Next Generation Air Traffic Controller - Software Design

Date: 12/3/2025
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Introduction

The document captures the requirements, design and test plan for the Next Generation Air Traffic Control (NGATC) system. The NGATC is composed of several modules, this document will discuss the architectural design of how these modules work together, as well as each of these modules individually.

Overview

The NGATC is a scalable, high availability and safety critical system that will manage air traffic throughout the United States. The system supports the ability to:

- Track aircraft position in US airspace
- Use flight plan data and current aircraft data to predict aircraft flight paths
- Use flight path predictions to predict and prevent any aircraft collisions
- Monitor and reject flight plans with invalid routes (e.g. through restricted airspace or into obstacles)
- Display information about flights to Air Traffic Controllers
- Support communication between the NGATC and pilots
- Allow administrators to configure the NGATC system as needed
- Monitor and log events throughout the system

Each of the modules in the NGATC will communicate with each other through the REST API protocol. The NGATC will be created as a Kubernetes cluster, enabling redundancy of the modules making up the system as well as allowing the system to be easily scaled and reconfigured.

The system will be tested at a functional level (verifying and validating the system as a whole), a module level (verifying individual modules) and at a unit level (unit testing of individual methods).

This document includes a discussion of the NGATC system as a whole, as well as each of the modules that make it up. This document also discusses the functional and non-functional requirements of the system and modules, as well as a high level test plan.

System Level Requirements

The following section discusses the system level requirements of the NGATC. More granular requirements are discusses in the module level requirements below.

Functional Requirements

Aircraft Tracking and Surveillance

Requirement: Real-Time Aircraft Data Ingestion
The NGATC shall ingest real-time position data from surveillance sources including radar, ADS-B, satellite and potential future sources through a well-defined API.

Requirement: Real-Time Aircraft Position Update
The NGATC shall update the real-time position of all tracked aircraft at a rate of at least once per second.

Requirement: Unified Aircraft Track
The NGATC shall synthesize surveillance inputs for a single aircraft into a single, unified aircraft track.

Requirement: Aircraft Data Display
The NGATC shall display the position, pitch, altitude, speed and heading of each tracked aircraft to controllers.

Flight Data Management

Requirement: Flight Plan Ingestion
The NGATC shall ingest aircraft flight plans through a well defined API.

Requirement: Flight Plan Association
The NGATC shall associate aircraft flight plans with aircraft tracks.

Requirement: Flight Plan Amendments
The NGATC shall support the ability for pilots and controllers to make amendments to flight plans.

Requirement: Pilot Flight Plan Amendment Acceptance
When the NGATC receives a proposed flight plan amendment from a pilot, the NGATC shall have the ability to accept or reject this proposal.

Requirement: Aircraft Trajectory Prediction
The NGATC shall predict aircraft trajectories based on the aircraft's speed, altitude and route.

Requirement: Flight Plan Deviation Notifications
The NGATC shall notify controllers of deviations between an aircraft's flight plan and its actual behavior beyond acceptable limits.

Communication Services

Requirement: Secure Pilot Messaging Interface
The NGATC shall provide a secure messaging interface between controllers and pilots.

Requirement: Communication Log Audits and Playback
The NGATC shall persistently store communication logs to enable audits and playback.

Requirement: Controller to Controller Messaging
The NGATC shall support the ability for any two controllers to message each other.

Requirement: Controller Status Indicators
The NGATC will make available to controllers, supervisors and administrators, status indicators showing which controller is responsible for which sector of airspace.

Requirement: High Priority Ports
Each module of the NGATC shall provide high priority communication ports to be only to be used to ensure real-time communication in emergency situations.

Conflict Detection and Safety Alerts

Requirement: Loss of Separation Detection
The NGATC shall detect any loss of separation conflict with other aircraft or with static hazards.

Requirement: Loss of Separation Alert to Aircraft
Upon detection of loss of separation, the NGATC shall provide an alert to the involved aircraft including [the position, altitude, heading, and vertical and horizontal speeds] of both aircraft, and avoidance guidance (both aircrafts' avoidance guidance are sent to both aircraft) within 100 ms.
Rationale: In loss of separation incidents, it is unacceptable to rely solely on the reaction time of a human operator. Therefore, it is preferable to trust the initial task of alerting the involved aircraft to automated systems.

Requirement: Loss of Separation Alert to Controller
When a loss of separation event occurs, the NGATC shall notify the relevant controller(s) with the same information and guidance provided to the involved aircraft.

Requirement: Restricted Airspace Alerts
The NGATC shall alert controllers when an aircraft violates restricted airspace.

Weather and External Data Integration

Requirement: Real-Time Weather Ingestion
The NGATC shall ingest real-time weather and turbulence data.

Requirement: Weather Impacts on Trajectories
The NGATC shall compensate for the impact of weather on flight trajectories.

Requirement: UI Weather Overlays
The NGATC shall include a weather overlay on controller displays.

Sector Management

Requirement: Dynamic Sector Boundaries
The NGATC shall support administrators merging and splitting sectors based on workload.

Requirement: Aircraft Sector Reassignment
The NGATC shall automatically reassign aircraft when sector boundaries change.

Requirement: Sector Workload Threshold Alerts
When a sector exceeds workload thresholds, the NGATC shall alert administrators and supervisors.

Airspace Automation and AI Assistance

Requirement: AI Assisted Conflict Prediction
The NGATC shall provide AI assisted conflict prediction for at least 3-5 minutes into the future.

Requirement: AI Assisted Conflict Alert
When a potential future conflict is identified by the AI assisted conflict prediction, an alert will be given to the controller.

Requirement: AI Generated Route Optimization Suggestions
The NGATC shall provide AI generated route optimization suggestions that controllers can either accept or reject.

Requirement: AI Detected Abnormal Aircraft Behavior
The NGATC shall provide alerts to the controller for AI detected abnormal aircraft behavior, such as altitude deviations.

Controller User Interface

Requirement: Real-Time Aircraft Map
The NGATC shall display aircraft on a real-time map with configurable zoom levels.

Requirement: Color Coded Alerts
The NGATC shall display color coded visual alerts to controllers. Red alerts indicate an immediate safety concern, yellow alerts indicate a potential future safety concern and white alerts are informational.

Requirement: Aircraft Details Window
The NGATC shall provide controllers an aircraft details window, display the aircraft's altitude, route, communication status and ETA.

Requirement: Drag and Drop Sector Reassignment
The NGATC shall support the ability for controllers to drag and drop aircraft to reassign their sector.

System Monitoring and Logging

Requirement: Event Logging
The NGATC shall log all system events, alerts and messaging for auditing.

Requirement: Module Health Monitoring
The NGATC shall provide health monitoring for each module, visible to administrators, supervisors and controllers.

Requirement: Service Unavailable Alert
The NGATC shall provide an alert to administrators, supervisors and controllers when any module becomes unavailable.

Administrative Functions

Requirement: System Configurability
The NGATC shall allow for the configuration of what inputs to accept as surveillance inputs, the severity of alerts and aircraft separation thresholds.

Requirement: Role Based Access
The NGATC shall support role based actions based on the controller, supervisor and administrator roles.

Requirement: Simulation Mode
The NGATC shall support a simulation mode for training.

Non-Functional Requirements

Performance

Requirement: Surveillance Latency
The NGATC shall process surveillance updates with a latency of less than 500 ms.

Requirement: Aircraft Volume
The NGATC shall support at least 5000 simultaneous aircraft tracks.

Requirement: Controller UI Refresh Rate
The NGATC controller user interface shall update aircraft positions at least once per second.

Availability and Reliability

Requirement: 5 Nines of Availability
The NGATC shall be available 99.999% of the time.

Requirement: Redundance Services
The NGATC shall provide redundancy with automatic within 250 ms for all modules whose absence could adversely affect aircraft safety.
Comment: This system does not necessarily require a "bumpless" switchover, so long as all data used by modules is not more than 2 seconds old (measured from when the NGATC ingested the data) and the module uses the most current available data within 1 second of the switchover event.

Requirement: Track Data Preservation
When the NGATC switches to another instance of a module due to a failure, this switchover shall preserve all track data.

Scalability

Requirement: Horizontal Scalability
The NGATC deployment shall scale horizontally to support increases in aircraft volume.

Requirement: Module Scaling
NGATC modules shall have the ability to scale independently based on loading.

Requirement: Data Pipeline Support
NGATC data pipelines shall support ingest rates of up to 100,000 messages per second.

Security

Requirement: Communication Encryption
All communication between modules shall use TLS encryption.

Requirement: Role-Based Authentication
The NGATC shall enforce role based authentication.

Requirement: Security Logging
The NGATC shall log all security-relevant events, including logins, changes and overrides.

Requirement: Flight Data Modification
The NGATC shall protect against the unauthorized modification of flight data.

Maintainability

Requirement: Microservice Use
NGATC modules shall be implemented as microservices using well-defined APIs.

Requirement: Module Failure Isolation
The NGATC shall isolate failures to individual modules to prevent cascading effects.

Requirement: Naming and Documentation
Code and service interactions shall follow clear naming conventions and documentation standards.

Usability

Requirement: Controller Alert Reaction Time
Controllers shall be able to identify conflicts within 2 seconds of an alert being generated.

Requirement: Color Coded Alerts
The NGATC UI shall distinguish between alert severity levels using different colors and shapes.

Requirement: Night and Day Mode
The NGATC UI shall support both night and day display modes.

Interoperability

Requirement: Surveillance Data Input Format
The NGATC shall use JSON as the supported input format for surveillance data.

Requirement: External REST API
The NGATC shall provide a REST API for integrating with external systems.

Requirement: New Data Sources
The NGATC shall support the "plug and play" addition of new data sources.

Testability

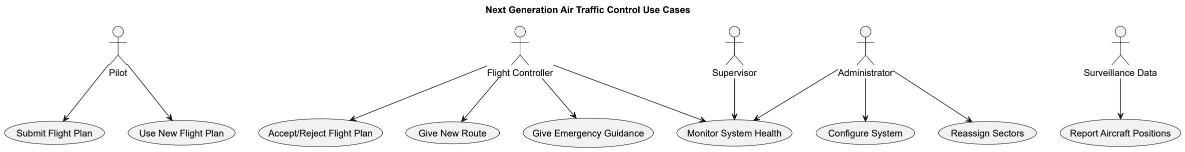
Requirement: Module Testability
Each module shall be independently testable using mock data.

Requirement: Simulation Testing
The NGATC shall provide simulation tools that can be used to test conflict detection logic at a system level.

Requirement: Automated Test Coverage
At least 80% automated test coverage of the NGATC core logic shall be achieved.

Use Cases

The following diagram summarizes the use cases of the NGATC.



The Pilot reports their flight plan to the flight controller and has regular contact with them. Part of the contact will be to receive and utilize new flight plans from the controller.

The controller works with the pilot and with the information from the NGATC to safety guide aircraft through their flight plans. Controllers have the responsibility of accepting or rejecting flight plans, rerouting aircraft as necessary and supporting the implementation of emergency guidance generated by the NGATC.

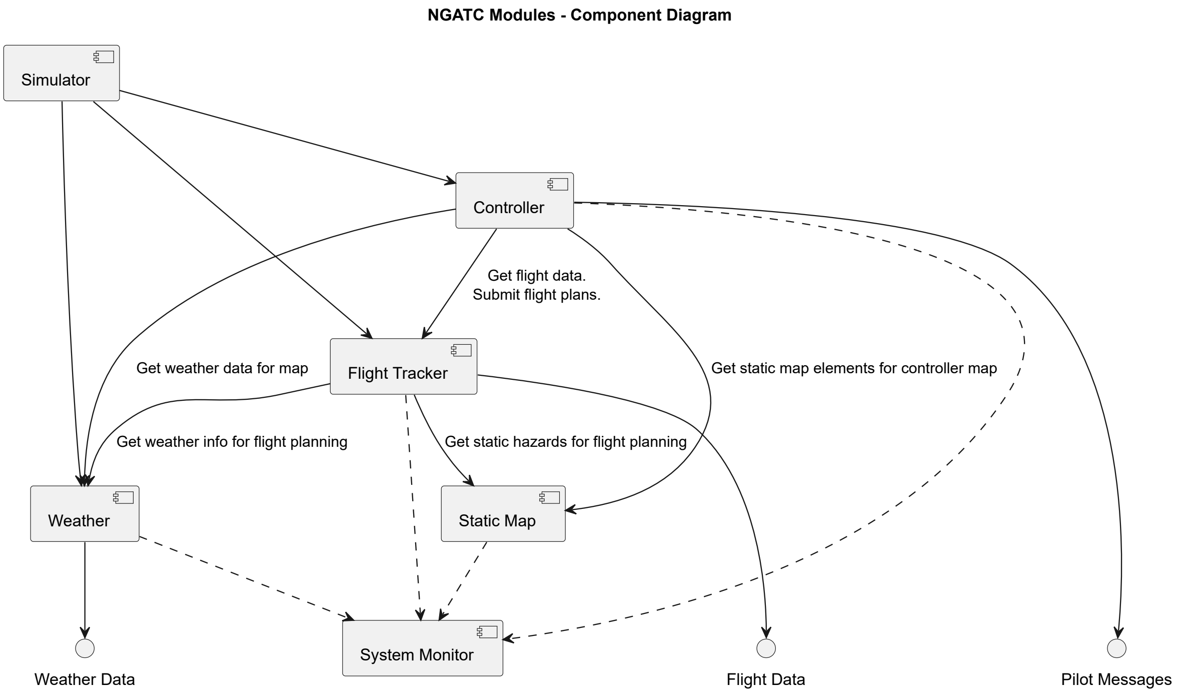
Supervisors monitor the system health and sector volume.

Administrators configure the system, divide the airspace into sectors and monitor the health of the system.

Finally, surveillance data is used to report the position of aircraft.

Module Summary

The modules that make up the NGATC are shown in the component diagram below and are explained in more detail following the diagram.



System Monitor

The System Monitor is responsible for monitoring the health of all modules in the NGATC system. The system monitor consumes the health of each module in the NGATC and produces an interface for modules (the Controller module, although there is nothing to preclude other modules from consuming this interface) to gain information about the NGATC system health.

Controller

The Controller module is the primary interface that flight controllers will directly interact with. This module exposes a GUI to flight controllers that shows aircraft light data, weather, map information and aircraft type information. The Controller module consumes this information from the Flight Tracker, Static Map and Weather modules. This module allows bidirectional communication between pilots and controllers, as well as between multiple controllers. It also provides alert information to controllers, as well as AI generated suggestions.

The Controller module also allows administrators and supervisors to configure airspace sectors.

Finally, the controller module allows pilots to have encrypted communication with flight controllers.

Flight Tracker

The Flight Tracker module is a safety critical module responsible for consuming all data related to aircraft flights and providing this information to the Controller module. In addition to consuming data, the Flight Tracker module has the responsibility to detect aircraft conflicts and any other unsafe conditions, and to respond appropriately. The module also uses an AI agent to make adjustments to flight plans, using safety critical code to detect for any hazards.

As the safety critical module of the NGATC, the Flight Tracker module shall be developed in compliance with Systematic Capability 3 as defined in IEC 61508-3.

Weather

The Weather module is responsible for ingesting weather reports and providing this information to the Flight Tracker.

Static Map

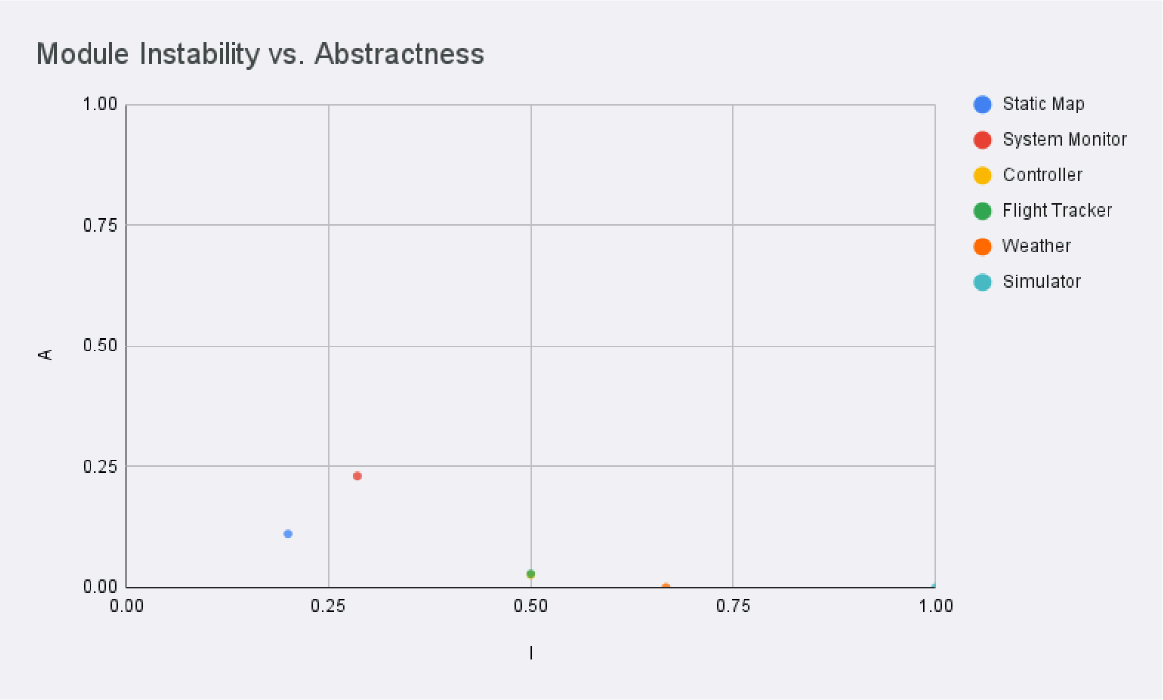
The Static Map module is responsible for managing the airspace map, including static hazards (e.g. mountains and tall buildings), restricted airspace and landmarks (e.g. airports). This information is consumed by the Flight Tracker and Controller modules.

