include a minimum of a 512GB SSD to quickly access and load simulation data.
- Processor/Computing Platform Requirements: Running XPlane at 120 fps demands a high-performance processor. An Intel i7 (or equivalent) with multiple cores and a minimum clock speed of 3.5 GHz is recommended. A dedicated high-performance graphics card will help maintain frame rate across multiple displays.
- Hardware Items and Positioning: The ClearPath system includes a yoke, throttle, mixture, and RPM sliders as control inputs. Three monitors are positioned in an extended array around the user to provide a wide field of view and enhance immersion within the simulation.
- Cable Types and Lengths: HDMI or display cables connect the three monitors to the computer. USB cables connect the control inputs, such as the yoke and throttle, to the main system.
- User Interfaces: The main user interfaces include the yoke, throttle, mixture, and RPM sliders. These controls allow the user to interact with and adjust the aircraft’s flight dynamics, providing a hands-on simulation experience.

## 4.2. Software Detailed Design

Clear Paths software design can be found in Sections 2.2 & 5.4.

## 4.3. Internal Communications Detailed Design

The ClearPath system, built on a 4D simulation platform, consists of multiple components that require internal communication to function cohesively. This section outlines the expected design for internal communications to ensure reliable data exchange, command distribution, and input/output support.

- **Number of Servers and Clients**: The system includes one main computer that processes simulation data and manages inputs from various devices, such as the yoke, throttle, mixture, and RPM sliders. The three monitors connected to the computer function as display clients, receiving continuous output from the computer.
- **Bus Timing Requirements and Control**: To achieve the target performance in XPlane, the system requires high-speed data transfer between the computer and peripheral components.
- **Data Format**: The data exchanged between the components follows standard input/output protocols. Control input data from the yoke, throttle, mixture, and RPM sliders is transmitted in USB, processed by the main computer, and translated into real-time simulation adjustments. The output to the monitors is transmitted in HDMI video signal format to ensure high-definition visual rendering. We also expect the live traffic data to integrate into XPlane via an Application Program Interface.
- **Data Flow**: The yoke, throttle, mixture, and RPM sliders send input data to the computer, where it is processed and integrated into the simulation. The live traffic data will be integrated into the simulation as 2D and 3D objects. The computer then sends video output to the three monitors.

# 5. External Interfaces

## 5.1. Hardware Interface Architecture

The Force Dynamics 401CR is not being changed for the scope of this project. The Force Dynamics 401CR simulator responds to changes in position, pitch, yaw, and roll in real-time depending on the user's inputs using the yoke and control box.

## *5.2.* Hardware Interface Detailed Design

The hardware design and interface has not been expanded as of now and has been described in Section 2, “System Architecture” and Section 3, “Human-Machine Interface”.

## 5.3. Software Interface Architecture

The software design interface is dependent on two databases communicating with XPlane 11. These 2 databases, OpenSky Network and adsb.fi, work on independent user submitted data from around the world. The goal is to get this data implemented into the game (XPlane 11) via a plugin, allowing real-time traffic to be seen in the game. (WIP)