Simulator

The Simulator module is responsible for providing mock data to the modules of the NGATC, as well as consuming information from the NGATC to inform this mock data.

Module Instability and Abstractness Metrics

The plot of module instability and abstractness is shown below.



For the NGATC system, this metric is somewhat complicated by the reality that many modules are sharing business domain classes, making the instability metric difficult to calculate in a meaningful way. However, it is evident that lower level modules, such as the Static Map and Weather modules are on the more stable side of the chart, as compared to high level modules, such as the Simulator.

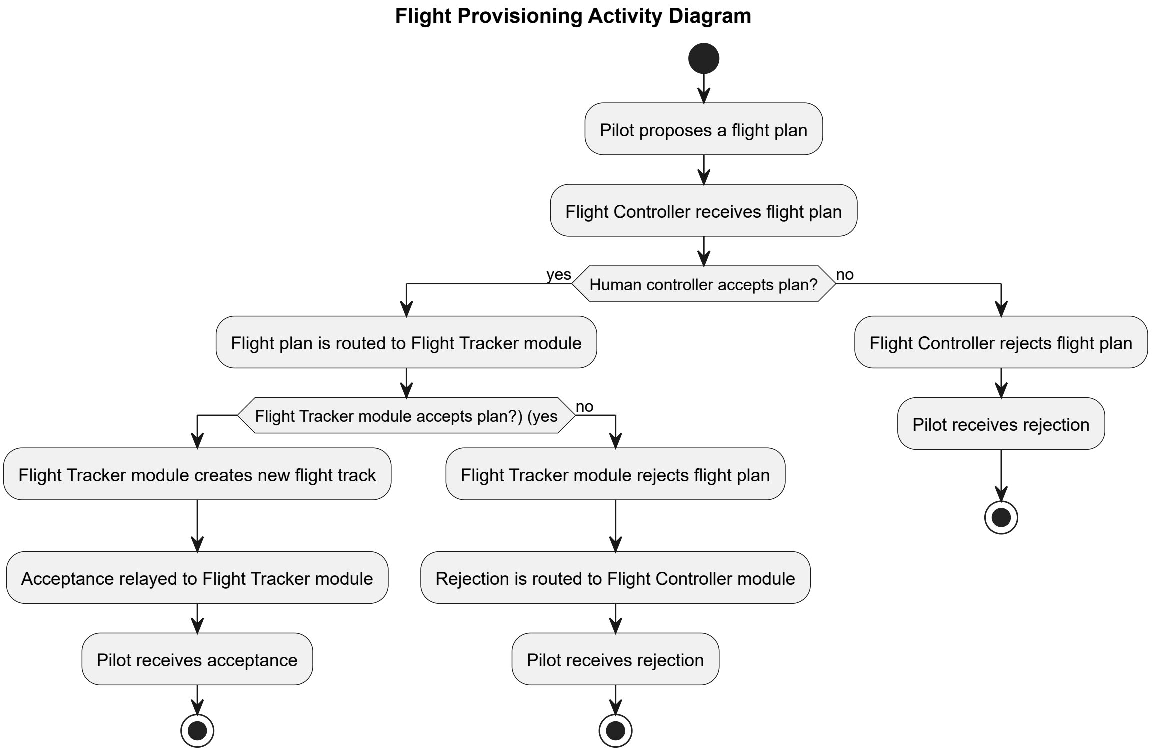
The modules do somewhat follow the "Main Sequence", although they are skewed toward concreteness because of the large number of concrete business domain classes used in this design.

Module Communications

Modules communicate with each other and with external services through REST APIs. Communication between modules is encrypted using TLS encryption.

Activity Diagram

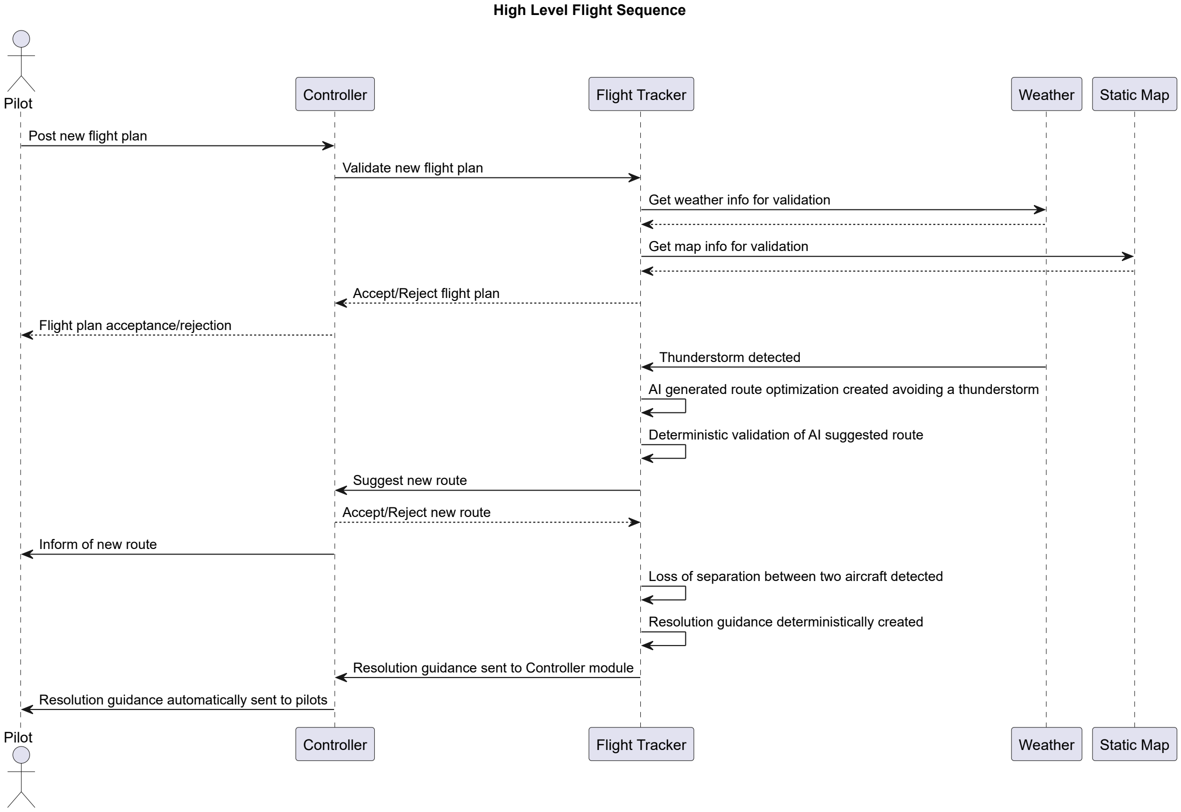
The process of provisioning a new flight is demonstrated in the activity diagram below.


Flight Provisioning Activity Diagram
Pilot proposes a flight plan
Flight Controller receives flight plan
Human controller accepts plan?
yes
no
Flight plan is routed to Flight Tracker module
Flight Controller rejects flight plan
Flight Tracker module accepts plan?) (yes
no
Pilot receives rejection
Flight Tracker module creates new flight track
Flight Tracker module rejects flight plan
Acceptance relayed to Flight Tracker module
Rejection is routed to Flight Controller module
Pilot receives acceptance
Pilot receives rejection

This diagram illustrates the a flight plan must be accepted by both a human flight controller as well as the analysis performed in the Flight Tracker module. If the flight plan is accepted, then the plan is entered into the NGATC system for the flight to begin. If the flight plan is rejected, then the pilot will need to submit a new plan.

High Level Flight Sequence

The diagram below shows a high level overview of the communication between modules during the course of an example flight.


High Level Flight Sequence
Pilot
Controller
Flight Tracker
Weather
Static Map
Post new flight plan
Validate new flight plan
Get weather info for validation
Get map info for validation
Accept/Reject flight plan
Flight plan acceptance/rejection
Thunderstorm detected
AI generated route optimization created avoiding a thunderstorm
Deterministic validation of AI suggested route
Suggest new route
Accept/Reject new route
Inform of new route
Loss of separation between two aircraft detected
Resolution guidance deterministically created
Resolution guidance sent to Controller module
Resolution guidance automatically sent to pilots
Pilot
Controller
Flight Tracker
Weather
Static Map

This diagram depicts how the pilots interact with flight controllers through the Flight Control module. It also depicts how the Flight Tracker module validates a flight plan, using data from other, lower level modules. The interactions in the flight plan validation process are meant to be illustrative, with more specific details available in the Flight Tracker module level design. Finally, the diagram depicts the process of receiving, validating and communicating an AI suggested route optimization, in this case, to avoid a thunderstorm. Of note is that once the suggestion is created, it is validated in a deterministic manner (i.e. not through the use of AI) to ensure the new flight plan is safe.

The thunderstorm route adjustment contrasts with the resolution guidance created to handle a loss of separation event. In this case, the resolution guidance is deterministically created, without the use of AI. This guidance is then automatically sent to the pilots. This removes any human reaction time from the flight controller in the implementation of the resolution guidance.

System Deployment

The NGATC is deployed through Kubernetes, with each module being deployed along with its database. Multiple instances of each module are deployed to allow for redundant switchover and automatic load balancing handled automatically by Kubernetes. To ensure resilience against any physical events, instances of each module are commissioned at disparate geographic locations.

Access Control

Access control for the NGATC will utilize the Entitlement Service developed by Housemate Inc. The four roles defined for the NGATC are controllers, supervisors, administrators, pilots, trusted data sources and internal modules. For all actions in the NGATC that are not "read-only", some level of authenticated access is required, with specifics discussed in the requirements and design details.

Persistence Strategy

For each module, all information needed to restore to the current running point in the event of failure is stored persistently in a database, accessed using Hibernate. For classes that must be persisted, the module level designs outline what property in the class maps to the primary key that relates the object to the persistent database.

Use of AI

AI agents are used to accomplish three tasks in the NGATC, all interfacing with the Flight Tracker module:

- To predict future aircraft conflicts (although detecting active loss of separation events is accomplished through deterministic, safety critical code)
- To generate route optimization suggestions (validated by deterministic code)
- To detect and report abnormal aircraft behavior

In no cases will an AI agent have the authority to direct edit a any data in the NGATC without being deterministically validated. Whenever possible, any actions proposed by an AI agent are also validated by a human.

High Level Testing Strategy

The NGATC is tested at three levels, unit testing, module testing and system testing.

Unit Testing

Unit testing is performed as needed on modules of the NGATC. For safety critical code, the following guidelines are established:

- CCN <= 3: Unit test not required
- CCN <= 9: Unit test required with reasonable branch coverage
- CCN >= 10: Unit test required with 100% branch coverage required

For non-safety critical code, the following guidelines are established:

- CCN <= 3: Unit test not recommended
- CCN <= 9: Unit test recommended with reasonable branch coverage
- CCN >= 10: Unit test required with reasonable branch coverage

Module Testing

Module testing validates an individual module's behavior. It is performed by ingesting communication directly into the module, interacting with the module's GUI as appropriate, and observing the communicates output from the module. Details on module testing are discussed in the module design sections.

System Testing

System testing is used to validate the NGATC's behavior as a "closed box". In system tests, the data for the NGATC to act upon are simulated through the Simulation module and user interactions with system GUIs are simulated using Functionize.

Happy Path Testa

- Mock weather, map and aircraft type data are input through the simulator
- Multiple flight plans are submitted that should be accepted
- It is validated that these flight plans are accepted
- The NGATC waits until an AI route optimization is suggested
- It is validated that this suggestion is correctly accepted or rejected
- Is is validated that any updates to a flight plan are communicated properly
- The simulator injects surveillance data that should move an aircraft between sectors
- It is validated that the aircraft correctly changed sectors
- The Flight Control module GUI changes a sector boundary
- It is validated the all aircraft are correctly re-assigned and the controller GUIs update as needed

Loss of Separation Test

This test validates that the system responds properly to aircraft loss of separation events with other aircraft and static hazards.

- Mock weather, map and aircraft type data are input through the simulator
- Multiple flight plans are submitted that should be accepted
- It is validated that these flight plans are accepted
- The simulator injects flight surveillance data that should indicate a loss of separation between two aircraft
- It is validated that the system responds correctly to this loss of separation
- The simulator injects flight surveillance data that should indicate a loss of separation between an aircraft and a static hazard
- It is validated that the system responds correctly to this loss of separation

Invalid Flight Plan Test

- Mock weather, map and aircraft type data are input through the simulator
- Multiple flight plans are submitted that should be rejected
- It is validated that these flight plans are rejected and not added to the NGATC system.

Risk Summary

The most critical risk for the NGATC is safety and availability. This risk comes in two forms: the risk that the system will cause a pilot to take an unsafe action and the risk that the system will fail to detect of act upon an existing unsafe condition. This risk is mitigated by the Flight Tracker module being treated as a safety critical module, with several design choices in the module reflecting the principal of diverse redundancy, and with the SC3 level of rigor the module is developed to. A significant challenge in developing the safety infrastructure of the NGATC is unlike in machine safety where "the safest machine is one that isn't running", there is no candidate for a "safe state" for the system. This means that the system must keep operating at all times and provide its best possible guidance to pilots.

Furthermore, this risk is mitigated by deploying redundant instances of the modules and corresponding databases making up the system, that automatically fail-over in the event of any failures.

Another class of risk in the NGATC is security. An unauthorized user making changes to this system could have catastrophic consequences. To mitigate this risk, the system is designed with access control using the Housemate Entitlement Service.

System Monitor Module

The System Monitor module is responsible for monitoring and reporting on the statuses and events of modules in the NGATC system. The module is implemented with a MySQL database and uses the Spring Boot framework for the REST API implementation.

Module Requirement Summary

Module Functional Requirements

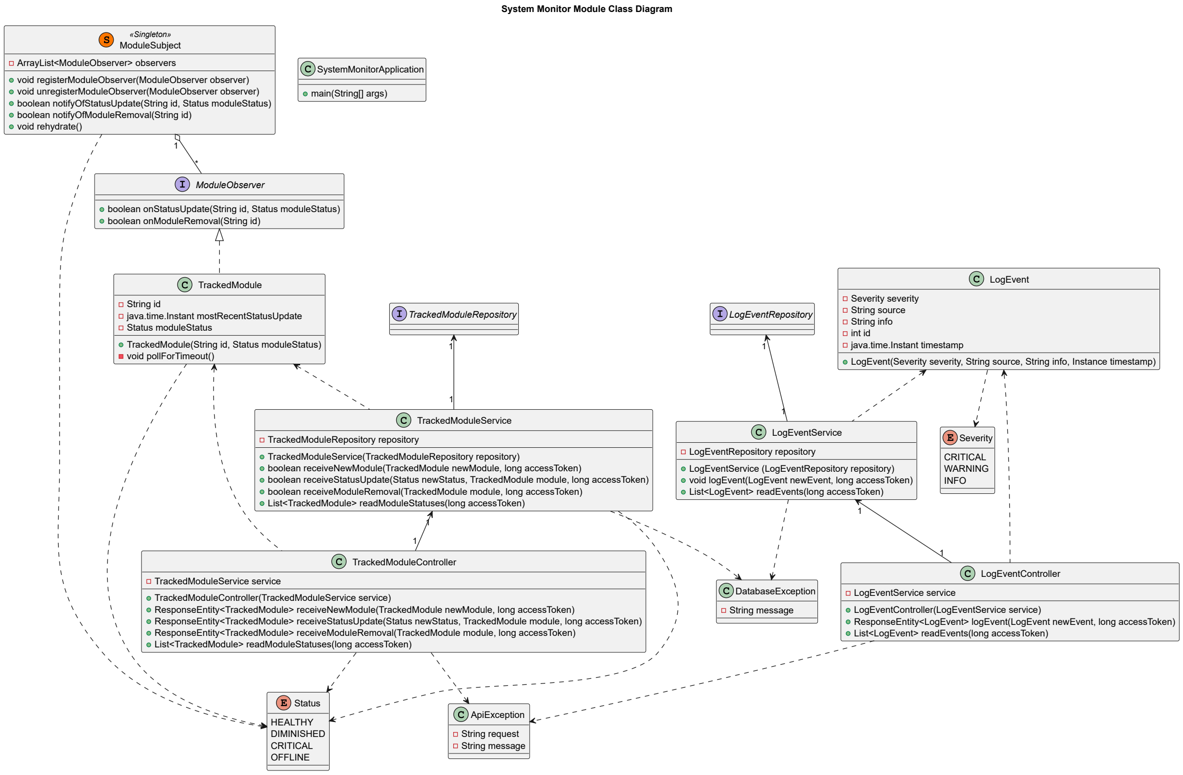
- Controller Status Indicators: The System Monitor module shall expose an interface for other modules to report their status.
- Module Health Monitoring: The System Monitor module shall make available to other modules the status of all modules for which it has status information.
- Service Unavailable Alert: When the System Monitor module has not received a status update from a module in 2 seconds, it shall report the module as offline.
- High Priority Ports: In the system deployment, the System Monitor module's service shall have high priority ports for other modules to communicate high priority status updates.
- Event Logging: The System Monitor module shall expose an interface for other modules to report system events.
- Event Logging: The System Monitor module shall persistently store all system events provided to the module.
- Event Logging: The System Monitor module shall expose an interface for other modules to access recorded system events. This service shall require an administrator access token.

Module Non-Functional Requirements

- The System Monitor module shall respond to all incoming requests within 50 ms.
- The System Monitor module shall reflect all status updates from other modules within 50 ms.
- The System Monitor module shall be deployed in a redundant configuration, such that if an instance of the module fails, a switchover to a working instance of the module is complete within 250 ms.
- The System Monitor module shall have the ability to scale horizontally to accommodate additional module instances.
- The System Monitor module shall be implemented in such a way to allow new module types to be added to the NGATC system.
- The System Monitor module shall use a REST API to communicate with other modules in the NGATC.

System Monitor Classes

The System Monitor is implemented with the following classes as shown below.


System Monitor Module Class Diagram
S «Singleton» ModuleSubject
ArrayList<ModuleObserver> observers
void registerModuleObserver(ModuleObserver observer)
void unregisterModuleObserver(ModuleObserver observer)
boolean notifyOfStatusUpdate(String id, Status moduleStatus)
boolean notifyOfModuleRemoval(String id)
void rehydrate()
C SystemMonitorApplication
main(String[] args)
1
*
I ModuleObserver
boolean onStatusUpdate(String id, Status moduleStatus)
boolean onModuleRemoval(String id)
C TrackedModule
String id
java.time.Instant mostRecentStatusUpdate
Status moduleStatus
TrackedModule(String id, Status moduleStatus)
void pollForTimeout()
I TrackedModuleRepository
1
1
I LogEventRepository
1
1
C LogEvent
Severity severity
String source
String info
int id
java.time.Instant timestamp
LogEvent(Severity severity, String source, String info, Instance timestamp)
C TrackedModuleService
TrackedModuleRepository repository
TrackedModuleService(TrackedModuleRepository repository)
boolean receiveNewModule(TrackedModule newModule, long accessToken)
boolean receiveStatusUpdate(Status newStatus, TrackedModule module, long accessToken)
boolean receiveModuleRemoval(TrackedModule module, long accessToken)
List<TrackedModule> readModuleStatuses(long accessToken)
C LogEventService
LogEventRepository repository
LogEventService (LogEventRepository repository)
void logEvent(LogEvent newEvent, long accessToken)
List<LogEvent> readEvents(long accessToken)
E Severity
CRITICAL
WARNING
INFO
1
1
1
1
C TrackedModuleController
TrackedModuleService service
TrackedModuleController(TrackedModuleService service)
ResponseEntity<TrackedModule> receiveNewModule(TrackedModule newModule, long accessToken)
ResponseEntity<TrackedModule> receiveStatusUpdate(Status newStatus, TrackedModule module, long accessToken)
ResponseEntity<TrackedModule> receiveModuleRemoval(TrackedModule module, long accessToken)
List<TrackedModule> readModuleStatuses(long accessToken)
C DatabaseException
String message
C LogEventController
LogEventService service
LogEventController(LogEventService service)
ResponseEntity<LogEvent> logEvent(LogEvent newEvent, long accessToken)
List<LogEvent> readEvents(long accessToken)
E Status
HEALTHY
DIMINISHED
CRITICAL
OFFLINE
C ApiException
String request
String message

Class Dictionary

SystemMonitorApplication

The SystemMonitorApplication class is the main class used by the Spring Boot framework to run the REST API and database implementation. No business logic occurs in this class.

Methods

Method Name	Method Signature	Description
main	main(String[] args)	Starts the SpringbootapiApplication, which runs the REST API and database implementation.

LogEvent

The LogEvent class is used to store information for a specific system event in the NGATC.

Methods

Method Name	Method Signature	Description
LogEvent	LogEvent(Severity severity, String source, String info, Instance timestamp)	Constructs a new LogEvent object.

Properties

Property Name	Type	Description
severity	Severity	The severity of the event.
source	String	A String with information about the module creating the event.
info	String	A String containing full information about the event.
timestamp	java.time.Instant	The time when the event occurred.
id	int	A unique ID of the LogEvent to use as the primary key in the database.

LogEventRepository

This interface is used by the Spring Boot framework to store instances of the LogEvent class in the database.

LogEventService

The LogEventService is used to handle the business logic of REST API requests involving the LogEvent object.

Methods

Method Name	Method Signature	Description
LogEventService	LogEventService (LogEventRepository repository)	Creates and logs a new LogEventService instance.
logEvent	void logEvent(LogEvent newEvent, long accessToken)	Logs a new LogEvent.
readEvents	List readEvents(long accessToken)	Returns a list of events in the NGATC if the provided access token has the administrator role.

Associations

Association Name	Type	Description
repository	LogEventRepository	A reference to a LogEventRepository instance used for this service.

LogEventController

The LogEventController class is used to generate HTTP responses to REST API requests involving the LogEvent class.

Methods

Method Name	Method Signature	Description
LogEventController	LogEventController(LogEventService service)	Creates and logs a new LogEventController instance.
logEvent	ResponseEntity logEvent(LogEvent newEvent, long accessToken)	Logs a new LogEvent.
readEvents	List readEvents(long accessToken)	Returns a list of events in the NGATC.

Associations

Association Name	Type	Description
service	LogEventService	A reference to a LogEventService instance used for this controller.

ModuleSubject

The ModuleSubject class fills the role of the "subject" in the observer design pattern. This is implemented as a singleton instance, with a list of its registered observers.

Methods

Method Name	Method Signature	Description
registerModuleObserver	void registerModuleObserver(ModuleObserver observer)	Registers a ModuleObserver to receive updates.
unregisterModuleObserver	void unregisterModuleObserver(ModuleObserver observer)	Removes the ModuleObserver from the list of ModuleObservers receiving updates.
notifyOfStatusUpdate	boolean notifyOfStatusUpdate(String id, Status moduleStatus)	Notifies all registered observers of a module giving a status update. Returns whether a module was found matching the ID.
notifyOfModuleRemoval	boolean notifyOfModuleRemoval(String id)	Notifies all registered observers that a module has been removed and its status should no longer be tracked. Returns whether a module was found matching the ID.
rehydrate	void rehydrate()	On power up, refreshes the list of tracked observers with the module database.

Associations

Association Name	Type	Description
observers	ArrayList	An ArrayList of all registers ModuleObservers.

ModuleObserver

The ModuleObserver interface fills the role of the observer in the observer framework. It should be noted that this interface is not currently needed, as there is only one concrete observer. However, the interface is included to provide for potential future expansion.

Methods

Method Name	Method Signature	Description
onStatusUpdate	boolean onStatusUpdate(String id, Status moduleStatus)	Processes a status update. The concrete implementation of this method will decide whether the ID is relevant and process the update if so. If the concrete implementation of this interface is tracking a timeout for status updates, the timeout time should be updated in this method. Returns whether this observer matches the provided ID.
onModuleRemoval	boolean onModuleRemoval(String id)	Processes a module removal. The concrete implementation of this method will decide whether the ID is relevant and remove the module from tracking if so. Returns whether this observer matches the provided ID.

TrackedModule

The TrackedModule class is the concrete observer for the observer design pattern. This represents a module in the NGATC system whose status is being tracked. It inherits from the ModuleObserver interface.

Methods

Method Name	Method Signature	Description
TrackedModule	TrackedModule(String id, Status moduleStatus)	Constructs a new TrackedModule instance and creates a thread to call the pollForTimeout method every 250 ms to monitor for a timeout of the module.
pollForTimeout	void pollForTimeout()	Checks if it has been more than 2 seconds since the last time a status update has been received from the module. If it has, the module status is set to OFFLINE.

Properties

Property Name	Type	Description
id	String	A String identifying the module. This is used as the primary key to store the TrackedModule in the database.
mostRecentStatusUpdate	java.time.Instant	The most recent time this module's status was updated.
moduleStatus	Status	The current status of the module.

TrackedModuleRepository

This interface is used by the Spring Boot framework to store instances of the TrackedModule class in the database.

TrackedModuleService

The TrackedModuleService is used to handle the business logic of REST API requests involving the TrackedModule object.

Methods

Method Name	Method Signature	Description
TrackedModuleService	TrackedModuleService (TrackedModuleRepository repository)	Creates and logs a new TrackedModuleService instance.
receiveNewModule	bool receiveNewModule(TrackedModule newModule, long accessToken)	Adds a new module to track the status of. Returns whether this module could be added.
receiveStatusUpdate	bool receiveStatusUpdate(Status newStatus, TrackedModule module, long accessToken)	Processes a module status update. Returns whether that module was found.
receiveModuleRemoval	bool receiveModuleRemoval(TrackedModule module, long accessToken)	Removes a module from tracking. Returns whether the module was found.
readModuleStatuses	List readModuleStatuses(long accessToken)	Returns a list of all tracked modules and their statuses.

Associations

Association Name	Type	Description
repository	TrackedModuleRepository	A reference to a TrackedModuleRepository instance used for this service.

TrackedModuleController

The TrackedModuleController class is used to generate HTTP responses to REST API requests involving the TrackedModule class.

Methods

Method Name	Method Signature	Description
TrackedModuleController	TrackedModuleController(TrackedModuleService service)	Creates and logs a new TrackedModuleController instance.
receiveNewModule	ResponseEntity receiveNewModule(TrackedModule newModule, long accessToken)	Adds a new module to track the status of. Returns an HTTP 501 status if the module could not be added (e.g. duplicate ID).
receiveStatusUpdate	ResponseEntity receiveStatusUpdate(Status newStatus, TrackedModule module, long accessToken)	Processes a module status update. Returns an HTTP 501 status if the module could not be found.
receiveModuleRemoval	ResponseEntity receiveModuleRemoval(TrackedModule module, long accessToken)	Removes a module from tracking. Returns an HTTP 501 status if the module could not be found.
readModuleStatuses	List readModuleStatuses(long accessToken)	Returns a list of all tracked modules and their statuses.

Associations

Association Name	Type	Description
service	TrackedModuleService	A reference to a TrackedModuleService instance used for this controller.

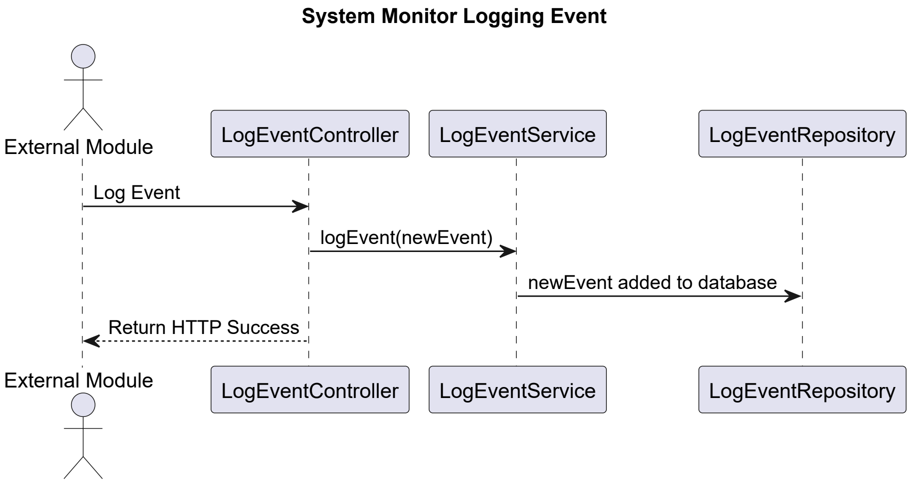
Service API

The Service Monitor module implements the following API services:

- Log Event: Log a new system event.
  - Path: POST/event
  - Inputs:
    - Event Severity (2=CRITICAL, 1=WARNING, 0=INFO)
    - Event Source (A String containing information about the module originating the event)
    - Event Info (A String with full information about the event)
    - Event Timestamp (Number of milliseconds past the Unix epoch)
    - Access Token
  - Output: HTTP Status
- Read Events: Return all logged system events.
  - Path: GET/events
  - Inputs: Access Token
  - Outputs: A list of logged events in the form:
    - Event Severity (2=CRITICAL, 1=WARNING, 0=INFO)
    - Event Source (A String containing information about the module originating the event)
    - Event Info (A String with full information about the event)
    - Event Timestamp (Number of milliseconds past the Unix epoch)
- New Module: Add a new module for status tracking.
  - Path: POST/module
  - Inputs:

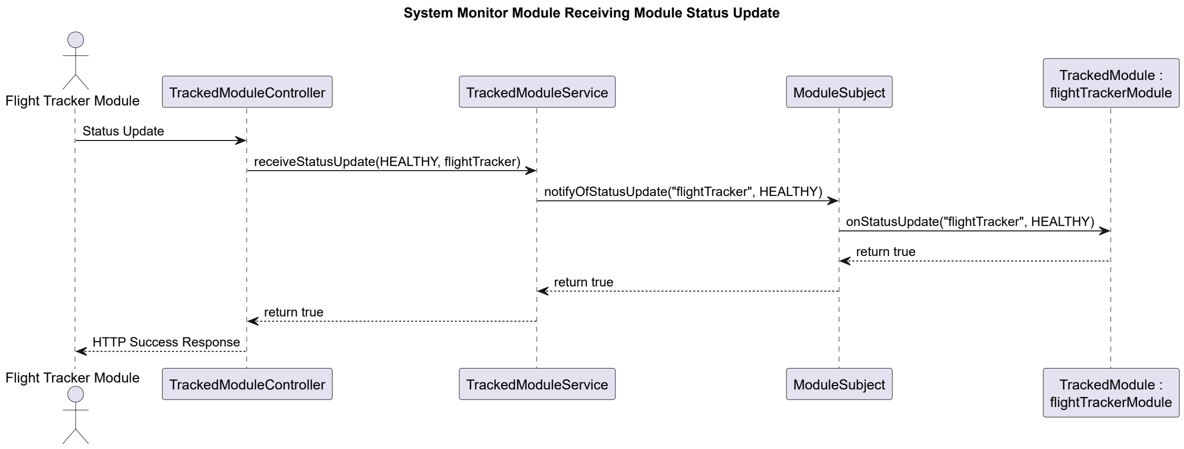
        - Module ID (String with the module name)
        - Status (3=HEALTHY, 2=DIMINISHED, 1=CRITICAL, 0=OFFLINE)
        - Access Token
    - Output: HTTP Status
- Status Update: Update a tracked module's status.
    - Path: PUT/module
    - Inputs:
        - Module ID (String with the module name)
        - Status (3=HEALTHY, 2=DIMINISHED, 1=CRITICAL, 0=OFFLINE)
        - Access Token
    - Output: HTTP Status
- Remove Module: Remove the module from tracking.
    - Path: DELETE/module
    - Inputs:
        - Module ID (String with the module name)
        - Access Token
    - Output: HTTP Status
- Read Module Statuses: Returns the status of all tracked modules.
    - Path: GET/modules
    - Inputs: Access Token
    - Output: A list of tracked modules in the form:
        - Module ID (String with the module name)
        - Status (3=HEALTHY, 2=DIMINISHED, 1=CRITICAL, 0=OFFLINE)

Event Logging Sequence Diagram



This diagram illustrates the interactions taking place with a new log event being received. The interactions involving the service, controller and repository classes are handled by the Spring Boot framework.

Module Status Update Sequence Diagram


System Monitor Module Receiving Module Status Update
Flight Tracker Module
TrackedModuleController
TrackedModuleService
ModuleSubject
TrackedModule : flightTrackerModule
Status Update
receiveStatusUpdate(HEALTHY, flightTracker)
notifyOfStatusUpdate("flightTracker", HEALTHY)
onStatusUpdate("flightTracker", HEALTHY)
return true
return true
return true
HTTP Success Response
Flight Tracker Module
TrackedModuleController
TrackedModuleService
ModuleSubject
TrackedModule : flightTrackerModule

This diagram illustrates the process of updating the status of a module and returning whether a matching module could be found to update the status of.

Entitlement Service Integration

The Read Events API service requires the administrator role to be performed. All other services require the Internal Module role.

Object Persistence

Object persistence is handled using the Spring Boot framework, using a MySQL database. The persisted classes are the TrackedModule and LogEvent classes. The observers list in the ModuleSubject class is rehydrated on power up using custom logic with the module database.

Testing Strategy

The following module level tests are specified for the System Monitor module:

Module Status Test

- Register new modules to the System Monitor module
- Read the module statuses and verify they match their initial statuses
- Send status updates
- Read the module statuses and verify they match their new statuses
- Remove a module
- Read the module statuses and verify the module is removed
- Let a module timeout
- Read the module statuses and verify the module is offline
- Restart the System Monitor module
- Read the module statuses and verify the statuses report their proper values
- Attempt to set a module status with an invalid access token
- Verify the API service is rejected

Logging Test

- Log several events
- Verify that the events can be read
- Attempt to read the events with an invalid access token
- Verify the API service is rejected

Exception Handling

Exceptions for the System Monitor module are handled primarily through the DatabaseException and ApiException classes. These exception classes are unchecked exceptions and are logged for future auditing.

Risks

For this module, the primary risk is security. For this reason, it is imperative that API request to this module have access protections. For module statuses, a malicious actor could potentially perform a denial of service attack by spoofing statuses claiming that modules were offline. A malicious actor could also spoof statuses claiming that the modules were healthy, masking actual issues with the modules. For event logging, a malicious actor accessing the NGATC event logs could potentially learn valuable information about the system that could be used for an attack.