## 5.4. Software Interface Detailed Design

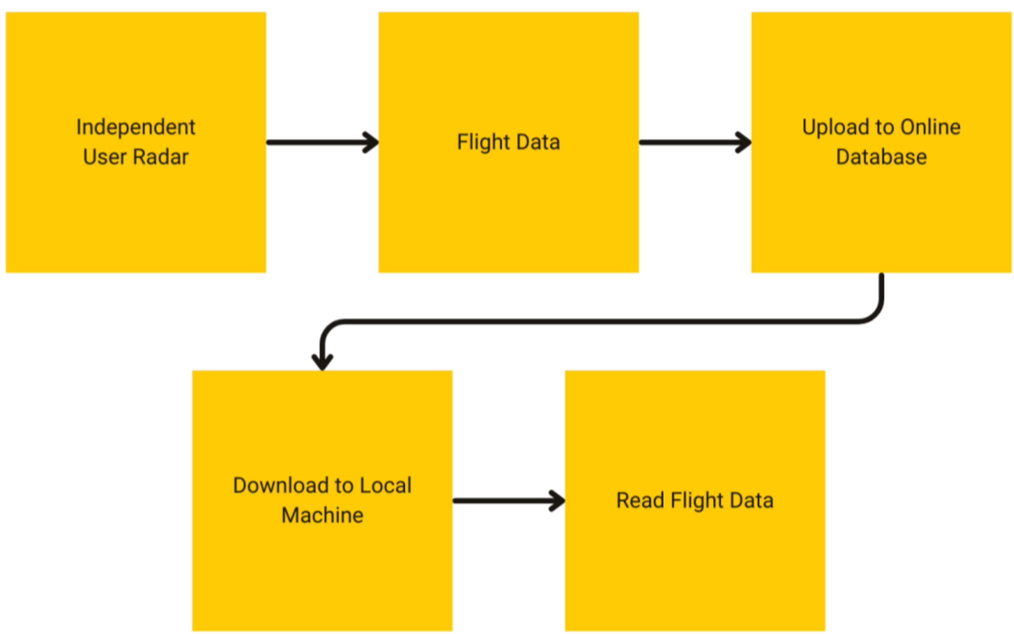


Figure 4. Detailed Software Communications (WIP)

Independent aviation enthusiasts set up their own RADAR and use it to record flight data. Flight data is uploaded to an online database, either OpenSky Network or adsb.fi. This is then downloaded to our machine and then the machine reads this data. The next step is to get this data to display as planes in the game.

# 6. System Integrity Controls

The ClearPath System incorporates rigorous integrity controls to safeguard critical data and maintain operational security. These controls prevent unauthorized access, ensure data accuracy, and support audit and verification processes necessary for sensitive information management.

## 6.1. Internal Security

**Access Restriction**: The system restricts access to critical simulation data based on user roles, ensuring that only authorized personnel can view, modify, or delete sensitive information.

- **Administrator Access**: Only users with Administrator credentials can access configuration settings, simulation parameters, and historical event logs.
- **Basic User Access**: Basic Users have limited access, restricted to viewing real-time simulation data and incursion alerts. They are unable to modify system configurations or access historical logs.

**Encryption of Sensitive Data**: Sensitive data, such as user credentials and API keys, is stored using SHA-256 encryption to prevent unauthorized access or interception during transmission.

**Session Management**: The system automatically logs out inactive sessions after a specified period to prevent unauthorized access from unattended terminals.

## 6.2. Audit Procedures

**Activity Logging**: All significant actions within the system, including changes to configuration settings, simulation start and stop actions, and threshold adjustments, are logged with timestamps, user IDs, and action descriptions.

**Data Access Logs**: Access to sensitive data, such as user credentials and event logs, is recorded in an access log, capturing the date, time, and user ID for each access attempt.

**Retention Period for Logs**: Operational and management logs are retained for 90 days, after which they are securely archived. Archived logs are retained for an additional 12 months to support audit and compliance requirements.

**Audit Reports**: The system generates periodic audit reports that summarize user activity, data access, and modifications to simulation parameters. These reports are accessible only to Administrators for monitoring and compliance checks.

## 6.3. Verification Processes

**Data Entry Verification**: All inputs, such as incursion threshold adjustments and API key entries, are subject to validation checks to ensure data integrity. Invalid entries trigger error messages and prevent the submission of incorrect data.

**Critical Data Change Verification**:

- **Additions, Deletions, and Updates**: For any additions, deletions, or updates to critical data (e.g., simulation parameters, access permissions), the system requires Administrator authentication and confirmation to finalize the action.
- **Event Log Integrity**: Each logged event (e.g., incursion detection, threshold adjustment) includes a digital signature to verify its authenticity and protect against unauthorized alterations.
- **Automated Backup and Recovery**: The system performs daily backups of all critical data, including user roles, access logs, and configuration settings. In the event of data corruption or system failure, backup data is used to restore the system to its last verified state.

These integrity controls ensure that the ClearPath System maintains high standards of data security, traceability, and accuracy, supporting safe and compliant operation in sensitive training environments.