Controller Module

The Controller module is the primary interface for human users of the NGATC system. The module provides information on flights, weather and maps to flight controllers. The module provides information on sector loading to administrators, allowing them to change sector boundaries. The module also interfaces with pilots to exchange messages.

Module Requirement Summary

Module Functional Requirements

- Real-Time Aircraft Position Update: The Controller module shall update the position of aircraft on flight controller maps at least once per second.
- Aircraft Data Display: The NGATC shall display the position, pitch, altitude, speed and heading of each tracked aircraft to controllers.
- Flight Plan Ingestion: The Controller module shall expose a well defined API for pilots to submit their flight plans.
- Flight Plan Association: The Controller module shall send proposed flight plans to the Flight Tracker module so that the Flight Tracker module can begin associating aircraft surveillance data with the flight plan.
- Flight Plan Amendments: The Controller module shall allow flight controllers to propose modified flight plans through the Controller GUI.
- Pilot Flight Plan Amendment Acceptance: When the Controller module receives a flight plan, flight controllers shall have the ability to accept or reject the proposed plan.
- Flight Plan Deviation Notifications: The Controller module shall display an indication to the flight controller when the Flight Tracker module detects deviations between an aircraft's flight plan and its actual behavior beyond acceptable limits.
- Secure Pilot Messaging Interface: The Controller module shall provide for secure messaging between controllers and pilots.
- Communication Log Audits and Playback: The Controller module shall persistently store a log of all communication between flight controllers and pilots.
- Controller to Controller Messaging: The Controller module shall provide the ability to transmit messages between controllers across sectors.
- Controller Status Indicators: The Controller module UI shall display what controllers are responsible for each sector of airspace.
- High Priority Ports: The Controller module shall be deployed with a high priority port to be used for emergency communication.
- Loss of Separation Alert to Aircraft: When the Controller module receives a loss of separation alert from the Flight Tracker module, the alert and corresponding guidance shall automatically be sent to the relevant pilot(s).
- Loss of Separation Alert to Controller: When a loss of separation event occurs, the NGATC shall notify the relevant controller(s) with the same information and guidance provided to the involved aircraft.
- Restricted Airspace Alerts: The Controller module UI shall alert controllers when an aircraft violates restricted airspace.
- UI Weather Overlays: The Controller module shall include a weather overlay on controller displays.
- Dynamic Sector Boundaries: The Controller module shall allow administrators to merge and split sectors based on workload.
- Aircraft Sector Reassignment: The Controller module shall automatically reassign aircraft when sector boundaries change.
- Sector Workload Threshold Alerts: When a sector exceeds workload thresholds, the Controller module shall alert administrators and supervisors.

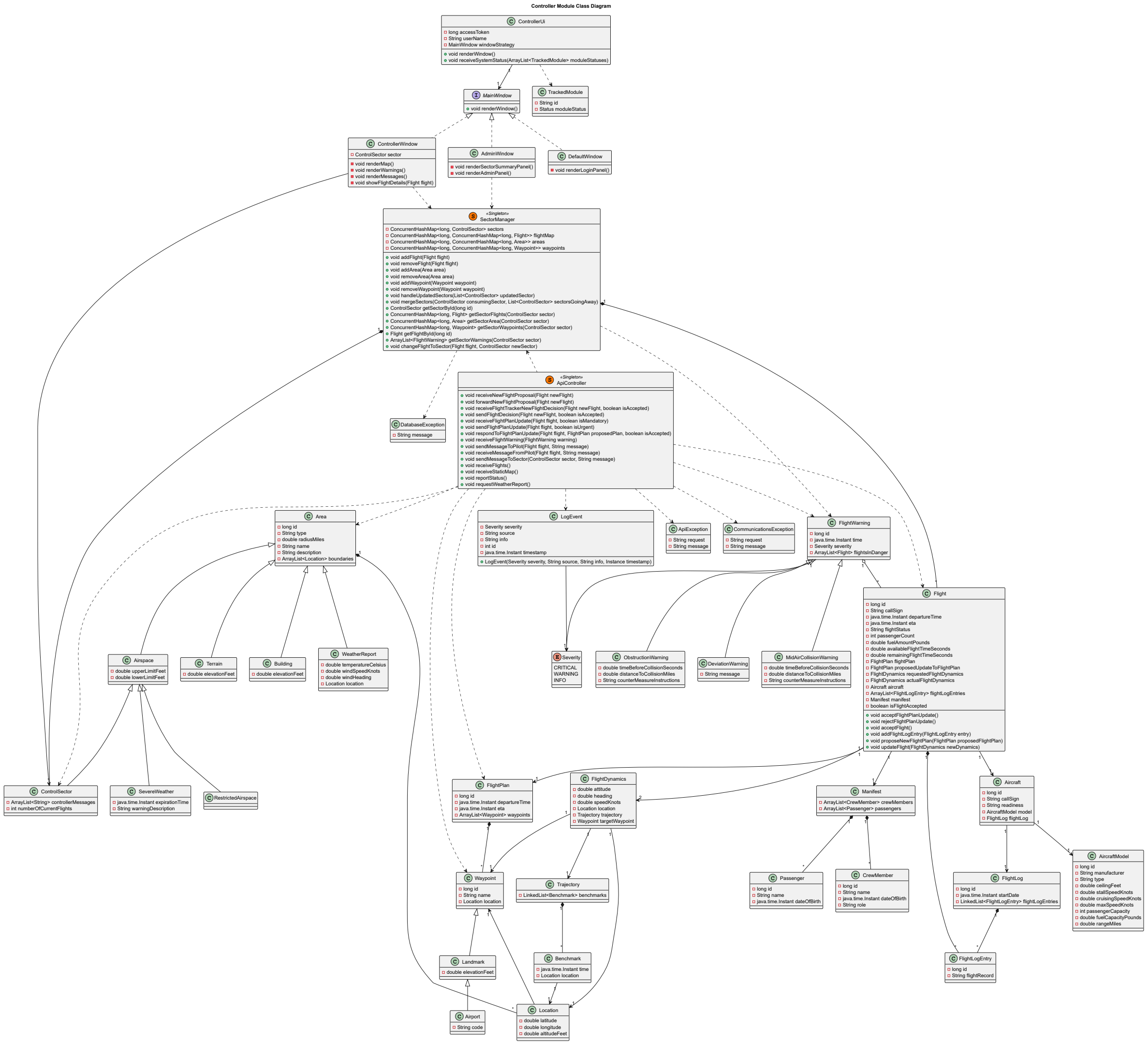
- AI Assisted Conflict Alert: When a potential future conflict is identified by the AI assisted conflict prediction, an alert will be given to the controller.
- AI Generated Route Optimization Suggestions: When the Flight Tracker module creates an AI generated route optimization suggestion, this suggestion shall be displayed to the flight controller to accept or reject.
- AI Detected Abnormal Aircraft Behavior: The Controller module shall provide alerts to the controller for AI detected abnormal aircraft behavior, such as altitude deviations.
- Real-Time Aircraft Map: The Controller module shall display aircraft on a real-time map with configurable zoom levels.
- Color Coded Alerts: The Controller module shall display color coded visual alerts to controllers. Red alerts indicate an immediate safety concern, yellow alerts indicate a potential future safety concern and white alerts are informational.
- Aircraft Details Window: The Controller module shall provide controllers an aircraft details window, display the aircraft's altitude, route, communication status and ETA.
- Drag and Drop Sector Reassignment: The Controller module shall support the ability for controllers to drag and drop aircraft to reassign their sector.
- Event Logging: The Controller module shall send all flight controller actions to the System Monitor module for logging.
- Module Health Monitoring: The Controller module shall provide health monitoring for each module, visible to administrators.
- Service Unavailable Alert: The NGATC shall provide an alert to administrators, supervisors and controllers when any module becomes unavailable.
- System Configurability: The Controller module shall allow administrators the ability to configure what inputs to accept as surveillance inputs, the severity of alerts and aircraft separation thresholds.

Module Non-Functional Requirements

- Surveillance Latency: The Controller module UI shall update aircraft on its UI within 200 ms of receiving location updates from the Flight Tracker module.
- Aircraft Volume: The Controller module shall support at least 5000 simultaneous aircraft tracks.
- Controller UI Refresh Rate: The controller user interface shall update aircraft positions at least once per second.
- Role-Based Authentication: The Controller module shall require authentication for all uses of the Controller module.
- Controller Alert Reaction Time: Controllers shall be able to identify conflicts within 2 seconds of an alert being generated.
- Color Coded Alerts: The Controller UI shall distinguish between alert severity levels using different colors and shapes.
- Night and Day Mode: The Controller UI shall support both night and day display modes.

Controller Module Classes

The classes that make up the Controller module are shown in the class diagram and described in greater detail in the class dictionary below.


Controller Module Class Diagram
ControllerUi
long accessToken
String userName
MainWindow windowStrategy
void renderWindow()
void receiveSystemStatus(ArrayList<TrackedModule> moduleStatuses)
MainWindow
void renderWindow()
TrackedModule
String id
Status moduleStatus
ControllerWindow
ControlSector sector
void renderMap()
void renderWarnings()
void renderMessages()
void showFlightDetails(Flight flight)
AdminWindow
void renderSectorSummaryPanel()
void renderAdminPanel()
DefaultWindow
void renderLoginPanel()
«Singleton»
SectorManager
ConcurrentHashMap<long, ControlSector> sectors
ConcurrentHashMap<long, ConcurrentHashMap<long, Flight>> flightMap
ConcurrentHashMap<long, ConcurrentHashMap<long, Area>> areas
ConcurrentHashMap<long, ConcurrentHashMap<long, Waypoint>> waypoints
void addFlight(Flight flight)
void removeFlight(Flight flight)
void addArea(Area area)
void removeArea(Area area)
void addWaypoint(Waypoint waypoint)
void removeWaypoint(Waypoint waypoint)
void handleUpdatedSectors(List<ControlSector> updatedSector)
void mergeSectors(ControlSector consumingSector, List<ControlSector> sectorsGoingAway)
ControlSector getSectorById(long id)
ConcurrentHashMap<long, Flight> getSectorFlights(ControlSector sector)
ConcurrentHashMap<long, Area> getSectorArea(ControlSector sector)
ConcurrentHashMap<long, Waypoint> getSectorWaypoints(ControlSector sector)
Flight getFlightById(long id)
ArrayList<FlightWarning> getSectorWarnings(ControlSector sector)
void changeFlightToSector(Flight flight, ControlSector newSector)
DatabaseException
String message
«Singleton»
ApiController
void receiveNewFlightProposal(Flight newFlight)
void forwardNewFlightProposal(Flight newFlight)
void receiveFlightTrackerNewFlightDecision(Flight newFlight, boolean isAccepted)
void sendFlightDecision(Flight newFlight, boolean isAccepted)
void receiveFlightPlanUpdate(Flight flight, boolean isMandatory)
void sendFlightPlanUpdate(Flight flight, boolean isUrgent)
void respondToFlightPlanUpdate(Flight flight, FlightPlan proposedPlan, boolean isAccepted)
void receiveFlightWarning(FlightWarning warning)
void sendMessageToPilot(Flight flight, String message)
void receiveMessageFromPilot(Flight flight, String message)
void sendMessageToSector(ControlSector sector, String message)
void receiveFlights()
void receiveStaticMap()
void reportStatus()
void requestWeatherReport()
Area
long id
String type
double radiusMiles
String name
String description
ArrayList<Location> boundaries
LogEvent
Severity severity
String source
String info
int id
java.time.Instant timestamp
LogEvent(Severity severity, String source, String info, Instance timestamp)
ApiException
String request
String message
CommunicationsException
String request
String message
FlightWarning
long id
java.time.Instant time
Severity severity
ArrayList<Flight> flightsInDanger
Airspace
double upperLimitFeet
double lowerLimitFeet
Terrain
double elevationFeet
Building
double elevationFeet
WeatherReport
double temperatureCelsius
double windSpeedKnots
double windHeading
Location location
Severity
CRITICAL
WARNING
INFO
ObstructionWarning
double timeBeforeCollisionSeconds
double distanceToCollisionMiles
String counterMeasureInstructions
DeviationWarning
String message
MidAirCollisionWarning
double timeBeforeCollisionSeconds
double distanceToCollisionMiles
String counterMeasureInstructions
Flight
long id
String callSign
java.time.Instant departureTime
java.time.Instant eta
String flightStatus
int passengerCount
double fuelAmountPounds
double availableFlightTimeSeconds
double remainingFlightTimeSeconds
FlightPlan flightPlan
FlightPlan proposedUpdateToFlightPlan
FlightDynamics requestedFlightDynamics
FlightDynamics actualFlightDynamics
Aircraft aircraft
ArrayList<FlightLogEntry> flightLogEntries
Manifest manifest
boolean isFlightAccepted
void acceptFlightPlanUpdate()
void rejectFlightPlanUpdate()
void acceptFlight()
void addFlightLogEntry(FlightLogEntry entry)
void proposeNewFlightPlan(FlightPlan proposedFlightPlan)
void updateFlight(FlightDynamics newDynamics)
ControlSector
ArrayList<String> controllerMessages
int numberOfCurrentFlights
SevereWeather
java.time.Instant expirationTime
String warningDescription
RestrictedAirspace
FlightPlan
long id
java.time.Instant departureTime
java.time.Instant eta
ArrayList<Waypoint> waypoints
FlightDynamics
double attitude
double heading
double speedKnots
Location location
Trajectory trajectory
Waypoint targetWaypoint
Manifest
ArrayList<CrewMember> crewMembers
ArrayList<Passenger> passengers
Aircraft
long id
String callSign
String readiness
AircraftModel model
FlightLog flightLog
Waypoint
long id
String name
Location location
Trajectory
LinkedList<Benchmark> benchmarks
Passenger
long id
String name
java.time.Instant dateOfBirth
CrewMember
long id
String name
java.time.Instant dateOfBirth
String role
FlightLog
long id
java.time.Instant startDate
LinkedList<FlightLogEntry> flightLogEntries
AircraftModel
long id
String manufacturer
String type
double ceilingFeet
double stallSpeedKnots
double cruisingSpeedKnots
double maxSpeedKnots
int passengerCapacity
double fuelCapacityPounds
double rangeMiles
Landmark
double elevationFeet
Benchmark
java.time.Instant time
Location location
FlightLogEntry
long id
String flightRecord
Airport
String code
Location
double latitude
double longitude
double altitudeFeet

Class Dictionary

Flight

The Flight class is the top level class that encapsulates all information relating to an individual flight.

Methods

Method Name	Method Signature	Description
acceptFlightPlanUpdate	void acceptFlightPlanUpdate()	Accepts a proposed edit to the Flight's FlightPlan and replaces the flightPlan with the proposedUpdateToFlightPlan and communicates the updated plan to the pilot.
rejectFlightPlanUpdate	void rejectFlightPlanUpdate()	Rejects the proposed update and removes it from the Flight.
acceptFlight	void acceptFlight()	Signals that a new flight has been accepted into the NGATC and communicates the acceptance to the pilot.
addFlightLogEntry	void addFlightLogEntry(FlightLogEntry entry)	Adds an entry in the flight's log.
proposeNewFlightPlan	void proposeNewFlightPlan(FlightPlan proposedFlightPlan)	Adds a new flight plan proposal to the flight.

Method Name	Method Signature	Description
updateFlight	void updateFlight(FlightDynamics newDynamics)	Updates a Flight with updated FlightDynamics.

Properties

Property Name	Type	Description
id	long	A globally unique ID used as the primary key in the database.
departureTime	java.time.Instant	The time the flight has departed or is planning to depart.
eta	java.time.Instant	The time the flight is expecting to land.
flightStatus	String	The current status (e.g. "Not Departed", "In Progress", "Landed") of the flight.
passengerCount	int	The number of passengers the flight is carrying.
fuelAmountPounds	double	The current amount of fuel in pounds.
availableFlightTimeSeconds	double	The amount of time the aircraft can fly given the current fuel, altitude and speed.
remainingFlightTimeSeconds	double	The amount of time remaining in the current flight plan.
isFlightAccepted	boolean	Whether the flight has been accepted by air traffic control.

Associations

Association Name	Type	Description
flightPlan	FlightPlan	The currently active flight plan.
proposedUpdateToFlightPlan	FlightPlan	A proposed updated flight plan to be evaluated.
requestedFlightDynamics	FlightDynamics	The flight dynamics the aircraft is requested to observe.
actualFlightDynamics	FlightDynamics	The actual flight dynamics of the aircraft.
aircraft	Aircraft	Information about the aircraft flying the flight.
flightLogEntries	ArrayList	The log entries from the flight.
manifest	Manifest	The flight manifest.

FlightPlan

The route, departure time and ETA of a flight.

Properties

Property Name	Type	Description
id	long	A unique identifier of the flight plan, used as the primary key in the database.
departureTime	java.time.Instant	The time the flight is planned to depart.
eta	java.time.Instant	The time the flight is planned to land.

Associations

Association Name	Type	Description
waypoints	ArrayList	A list of waypoints the flight is planned to follow.

FlightDynamics

Information giving the current attitude, heading and speed of the aircraft.

Properties

Property Name	Type	Description
attitude	double	The attitude of the aircraft in degrees. 0 degrees is horizontal and positive degrees are climbing.
heading	double	The heading relative to magnetic north, with 0 degrees corresponding to north.
speedKnots	double	The speed of the aircraft in knots.

Associations

Association Name	Type	Description
location	Location	The current location of the aircraft.
trajectory	Trajectory	The current trajectory of the aircraft.
targetWaypoint	Waypoint	The waypoint the aircraft is flying toward.

Location

A GPS coordinate with an altitude.

Properties

Property Name	Type	Description
latitude	double	The GPS latitude with north as positive.
longitude	double	The GPS longitude with east as positive.
altitudeFeet	double	The altitude in feet above sea level.

Benchmark

A Location augmented with a time, used to create Trajectories.

Properties

Property Name	Type	Description
time	java.time.Instant	The time the location will be reached.

Associations

Association Name	Type	Description
location	Location	The location that will be reached.

Trajectory

A list of time/location benchmarks describing a flight's trajectory.

Associations

Association Name	Type	Description
benchmarks	LinkedList	A list of benchmarks for the trajectory.

Aircraft

The Aircraft class represents information about a particular aircraft making a flight.

Properties

Property Name	Type	Description
id	long	A globally unique ID for the aircraft, used as the primary key in the database.
readiness	String	A String representing the readiness of the aircraft.

Associations

Association Name	Type	Description
model	AircraftModel	The model of the aircraft (e.g. Boeing 737-700)
flightLog	FlightLog	A log of flights made by the aircraft.

AircraftModel

The AircraftModel class represents a specific model of Aircraft (e.g. Boeing 737-700).

Properties

Property Name	Type	Description
id	long	A globally unique ID of the aircraft model
manufacturer	String	The manufacturer of the aircraft model (e.g. AirBus)
type	String	The type of aircraft (e.g. Dual Engine, Single Aisle)
ceilingFeet	double	The height altitude above sea level the aircraft model can fly at.
stallSpeedKnots	double	The minimum speed the aircraft can fly without stalling.
cruisingSpeedKnots	double	The optimal speed for the aircraft to cruise at.
maxSpeedKnots	double	The maximum speed the aircraft is capable of flying at.
passengerCapacity	int	The maximum number of passengers the aircraft can carry.
fuelCapacityPounds	double	The fuel capacity of the aircraft.
rangeMiles	double	The maximum number of miles the aircraft can fly.

FlightLog

A list of flight log entries.

Properties

Property Name	Type	Description
id	long	A globally unique ID of the flight log, used as the primary key in the database.
startDate	java.time.Instant	The time the flight log was created.

Associations

Association Name	Type	Description
flightLogEntries	LinkedList	A list of entries into the flight log.

FlightLogEntry

An individual entry into the flight log.

Properties

Property Name	Type	Description
id	long	A globally unique ID of the entry, used as the primary key in the database.
flightRecord	String	The message to record.

Waypoint

Describes a location augmented with a name.

Properties

Property Name	Type	Description
id	long	A globally unique ID of the waypoint, used as the primary key in the database.
name	String	The name of the waypoint.

Associations

Association Name	Type	Description
location	Location	The location of the waypoint.

FlightWarning

A class used to describe types of warnings that could occur during a flight.

Properties

Property Name	Type	Description
id	long	A globally unique ID, used as the primary key in the database.
time	java.time.Instant	The time the warning occurred.

Associations

Association Name	Type	Description
severity	Severity	The severity of the warning.
flightsInDanger	ArrayList	A list of the flights in danger with regards to the warning.

MidAirCollisionWarning

A type of FlightWarning of an aircraft colliding with another aircraft in midair.

Properties

Property Name	Type	Description
timeBeforeCollisionSeconds	double	The number of seconds before collision.
distanceToCollisionMiles	double	The number of miles until the projected collision.
counterMeasureInstructions	String	The instructions provided to pilots to avoid the collision.

ObstructionWarning

A type of FlightWarning of an aircraft colliding with a static hazard.

Properties

Property Name	Type	Description
timeBeforeCollisionSeconds	double	The number of seconds before collision.
distanceToCollisionMiles	double	The number of miles until the projected collision.
counterMeasureInstructions	String	The instructions provided to pilots to avoid the collision.

DeviationWarning

A type of FlightWarning indicating that a flight has made a significant deviation from its flight plan.

Properties

Property Name	Type	Description
message	String	A message explaining the deviation.

Area

Represents an area in the NGATC system.

Properties

Property Name	Type	Description
id	long	A globally unique ID, used as the primary key in the database.
type	String	A String indicating the type of area.
radiusMiles	double	The radius of the area in miles.
name	String	The name of the area.
description	String	A description of the area.

Associations

Association Name	Type	Description
boundaries	ArrayList	An ordered list of the boundaries of the area.

Airspace

A type of area describing a volume of airspace.

Properties

Property Name	Type	Description
upperLimitFeet	double	The upper limit of airspace altitude.
lowerLimitFeet	double	The lower limit of the airspace altitude.

RestrictedAirspace

A type of Airspace that is restricted for civil aviation.

SevereWeather

A type of Airspace experiencing hazardous weather conditions for flight.

Properties

Property Name	Type	Description
expirationTime	java.time.Instant	The time the weather will expire.
warningDescription	String	A description of the severe weather.

ControlSector

A type of airspace describing a region of responsibility for a flight controller.

Properties

Property Name	Type	Description
controllerMessages	ArrayList	A list of messages sent between controllers.
numberOfCurrentFlights	int	The current number of flights active in the sector.

SectorManager

The SectorManager class is responsible for categorizing objects into ControlSectors and reporting on those objects to other sectors. Concurrent hash maps are used to both ensure thread safety and to enable O(1) access to control sectors, O(1) access to objects within a sector and O(m) access to objects globally, where m is the number of sectors.

Methods

Method Name	Method Signature	Description
addFlight	void addFlight(Flight flight)	Adds a flight to the system and categorizes it into the correct sector based on its takeoff location.
removeFlight	void removeFlight(Flight flight)	Removes a flight from the system after it has completed.
addArea	void addArea(Area area)	Adds an area to the system and categorizes it into the correct sector(s)
removeArea	void removeArea(Area area)	Removes an area from the system.
addWaypoint	void addWaypoint(Waypoint waypoint)	Adds a waypoint to the system and categorizes it into the correct sector
removeWaypoint	void removeWaypoint(Waypoint waypoint)	Removes a waypoint from the system
handleUpdatedSectors	void handleUpdatedSectors(List updatedSector)	When sector boundaries change, updates the objects owned by the updated sectors.
mergeSectors	void mergeSectors(ControlSector consumingSector, List sectorsGoingAway)	Merges two sectors and reassigns objects as appropriate.
getSectorById	ControlSector getSectorById(long id)	Returns a reference to a sector by its ID.
getSectorFlights	ConcurrentHashMap<long, Flight> getSectorFlights(ControlSector sector)	Gets the flights associated with the sector.
getSectorAreas	ConcurrentHashMap<long, Area> getSectorAreas(ControlSector sector)	Gets the areas associated with the sector.

Method Name	Method Signature	Description
getSectorWaypoints	ConcurrentHashMap<long, Waypoint> getSectorWaypoints(ControlSector sector)	Gets the waypoints associated with the sector.
getFlightById	Flight getFlightById(long id)	Gets a reference to a flight by its ID.
getSectorWarnings	ArrayList getSectorWarnings(ControlSector sector)	Gets the warnings associated with a sector.
changeFlightToSector	void changeFlightToSector(Flight flight, ControlSector newSector)	Changes a flight to a new sector.

Associations

Association Name	Type	Description
sectors	ConcurrentHashMap<long, ControlSector>	A map of sectors in the NGATC.
flightMap	ConcurrentHashMap<long, ConcurrentHashMap<long, Flight>>	A map of flights in the NGATC, organized by sector.
areas	ConcurrentHashMap<long, ConcurrentHashMap<long, Area>>	A map of areas in the NGATC, organized by sector (with duplicate entries for areas that span multiple sectors).
waypoints	ConcurrentHashMap<long, ConcurrentHashMap<long, Waypoint>>	A map of waypoints in the NGATC, organized by sector.

ControllerUi

Represents the top level GUI used to interact with the Controller module. The class provides GUI elements common across all roles, such as system status, and uses the strategy design pattern to display information specific to a user's role. It also provides login, logout and create user functionality.

Methods

Method Name	Method Signature	Description
render	void renderWindow()	Updates the UI with the main window indicated by the windowStrategy. This also starts a thread every second to update the system status render the main window, and update night/day mode.
receiveSystemStatus	void receiveSystemStatus(ArrayList moduleStatuses)	Receives a system status update.

Properties

Property Name	Type	Description
accessToken	long	The access token being used to access the UI. This is used to control the MainWindow being shown to the user.
userName	String	The username currently signed in.

Associations

Association Name	Type	Description
windowStrategy	MainWindow	The MainWindow being displayed to the user as part of the Strategy design pattern.

Association Name	Type	Description
moduleStatuses	ArrayList	The statuses of modules in the NGATC.

MainWindow (interface)

This is the interface for all windows displayed within the controller UI. It is implemented by a variety of windows, using the strategy design pattern.

Methods

Method Name	Method Signature	Description
renderWindow	void renderWindow()	Renders this window, taking into account the time of day to decide between night and day mode.

ControllerWindow

This is the window used by flight controllers to interact with the NGATC.

Methods

Method Name	Method Signature	Description
renderMap	void renderMap()	Renders the controller map of the sector.
renderWarnings	void renderWarnings()	Renders the warnings relevant to the sector.
renderMessages	void renderMessages()	Renders the messages from pilots and other controllers relevant to the sector.
showFlightDetails	void showFlightDetails(Flight flight)	Shows the details of a particular flight.

Associations

Association Name	Type	Description
sector	ControlSector	A reference to the sector being controlled.

AdminWindow

A window used by supervisors and administrators to manage the NGATC.

Methods

Method Name	Method Signature	Description
renderSectorSummaryPanel	void renderSectorSummaryPanel()	Displays a summary of sectors and allows users to manage these sectors.
renderAdminPanel	void renderAdminPanel()	Displays a panel enabling a variety of configuration actions for the NGATC.

DefaultWindow

Displays a window when no user is logged in, prompting users to login.

Methods

Method Name	Method Signature	Description
renderLoginPanel	void renderLoginPanel()	Displays a login prompt to the user.

ApiController

The ApiController class is a singleton class used to send and receive messages through the module's REST API.

Methods

Method Name	Method Signature	Description
receiveNewFlightProposal	void receiveNewFlightProposal(Flight newFlight)	Receives a proposed flight and adds the flight in the SectorManager.
forwardNewFlightProposal	void forwardNewFlightProposal(Flight newFlight)	Sends a new flight proposal to the Flight Tracker module for final acceptance.
receiveFlightTrackerNewFlightDecision	void receiveFlightTrackerNewFlightDecision(Flight newFlight, boolean isAccepted)	Receives an accept/reject decision from the Flight Tracker module and uses that decision to send a decision to the pilot using sendFlightDecision and update the status of the flight in the Controller module.
sendFlightDecision	void sendFlightDecision(Flight newFlight, boolean isAccepted)	Sends the acceptance or rejection of a new flight to the pilots.
receiveFlightPlanUpdate	void receiveFlightPlanUpdate(Flight flight, boolean isMandatory)	Receives a flight plan update from the FlightTracker module or pilot and updates the Flight with the proposed plan in the Controller module, for a controller to accept or reject. If the update is marked as mandatory (e.g. emergency conflict resolution), the update is accepted automatically.
sendFlightPlanUpdate	void sendFlightPlanUpdate(Flight flight, boolean isUrgent)	Sends an updated flight plan to the pilots and Flight Tracker module.
respondToFlightPlanUpdate	void respondToFlightPlanUpdate(Flight flight, FlightPlan proposedPlan, boolean isAccepted)	Responds to the Flight Tracker module with weather a FlightPlan update was accepted.
receiveFlightWarning	void receiveFlightWarning(FlightWarning warning)	Receives a warning from the Flight Tracker module.
sendMessageToPilot	void sendMessageToPilot(Flight flight, String message)	Sends a message to a pilot.
receiveMessageFromPilot	void receiveMessageFromPilot(Flight flight, String message)	Receives a message from a pilot and adds the message to the appropriate sector.
sendMessageToSector	void sendMessageToSector(ControlSector sector, String message)	Sends a message to another sector encoded with the source sector.

Method Name	Method Signature	Description
receiveFlights	void receiveFlights()	Receives all the currently active flights from the Flight Tracker module, updates their FlightDynamics and ensures they are in the correct sector.
receiveStaticMap	void receiveStaticMap()	Requests a list of static map objects from the Static Map module.
reportLogEvent	void reportLogEvent(LogEvent event)	Reports an event to the System Monitor module.
receiveModuleStatuses	void receiveModuleStatuses(ArrayList)	Receives the status of all NGATC modules.
reportStatus	void reportStatus()	Report's the module's status to the System Monitor module every second.
requestWeatherReport	void requestWeatherReport()	Runs in a thread once per second to request a weather report from the Weather module. The information is then incorporated into the SectorManager.

Service API

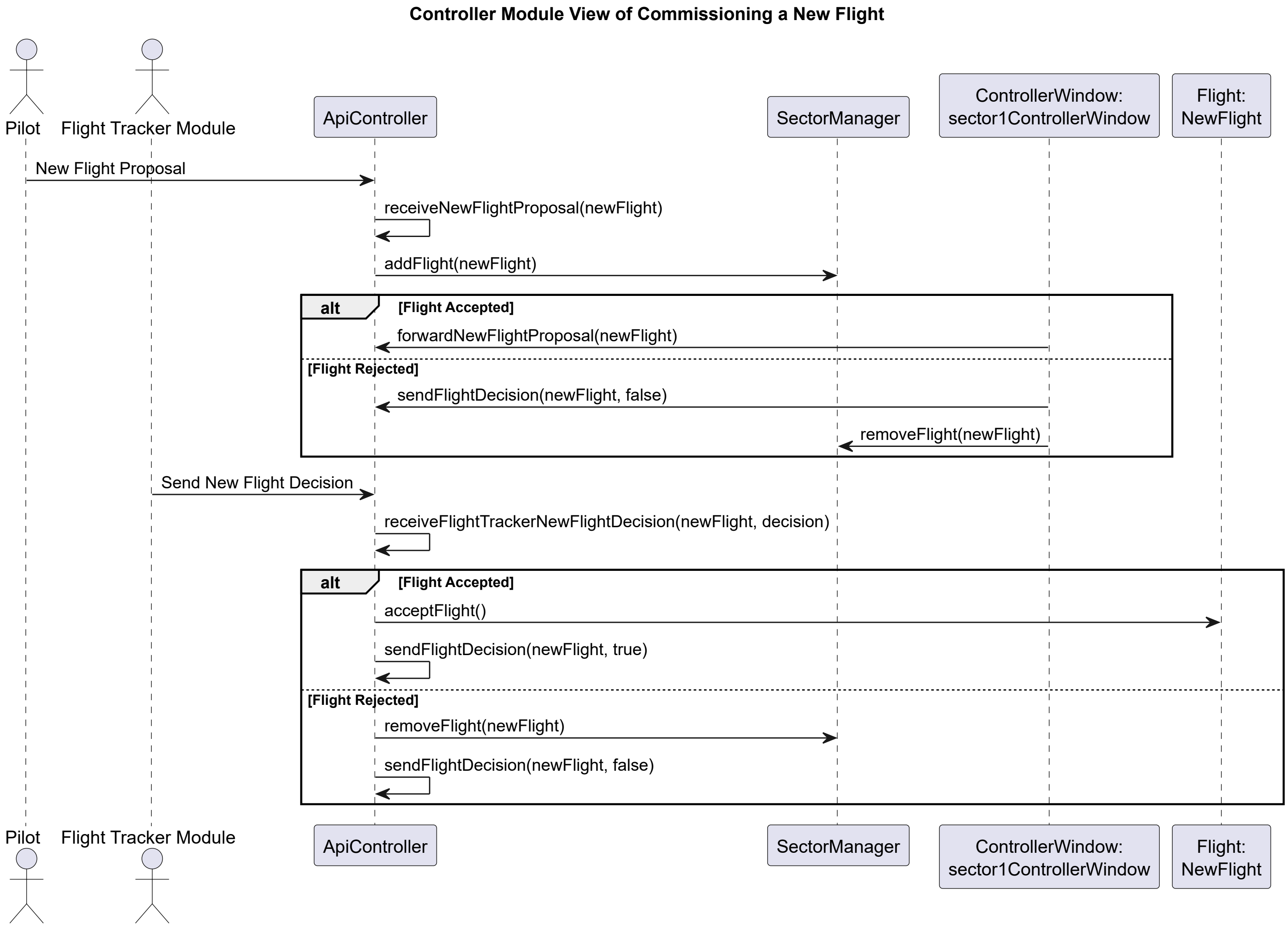
The Controller module implements the following API services:

- New Flight Proposal
  - Path: POST/flight
  - Inputs:
    - Flight: The Flight in JSON encoding
    - Access Token: Requires a Pilot role
  - Output: HTTP Status, the accept/reject decision will be communicated asynchronously
- Flight Tracker New Flight Decision:
  - Path: POST/flight
  - Inputs:
    - Flight: The Flight in JSON encoding
    - Is Accepted: A boolean representing whether the new flight was accepted
    - Access Token: Requires an internal module role
  - Output: HTTP status
- Update Flight Plan:
  - Path: PUT/flightPlan
  - Inputs:
    - Flight: The Flight in JSON Encoding
    - Is Mandatory: Whether updating the Flight Plan is mandatory (e.g. emergency conflict resolution)
    - Access Token: Requires an internal module role
  - Output: HTTP status
- Flight Warning:
  - Path: POST/warning
  - Inputs:
    - Warning: A FlightWarning in JSON encoding
    - Access Token: Requires an internal module role
  - Output: HTTP status

- Receive Pilot Message:
  - Path: POST/message
  - Inputs:
    - Flight: The Flight in JSON encoding
    - Message: The message to be sent
    - Access Token: Requires a Pilot role
  - Output: HTTP status
- Update Flights:
  - Path: PUT/flights
  - Inputs:
    - Flights: All currently active flights in JSON encoding
    - Access Token: Requires an internal module role
  - Output: HTTP status
- Update Module Statuses:
  - Path: PUT/modules
  - Inputs:
    - Statuses: A list of TrackedModules in JSON encoding
    - Access Token: Requires an internal module role
  - Output: HTTP status

Sequence Diagram

The following sequence diagram shows the commissioning of a hypothetical flight with emphasis on the Controller module.


Controller Module View of Commissioning a New Flight
Pilot
Flight Tracker Module
ApiController
SectorManager
ControllerWindow: sector1ControllerWindow
Flight: NewFlight
New Flight Proposal
receiveNewFlightProposal(newFlight)
addFlight(newFlight)
alt
[Flight Accepted]
forwardNewFlightProposal(newFlight)
[Flight Rejected]
sendFlightDecision(newFlight, false)
removeFlight(newFlight)
Send New Flight Decision
receiveFlightTrackerNewFlightDecision(newFlight, decision)
alt
[Flight Accepted]
acceptFlight()
sendFlightDecision(newFlight, true)
[Flight Rejected]
removeFlight(newFlight)
sendFlightDecision(newFlight, false)

This diagram shows how a flight is first accepted by a human flight controller and then sent to the Flight Tracker module for automated processing of the flight plan, before the accept/reject decision is communicated back to the pilots.

Entitlement Service Integration

The entitlement service is used to support login/logout and create user functionality for the Controller module UI. The entitlement service is also used to verify proper access levels for all Controller module API calls.

Object Persistence

Object persistence is handled through the Hibernate framework, with API primary keys documented in the class dictionary.

Testing Strategy

The module level testing for the Controller module is described below:

- New Flight Test:
  - A flight is proposed that is rejected by the controller
  - A flight is proposed that is accepted by the controller and rejected by the Flight Tracker module (simulated by the testing framework)
  - A flight is proposed that is accepted by both the controller and Flight Tracker module
- Flight Update Test:
  - A mandatory flight update is proposed by the Flight Tracker module
  - An optional flight update is proposed by the Flight Tracker module and accepted by the flight controller

  - An optional flight update is proposed by the Flight Tracker module and rejected by the flight controller
- Sector Reassignment Test:
  - Flight updates are send by the Flight Tracker module
  - A flight is "dragged and dropped" by a flight controller to another sector
  - Two sectors are merged by an administrator
  - A sector is split by an administrator

Exception Handling

Exceptions for the Controller module are handled primarily through the DatabaseException, CommunicationsException and ApiException classes. These exception classes are unchecked exceptions and are logged for future auditing.

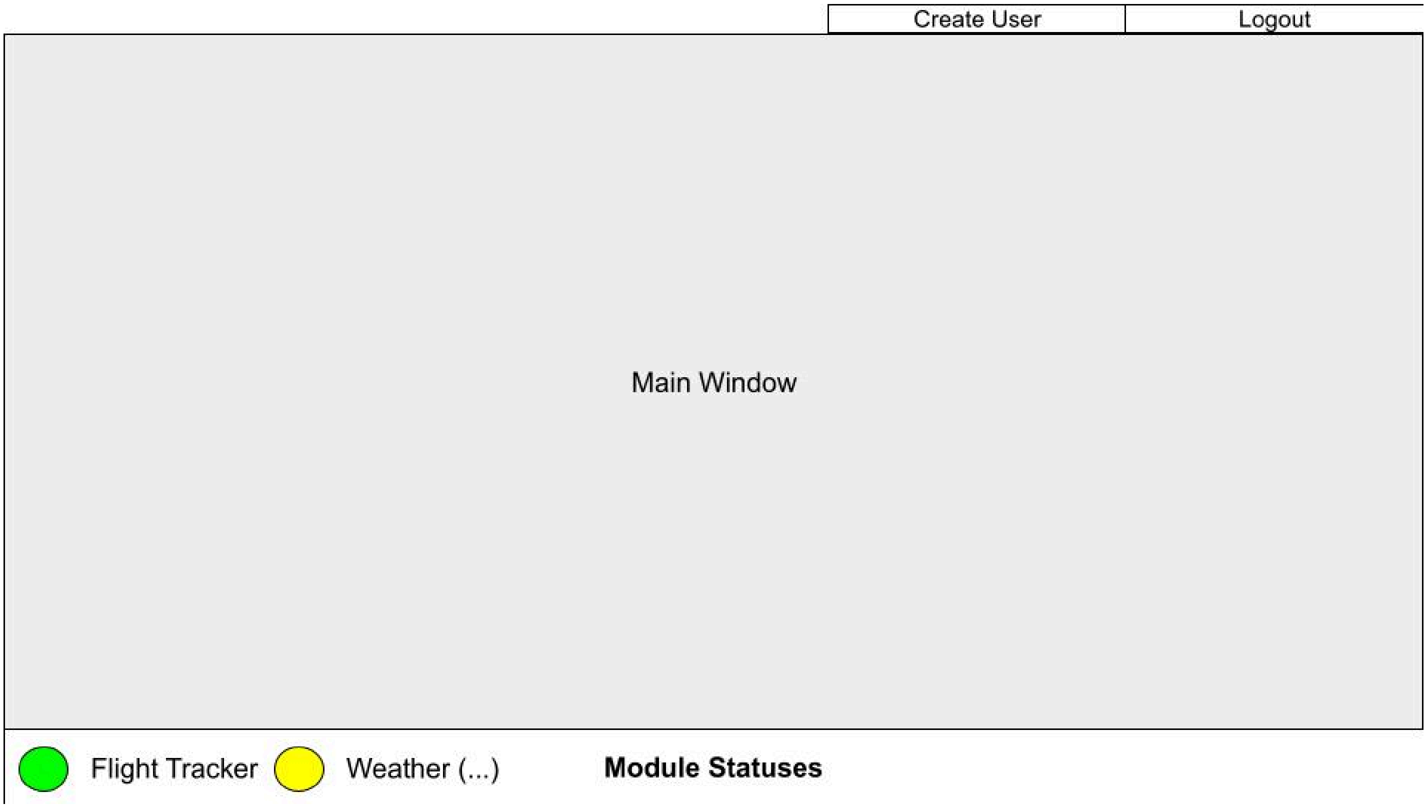
Risks

Many of the risks that would typically be considered in an air traffic control system have been segregated out of this module by leaving it separate from the Flight Tracker module. This leaves much of the flight validation and conflict detection in its own module. A risk in this module is that it is responsible for communicating with pilots, and any outage of this communication could have significant consequences. For this reason, redundant instances of this module are commissioned in Kubernetes, which mitigates the risk of a communications failure.

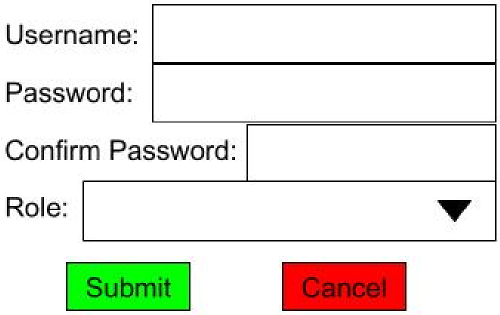
Another risk is the security risk of unauthorized users interacting with the module. For this reason, all meaningful UI and API interactions with this module are access controlled through the Entitlement Service.

UI Wireframes

The Base Controller UI, which contains the main window is displayed below. This window, like all others, has a night and day mode and is responsible for displaying system information and Create User (only when an Admin is signed in) and Logout options (when applicable). When a user clicks on Create User, a dialog box will appear.

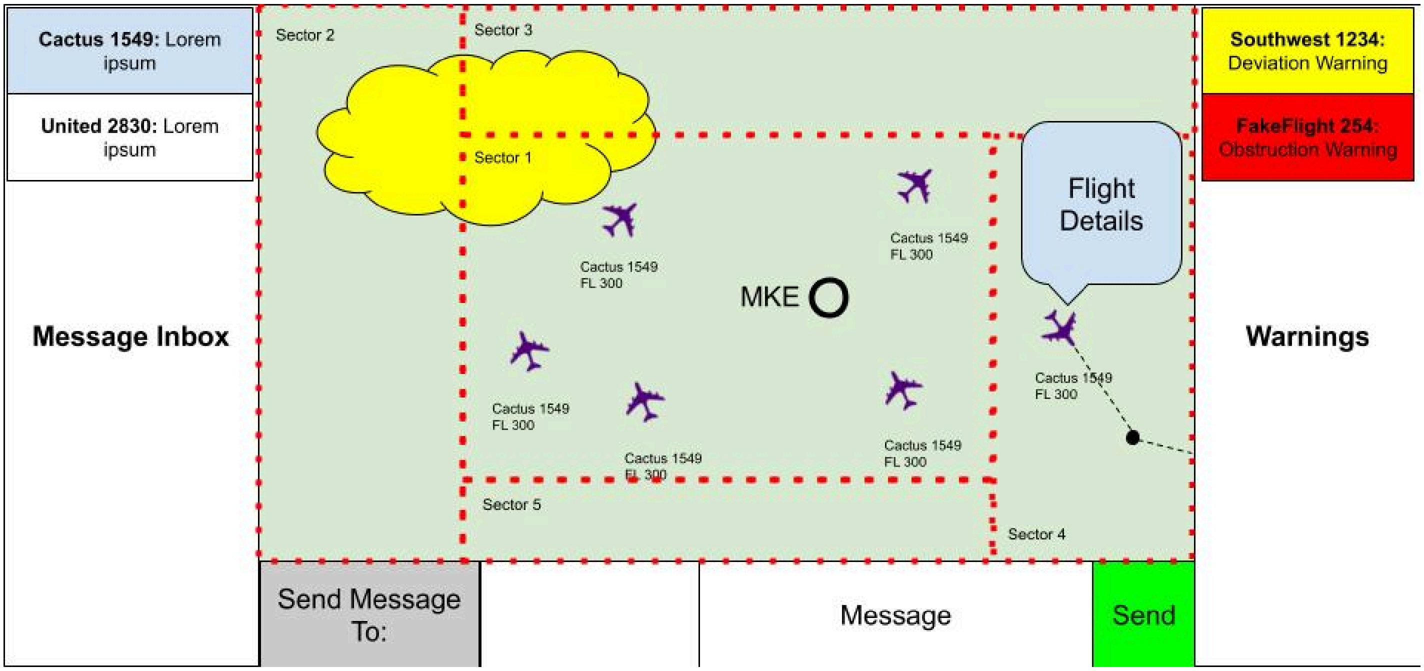


The create user dialog box is shown below:



The Controller window is the window that flight controllers interact with the control flights. It is shown below. Of note, this interface supports the drag and drop transfer of aircraft between sectors. Also of note is that messages are color coded between read and unread and warnings are color coded by severity. It also supports the use of the scroll wheel to zoom in and out of the map.

The map allows flight controllers to amend the flight plan by clicking on an aircraft and dragging and dropping waypoints.

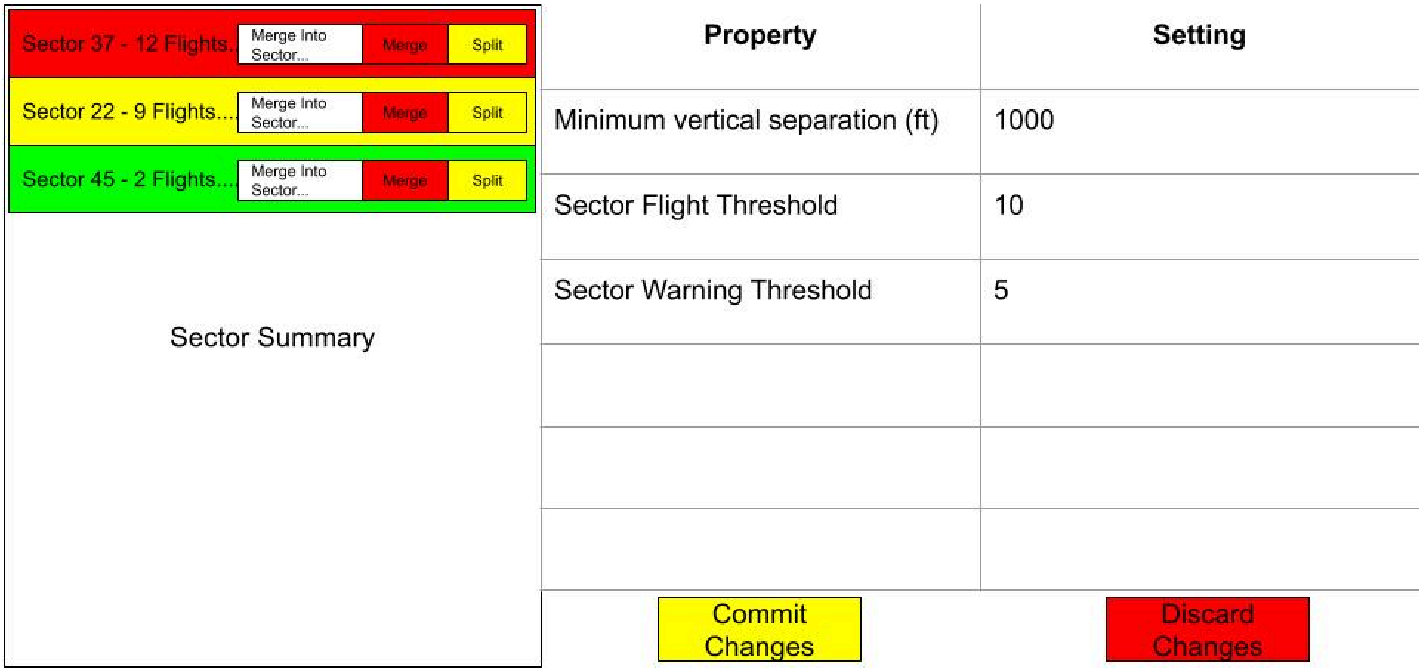

Cactus 1549: Lorem ipsum

United 2830: Lorem ipsum

Southwest 1234: Deviation Warning

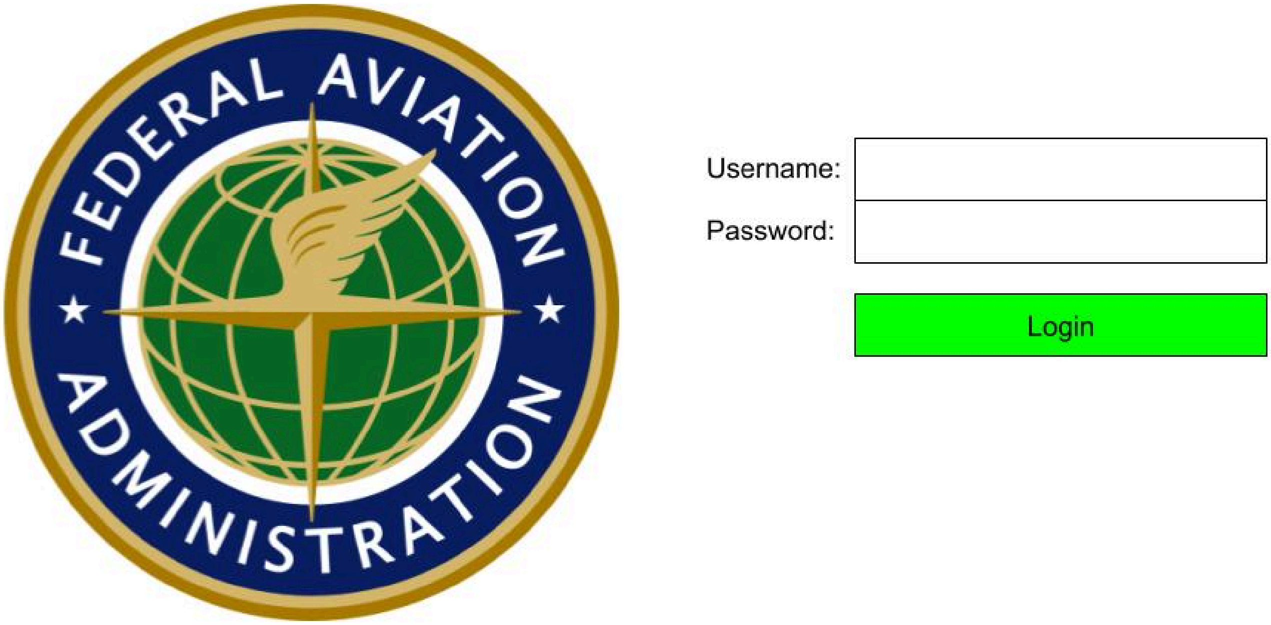
FakeFlight 254: Obstruction Warning

The Administrator window is displayed to administrators and supervisors. It is shown below. Note that on the configuration panel on the right, supervisor users will only have read-only access to this table.



Property	Setting
Minimum vertical separation (ft)	1000
Sector Flight Threshold	10
Sector Warning Threshold	5

The default window, which is displayed to users who are not logged in, is displayed below:



Flight Tracker Module

The Flight Tracker module is responsible for ingesting real-time surveillance data and using to predict and analyze flights. This information is used to optimize flight plans, predict future issues and report and resolve current incidents.

Module Functional Requirements Summary

The Flight Tracker module implements the following requirements:

- Real-Time Aircraft Data Ingestion: The Flight Tracker module shall use real-time surveillance data to track flights in the NGATC.
- Real-Time Aircraft Position Update: The Flight Tracker module shall update the real-time position of all tracked aircraft and send this information to any relevant modules at a rate of at least once per second.

- Unified Aircraft Track: The Flight Tracker module shall synthesize surveillance inputs for a single aircraft into a single, unified aircraft track.
- Flight Plan Ingestion: The Flight Tracker module shall ingest flight plans through a well-defined API and accept or reject them.
- Flight Plan Association: The Flight Tracker module shall associate aircraft flight plans with aircraft tracks.
- Flight Plan Amendments: The Flight Tracker module shall support flight plan amendments from external sources (e.g. Controller module or pilots), or amendments generated within the module.
- Pilot Flight Plan Amendment Acceptance: The Flight Tracker module shall validate all flight plan adjustments before they are accepted.
- Aircraft Trajectory Prediction: The Flight Tracker module shall predict aircraft trajectories based on the aircraft's speed, altitude and route.
- Flight Plan Deviation Notifications: The Flight Tracker module shall notify the Controller module of deviations between an aircraft's flight plan and its actual behavior beyond acceptable limits.
- High Priority Ports: The Flight Tracker module shall use the high priority ports exposed by the Controller module for urgent communication.
- Loss of Separation Detection: The Flight Tracker module shall detect any loss of separation conflicts between aircraft or between an aircraft and a static hazard.
- Loss of Separation Alert to Aircraft: Upon detection of loss of separation, the Flight Tracker module shall communicate a resolution plan for use by the involved aircraft.
- Restricted Airspace Alerts: The Flight Tracker module shall detect and communicate when a flight violates restricted airspace.
- Real-Time Weather Ingestion: The Flight Tracker module shall ingest real-time weather and turbulence data.
- Weather Impacts on Trajectories: The Flight Tracker module shall compensate for the impact of weather on trajectories.
- AI Assisted Conflict Prediction: The Flight Tracker module shall provide AI assisted conflict prediction for at least 3-5 minutes into the future.
- AI Assisted Conflict Alert: When a potential future conflict is identified by the AI assisted conflict prediction, an alert will be given to the controller.
- AI Generated Route Optimization Suggestions: The Flight Tracker module shall provide AI generated route optimization suggestions that controllers can either accept or reject.
- AI Detected Abnormal Aircraft Behavior: The Flight Tracker module shall provide alerts for AI detected abnormal aircraft behavior, such as altitude deviations.
- Event Logging: The Flight Tracker module shall report all warnings to the System Monitor module for logging.

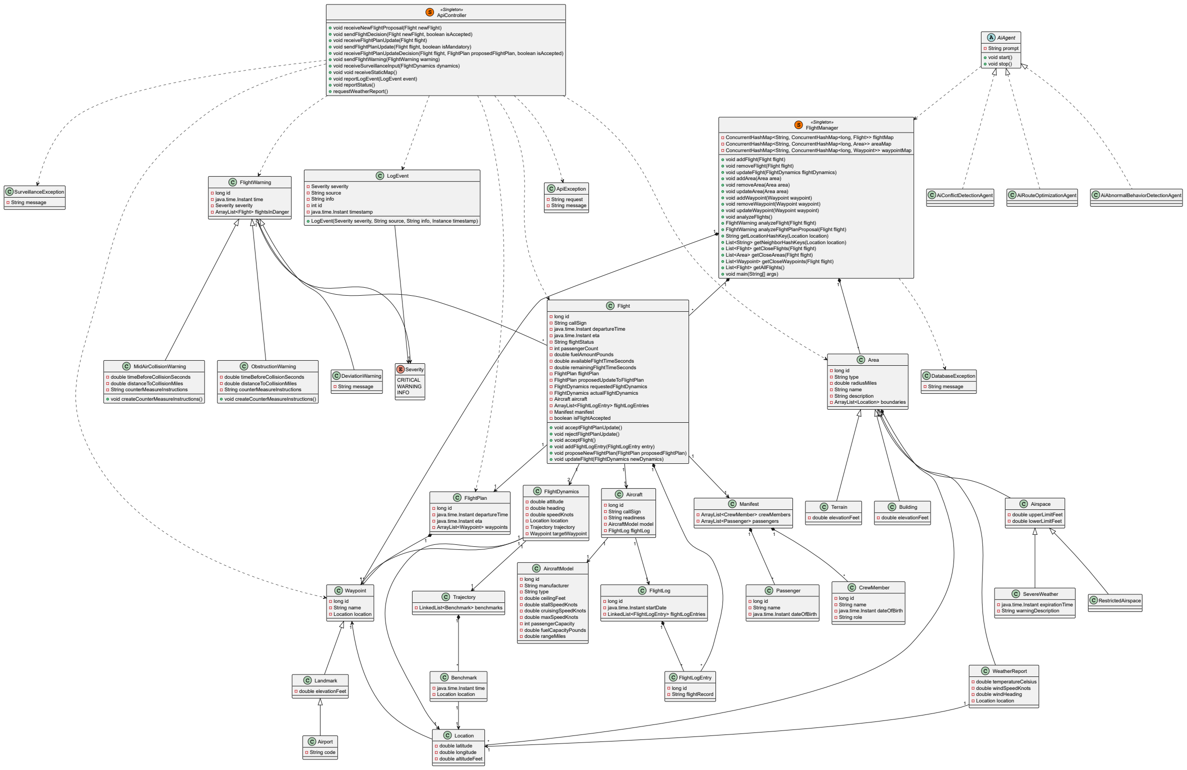
Module Non-Functional Requirements Summary

- Surveillance Latency: The Flight Tracker module shall process surveillance updates with a latency of less than 500 ms.
- Aircraft Volume: The Flight Tracker shall support at least 5000 simultaneous aircraft tracks.
- 5 Nines of Availability: The Flight Tracker module shall be available 99.999% of the time.
- Redundance Services: The Flight Tracker module shall provide for automatic switchover in the event of a failure.
- Track Data Preservation: When the Flight Tracker module switches to another instance of a module due to a failure, this switchover shall preserve all track data.
- Horizontal Scalability: The Flight Tracker module deployment shall scale horizontally to support increases in aircraft volume.
- Communication Encryption: Communication between the Flight Tracker module and other modules shall use TLS encryption.
- Role-Based Authentication: The Flight Tracker module shall require authentication before trusting any external data.
- Flight Data Modification: The Flight Tracker module shall protect against the unauthorized modification of flight data.
- New Data Sources: The Flight Tracker module shall support the "plug and play" addition of new data sources.
- Module Testability: The Flight Tracker module shall be created such that it can be tested independently using mock data.
- Automated Test Coverage: At least 80% automated test coverage of the Flight Tracker module core logic shall be achieved.

Flight Tracker Module Classes

The classes that make up the Flight Tracker module are shown below and described in greater detail in the class dictionary.

Flight Tracker Module Class Diagram


«Singleton»
ApiController
void receiveNewFlightProposal(Flight newFlight)
void sendFlightDecision(Flight newFlight, boolean isAccepted)
void receiveFlightPlanUpdate(Flight flight)
void sendFlightPlanUpdate(Flight flight, boolean isMandatory)
void receiveFlightPlanUpdateDecision(Flight flight, FlightPlan proposedFlightPlan, boolean isAccepted)
void sendFlightWarning(FlightWarning warning)
void receiveSurveillanceInput(FlightDynamics dynamics)
void void receiveStaticMap()
void reportLogEvent(LogEvent event)
void reportStatus()
requestWeatherReport()
AiAgent
String prompt
void start()
void stop()
«Singleton»
FlightManager
ConcurrentHashMap<String, ConcurrentHashMap<long, Flight>> flightMap
ConcurrentHashMap<String, ConcurrentHashMap<long, Area>> areaMap
ConcurrentHashMap<String, ConcurrentHashMap<long, Waypoint>> waypointMap
void addFlight(Flight flight)
void removeFlight(Flight flight)
void updateFlight(FlightDynamics flightDynamics)
void addArea(Area area)
void removeArea(Area area)
void updateArea(Area area)
void addWaypoint(Waypoint waypoint)
void removeWaypoint(Waypoint waypoint)
void updateWaypoint(Waypoint waypoint)
void analyzeFlights()
FlightWarning analyzeFlight(Flight flight)
FlightWarning analyzeFlightPlanProposal(Flight flight)
String getLocationHashKey(Location location)
List<String> getNeighborHashKeys(Location location)
List<Flight> getCloseFlights(Flight flight)
List<Area> getCloseAreas(Flight flight)
List<Waypoint> getCloseWaypoints(Flight flight)
List<Flight> getAllFlights()
void main(String[] args)
AiConflictDetectionAgent
AiRouteOptimizationAgent
AiAbnormalBehaviorDetectionAgent
SurveillanceException
String message
FlightWarning
long id
java.time.Instant time
Severity severity
ArrayList<Flight> flightsInDanger
LogEvent
Severity severity
String source
String info
int id
java.time.Instant timestamp
LogEvent(Severity severity, String source, String info, Instance timestamp)
ApiException
String request
String message
MidAirCollisionWarning
double timeBeforeCollisionSeconds
double distanceToCollisionMiles
String counterMeasureInstructions
void createCounterMeasureInstructions()
ObstructionWarning
double timeBeforeCollisionSeconds
double distanceToCollisionMiles
String counterMeasureInstructions
void createCounterMeasureInstructions()
DeviationWarning
String message
Severity
CRITICAL
WARNING
INFO
Flight
long id
String callSign
java.time.Instant departureTime
java.time.Instant eta
String flightStatus
int passengerCount
double fuelAmountPounds
double availableFlightTimeSeconds
double remainingFlightTimeSeconds
FlightPlan flightPlan
FlightPlan proposedUpdateToFlightPlan
FlightDynamics requestedFlightDynamics
FlightDynamics actualFlightDynamics
Aircraft aircraft
ArrayList<FlightLogEntry> flightLogEntries
Manifest manifest
boolean isFlightAccepted
void acceptFlightPlanUpdate()
void rejectFlightPlanUpdate()
void acceptFlight()
void addFlightLogEntry(FlightLogEntry entry)
void proposeNewFlightPlan(FlightPlan proposedFlightPlan)
void updateFlight(FlightDynamics newDynamics)
Area
long id
String type
double radiusMiles
String name
String description
ArrayList<Location> boundaries
DatabaseException
String message
FlightPlan
long id
java.time.Instant departureTime
java.time.Instant eta
ArrayList<Waypoint> waypoints
FlightDynamics
double attitude
double heading
double speedKnots
Location location
Trajectory trajectory
Waypoint targetWaypoint
Aircraft
long id
String callSign
String readiness
AircraftModel model
FlightLog flightLog
Manifest
ArrayList<CrewMember> crewMembers
ArrayList<Passenger> passengers
Terrain
double elevationFeet
Building
double elevationFeet
Airspace
double upperLimitFeet
double lowerLimitFeet
Waypoint
long id
String name
Location location
Trajectory
LinkedList<Benchmark> benchmarks
AircraftModel
long id
String manufacturer
String type
double ceilingFeet
double stallSpeedKnots
double cruisingSpeedKnots
double maxSpeedKnots
int passengerCapacity
double fuelCapacityPounds
double rangeMiles
FlightLog
long id
java.time.Instant startDate
LinkedList<FlightLogEntry> flightLogEntries
Passenger
long id
String name
java.time.Instant dateOfBirth
CrewMember
long id
String name
java.time.Instant dateOfBirth
String role
SevereWeather
java.time.Instant expirationTime
String warningDescription
RestrictedAirspace
Landmark
double elevationFeet
Benchmark
java.time.Instant time
Location location
FlightLogEntry
long id
String flightRecord
WeatherReport
double temperatureCelsius
double windSpeedKnots
double windHeading
Location location
Airport
String code
Location
double latitude
double longitude
double altitudeFeet

Class Dictionary

Flight

The Flight class is the top level class that encapsulates all information relating to an individual flight.

Methods

Method Name	Method Signature	Description
acceptFlightPlanUpdate	void acceptFlightPlanUpdate()	Accepts a proposed edit to the Flight's FlightPlan and replaces the flightPlan with the proposedUpdateToFlightPlan.
rejectFlightPlanUpdate	void rejectFlightPlanUpdate()	Rejects the proposed update and removes it from the Flight.
acceptFlight	void acceptFlight()	Signals that a new flight has been accepted into the NGATC.
addFlightLogEntry	void addFlightLogEntry(FlightLogEntry entry)	Adds an entry in the flight's log.
proposeNewFlightPlan	void proposeNewFlightPlan(FlightPlan proposedFlightPlan)	Adds a new flight plan proposal to the flight.
updateFlight	void updateFlight(FlightDynamics newDynamics)	Updates a Flight with updated FlightDynamics.

Properties

Property Name	Type	Description
id	long	A globally unique ID used as the primary key in the database.
departureTime	java.time.Instant	The time the flight has departed or is planning to depart.
eta	java.time.Instant	The time the flight is expecting to land.
flightStatus	String	The current status (e.g. "Not Departed", "In Progress", "Landed") of the flight.

Property Name	Type	Description
passengerCount	int	The number of passengers the flight is carrying.
fuelAmountPounds	double	The current amount of fuel in pounds.
availableFlightTimeSeconds	double	The amount of time the aircraft can fly given the current fuel, altitude and speed.
remainingFlightTimeSeconds	double	The amount of time remaining in the current flight plan.
isFlightAccepted	boolean	Whether the flight has been accepted by air traffic control.

Associations

Association Name	Type	Description
flightPlan	FlightPlan	The currently active flight plan.
proposedUpdateToFlightPlan	FlightPlan	A proposed updated flight plan to be evaluated.
requestedFlightDynamics	FlightDynamics	The flight dynamics the aircraft is requested to observe.
actualFlightDynamics	FlightDynamics	The actual flight dynamics of the aircraft.
aircraft	Aircraft	Information about the aircraft flying the flight.
flightLogEntries	ArrayList	The log entries from the flight.
manifest	Manifest	The flight manifest.

FlightPlan

The route, departure time and ETA of a flight.

Properties

Property Name	Type	Description
id	long	A unique identifier of the flight plan, used as the primary key in the database.
departureTime	java.time.Instant	The time the flight is planned to depart.
eta	java.time.Instant	The time the flight is planned to land.

Associations

Association Name	Type	Description
waypoints	ArrayList	A list of waypoints the flight is planned to follow.

FlightDynamics

Information giving the current attitude, heading and speed of the aircraft.

Properties

Property Name	Type	Description
attitude	double	The attitude of the aircraft in degrees. 0 degrees is horizontal and positive degrees are climbing.
heading	double	The heading relative to magnetic north, with 0 degrees corresponding to north.
speedKnots	double	The speed of the aircraft in knots.

Associations

Association Name	Type	Description
location	Location	The current location of the aircraft.
trajectory	Trajectory	The current trajectory of the aircraft.
targetWaypoint	Waypoint	The waypoint the aircraft is flying toward.

Location

A GPS coordinate with an altitude.

Properties

Property Name	Type	Description
latitude	double	The GPS latitude with north as positive.
longitude	double	The GPS longitude with east as positive.
altitudeFeet	double	The altitude in feet above sea level.

Benchmark

A Location augmented with a time, used to create Trajectories.

Properties

Property Name	Type	Description
time	java.time.Instant	The time the location will be reached.

Associations

Association Name	Type	Description
location	Location	The location that will be reached.

Trajectory

A list of time/location benchmarks describing a flight's trajectory.

Associations

Association Name	Type	Description
benchmarks	LinkedList	A list of benchmarks for the trajectory.

Aircraft

The Aircraft class represents information about a particular aircraft making a flight.

Properties

Property Name	Type	Description
id	long	A globally unique ID for the aircraft, used as the primary key in the database.
readiness	String	A String representing the readiness of the aircraft.

Associations

Association Name	Type	Description
model	AircraftModel	The model of the aircraft (e.g. Boeing 737-700)
flightLog	FlightLog	A log of flights made by the aircraft.

AircraftModel

The AircraftModel class represents a specific model of Aircraft (e.g. Boeing 737-700).

Properties

Property Name	Type	Description
id	long	A globally unique ID of the aircraft model
manufacturer	String	The manufacturer of the aircraft model (e.g. AirBus)
type	String	The type of aircraft (e.g. Dual Engine, Single Aisle)
ceilingFeet	double	The height altitude above sea level the aircraft model can fly at.
stallSpeedKnots	double	The minimum speed the aircraft can fly without stalling.
cruisingSpeedKnots	double	The optimal speed for the aircraft to cruise at.
maxSpeedKnots	double	The maximum speed the aircraft is capable of flying at.
passengerCapacity	int	The maximum number of passengers the aircraft can carry.
fuelCapacityPounds	double	The fuel capacity of the aircraft.
rangeMiles	double	The maximum number of miles the aircraft can fly.

FlightLog

A list of flight log entries.

Properties

Property Name	Type	Description
id	long	A globally unique ID of the flight log, used as the primary key in the database.
startDate	java.time.Instant	The time the flight log was created.

Associations

Association Name	Type	Description
flightLogEntries	LinkedList	A list of entries into the flight log.

FlightLogEntry

An individual entry into the flight log.

Properties

Property Name	Type	Description
id	long	A globally unique ID of the entry, used as the primary key in the database.
flightRecord	String	The message to record.

Waypoint

Describes a location augmented with a name.

Properties

Property Name	Type	Description
id	long	A globally unique ID of the waypoint, used as the primary key in the database.
name	String	The name of the waypoint.

Associations

Association Name	Type	Description
location	Location	The location of the waypoint.

FlightWarning

A class used to describe types of warnings that could occur during a flight.

Properties

Property Name	Type	Description
id	long	A globally unique ID, used as the primary key in the database.
time	java.time.Instant	The time the warning occurred.

Associations

Association Name	Type	Description
severity	Severity	The severity of the warning.
flightsInDanger	ArrayList	A list of the flights in danger with regards to the warning.

MidAirCollisionWarning

A type of FlightWarning of an aircraft colliding with another aircraft in midair.

Methods

Method Name	Method Signature	Description
createCounterMeasureInstructions	void createCounterMeasureInstructions()	Creates instructions to resolve the potential mid-air collision.

Properties

Property Name	Type	Description
timeBeforeCollisionSeconds	double	The number of seconds before collision.
distanceToCollisionMiles	double	The number of miles until the projected collision.
counterMeasureInstructions	String	The instructions provided to pilots to avoid the collision.

ObstructionWarning

A type of FlightWarning of an aircraft colliding with a static hazard.

Methods

Method Name	Method Signature	Description
createCounterMeasureInstructions	void createCounterMeasureInstructions()	Creates instructions to resolve the potential collision.

Properties

Property Name	Type	Description
timeBeforeCollisionSeconds	double	The number of seconds before collision.
distanceToCollisionMiles	double	The number of miles until the projected collision.
counterMeasureInstructions	String	The instructions provided to pilots to avoid the collision.

DeviationWarning

A type of FlightWarning indicating that a flight has made a significant deviation from its flight plan.

Properties

Property Name	Type	Description
message	String	A message explaining the deviation.

Area

Represents an area in the NGATC system.

Properties

Property Name	Type	Description
id	long	A globally unique ID, used as the primary key in the database.
type	String	A String indicating the type of area.
radiusMiles	double	The radius of the area in miles.
name	String	The name of the area.
description	String	A description of the area.

Associations

Association Name	Type	Description
boundaries	ArrayList	An ordered list of the boundaries of the area.

Airspace

A type of area describing a volume of airspace.

Properties

Property Name	Type	Description
upperLimitFeet	double	The upper limit of airspace altitude.
lowerLimitFeet	double	The lower limit of the airspace altitude.

RestrictedAirspace

A type of Airspace that is restricted for civil aviation.

SevereWeather

A type of Airspace experiencing hazardous weather conditions for flight.

Properties

Property Name	Type	Description
expirationTime	java.time.Instant	The time the weather will expire.
warningDescription	String	A description of the severe weather.

WeatherReport

A type of Area used to report the weather conditions for a Location (with resolution of 1 GPS degree).

Properties

Property Name	Type	Description
temperatureCelsius	double	The temperature in Celsius.
windSpeedKnots	double	The wind speed in knots.
windHeading	double	The wind heading in degrees.

Associations

Association Name	Type	Description
location	Location	The location for this WeatherReport, which is valid for one GPS degree of latitude and longitude.

FlightManager

The FlightManager is the main class responsible for predicting Flight trajectories and using these predictions to detect imminent collisions. This class performs its own analysis and is also used a a resource by the AI agents to perform their analysis.

Methods

Method Name	Method Signature	Description
addFlight	void addFlight(Flight flight)	Adds a Flight to the FlightManager and classifies it in the flightMap.
removeFlight	void removeFlight(Flight flight)	Removes a Flight from the flightMap.
updateFlight	void updateFlight(FlightDynamics flightDynamics)	Updates the closest Flight with FlightDynamics from surveillance inputs.
addArea	void addArea(Area area)	Adds a new Area to the areaMap.
removeArea	void removeArea(Area area)	Removes an Area from the areaMap.
updateArea	void updateArea(Area area)	Updates an Area.
addWaypoint	void addWaypoint(Waypoint waypoint)	Adds a Waypoint to the waypointMap.
removeWaypoint	void removeWaypoint(Waypoint waypoint)	Removes a Waypoint from the waypointMap.

Method Name	Method Signature	Description
updateWaypoint	void updateWaypoint(Waypoint waypoint)	Updates a Waypoint.
analyzeFlights	void analyzeFlights()	Analyzes all Flights to update predictions based on weather and surveillance data and to detect imminent collisions.
analyzeFlight	FlightWarning analyzeFlight(Flight flight)	Analyzes an individual flight and returns a FlightWarning if an issue is detected or null if no issue is detected.
analyzeFlightPlanProposal	FlightWarning analyzeFlightPlanProposal(Flight flight)	Analyzes a Flight with a proposed new FlightPlan to determine if this proposal will result in any conflicts. Returns a FlightWarning if an issue is detected or null if no issue is detected.
getLocationHashKey	String getLocationHashKey(Location location)	Returns a hash key to use with the maps in this class. The key if XX_YY where XX is GPS longitude, and YY is GPS latitude, both truncated to an integer.
getNeighborHashKeys	List getNeighborHashKeys(Location location)	Gets the hash keys of the neighboring regions around a location. This is used for analyzing the area around a flight.
getCloseFlights	List getCloseFlights(Flight flight)	Gets all the flights within the current flight's region (as defined by the location hash key) and its neighbors. This is provided primarily as a resource to the AI agents.
getCloseAreas	List getCloseAreas(Flight flight)	Gets all the Areas within the current flight's region (as defined by the location hash key) and its neighbors. This is provided primarily as a resource to the AI agents.
getCloseWaypoints	List getCloseWaypoints(Flight flight)	Gets all the Waypoints within the current flight's region (as defined by the location hash key) and its neighbors. This is provided primarily as a resource to the AI agents.
getAllFlights	List getAllFlights()	Returns a list of all tracked Flights. This is provided primarily as a resources to the AI agents.
main	void main(String[] args)	The main method of the module. Used to start the needed AI agents and start a thread to analyze all flights and report the module status every second.

Associations

Association Name	Type	Description
flightMap	ConcurrentHashMap<String, ConcurrentHashMap<long, Flight>>	A hashmap grouping Flights by their GPS coordinates. This allows for O(1) access to a list of all nearby Flights.
areaMap	ConcurrentHashMap<String, ConcurrentHashMap<long, Area>>	A hashmap grouping Areas by their GPS coordinates. This allows for O(1) access to a list of all nearby Areas.
waypointMap	ConcurrentHashMap<String, ConcurrentHashMap<long, Waypoint>>	A hashmap grouping Waypoints by their GPS coordinates. This allows for O(1) access to a list of all nearby Waypoints.

AiAgent (abstract class)

The AiAgent abstract class is used to model an AI automation agent and provide functionality shared by all agents. Specific agents are implemented to achieve well defined purposes.

Methods

Method Name	Method Signature	Description
start	void start()	Starts the AI agent and continues its execution in a thread.
stop	void stop()	Stops the execution of the AI agent thread.

Properties

Property Name	Type	Description
prompt	String	The prompt given to the AI agent describing the details of its persona.

AiConflictDetectionAgent

The AiConflictDetectionAgent is a specific type of agent. The goal of this agent is to predict conflicts (mid-air collisions and obstruction collisions) on a 3-5 minute time horizon. The agent is empowered to create a FlightWarning and propose a new FlightPlan, but cannot directly change any flight data.

AiRouteOptimizationAgent

The AiRouteOptimizationAgent is a specific type of agent. The goal of this agent is to optimize routes by avoiding bad weather, finding more direct paths, or other means. The agent is empowered to propose new FlightPlans, but cannot directly change any flight data.

AiAbnormalBehaviorDetectionAgent

The AiAbnormalBehaviorDetectionAgent is a specific type of agent. The goal of this agent is to detect any flights which have deviated in a meaningful from the FlightPlan. The agent is empowered to create a FlightWarning, but cannot directly change any flight data.

ApiController

The ApiController class is a singleton class used to send and receive messages through the module's REST API.

Methods

Method Name	Method Signature	Description
receiveNewFlightProposal	void receiveNewFlightProposal(Flight newFlight)	Receives a proposal for a new flight that the Flight Tracker module will analyze and accept or reject.
sendFlightDecision	void sendFlightDecision(Flight newFlight, boolean isAccepted)	Sends the accept/reject decision for a new flight to the Controller module.
receiveFlightPlanUpdate	void receiveFlightPlanUpdate(Flight flight)	Receives an updated flight plan.
sendFlightPlanUpdate	void sendFlightPlanUpdate(Flight flight, boolean isMandatory)	Sends an update to a flight plan to the Controller module.
receiveFlightPlanUpdateDecision	void receiveFlightPlanUpdateDecision(Flight flight, FlightPlan proposedFlightPlan, boolean isAccepted)	Receives an accept/reject decision for a FlightPlan update.
sendFlightWarning	void sendFlightWarning(FlightWarning warning)	Sends a warning to the Controller module.
receiveSurveillanceInput	void receiveSurveillanceInput(FlightDynamics dynamics)	Receives surveillance input and applies the input to the appropriate flight.

Method Name	Method Signature	Description
receiveStaticMap	void receiveStaticMap()	Requests static map objects from the Static Map module.
reportLogEvent	void reportLogEvent(LogEvent event)	Reports an event, such as a FlightWarning or failure to the System Monitor module.
reportStatus	void reportStatus()	Report's the module's status to the System Monitor module every second.
requestWeatherReport	void requestWeatherReport()	Runs in a thread once per second to request a weather report from the Weather module. The information is then incorporated into the FlightManager.

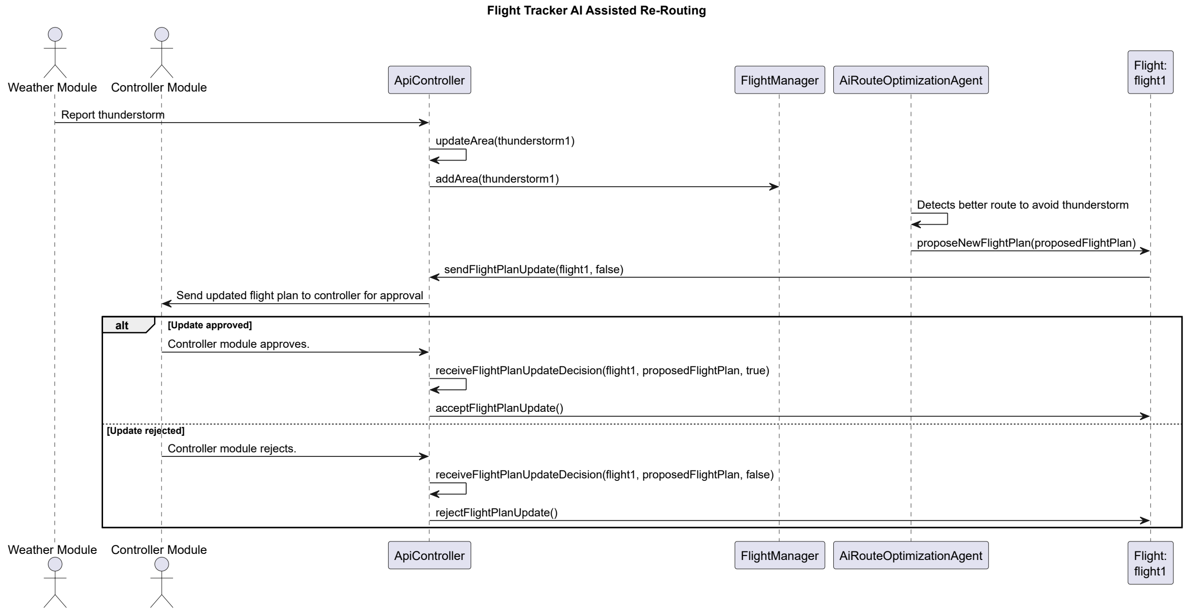
Service API

The Flight Tracker module implements the follow REST API interface:

- New Flight Proposal: Receives a proposal for a new flight that will be either accepted or rejected.
  - Path: POST/flight
  - Inputs:
    - Flight: A JSON encoded Flight object representing the new flight.
    - Access Token: Requires an internal module role
  - Output: HTTP status. The accept/reject decision will be sent asynchronously.
- Flight Plan Update: Receives an updated flight plan.
  - Path: PUT/flightPlan
  - Inputs:
    - Flight: A JSON encoded Flight object with the new FlightPlan.
    - Access Token: Requires an internal module role
  - Output: HTTP status.
- Surveillance Input: Receives a surveillance input reading.
  - Path: PUT/surveillance
  - Inputs:
    - Dynamics: A JSON encoded FlightDynamics object representing surveillance input.
    - Access Token: Requires an internal module or trusted data source role
  - Output: HTTP status.

Sequence Diagram

The following sequence diagram will illustrate how the Flight Tracker module as an AI agent to avoid severe weather.


Flight Tracker AI Assisted Re-Routing
Weather Module
Controller Module
ApiController
FlightManager
AiRouteOptimizationAgent
Flight: flight1
Report thunderstorm
updateArea(thunderstorm1)
addArea(thunderstorm1)
Detects better route to avoid thunderstorm
proposeNewFlightPlan(proposedFlightPlan)
sendFlightPlanUpdate(flight1, false)
Send updated flight plan to controller for approval
alt
[Update approved]
Controller module approves.
receiveFlightPlanUpdateDecision(flight1, proposedFlightPlan, true)
acceptFlightPlanUpdate()
[Update rejected]
Controller module rejects.
receiveFlightPlanUpdateDecision(flight1, proposedFlightPlan, false)
rejectFlightPlanUpdate()

This diagram depicts how an AI agent is used for this type of route optimization, with the proposal being accepted or rejected by a human operator.

Entitlement Service Integration

This module interacts through a REST API with other modules and with data sources external to the NGATC system. For other modules, an internal module role is used to control access. For data sources such as surveillance inputs, the trusted data source role is used, to give this data source the minimum permission needed to send its data.

Object Persistence

Object persistence for the Flight Tracker module is achieved through the use of the Hibernate framework, with database primary keys noted in the class dictionary.

AI Automation Strategy

There are three agents that are used in the Flight Tracker module, each with their own responsibilities. These agents are described in greater detail below. In all cases, AI agents do not have the ability to directly modify flight data without human acceptance.

Conflict Detection Agent

The Conflict Detection Agent is used to detect collisions between flights or a flight and a static hazard. The agent has read access to flight, area and waypoint information in the Flight Tracker module. The agent also has the ability to create a FlightWarning and propose a FlightPlan.

Route Optimization Agent

The Route Optimization Agent is used to optimize flight plans. The primary goal is to avoid hazardous weather, the second goal is to reduce fuel consumption and the final goal is to reduce flight time. The agent has read access to flight, area and waypoint information in the Flight Tracker module. The agent also has the ability to propose a FlightPlan.

Flight Deviation Agent

The Flight Deviation Agent is used to detect notable deviations of flights from their expected dynamics. The agent has read access to flight, area and waypoint information in the Flight Tracker module. The agent also has the ability to create a FlightWarning.

Testing Strategy

The module level testing for the Flight Tracker module is as follows:

- Conflict detection test:
  - Simulated flights are created
  - Simulated surveillance inputs are created to show an imminent mid-air collision
  - It is verified that the module properly responds to the imminent collision
  - Simulated surveillance inputs are created to show a flight about to collide with an obstacle
  - It is verified that the module properly responds to the imminent collision
- AI Automation Test:
  - Simulated flights are created
  - Simulated inputs are sent to show a flight moving into a thunderstorm
  - It is verified that a flight plan is proposed to avoid the thunderstorm
  - Simulated flights are created that will collide in approximately 5 minutes
  - It is verified that a flight plan is proposed to avoid this future collision
  - Simulated inputs are sent to show a flight deviating from its flight plan
  - Is is verified that a warning is sent to reflect this deviation

Exception Handling

Exceptions for the Flight Tracker module are handled primarily through the DatabaseException, SurveillanceException and ApiException classes. These exception classes are unchecked exceptions and are logged for future auditing.

Risks

The Flight Tracker module is a safety critical module that is required to work with a very high degree of reliability. Using the terminology of functional safety, the "Safety Function" of this module is to detect an imminent collision of an aircraft and report it, along with suitable resolution guidance within 1 second of detection. A few of the failures that could cause this safety function to fail are:

- **Random Fault**: A physical issue (e.g. loss of power) causes an instance of this service to go offline. *Mitigation:* Redundant instances of the services are commissioned, which can automatically take over when a failure occurs.
- **Random Fault**: A surveillance input is either not received or corrupted. *Mitigation*: Redundant and diverse surveillance inputs are used.
- **Systematic Fault**: A software defect in the Flight Tracker module causes a collision not to be detected. *Mitigation*: Software testing and static analysis are performed to lessen the risk of a critical software defect.
- **Systematic Fault**: A defect in the database or database integration framework causes a collision not to be detected. *Mitigation*: These tools are treated as "online tools" in IEC 61508-3 and would therefore need to be proven reliable. After investigation, and likely collaboration with the software vendors, a "proven in use" argument could likely be made for this software. Additionally, the specific versions of these tools would need to be managed and controlled.
- **Systematic Fault**: A defect in the integration between NGATC modules causes a collision not to be detected or properly communicated. *Mitigation*: System level testing lessens the risk of this class of failure. Additionally, versions of these modules are managed and qualified together before any updates are made.
- **Systematic Fault**: A fault in the operating system used to run the Flight Tracker module causes a collision not to be detected. *Mitigation*: The Flight Tracker module is deployed in Kubernetes on diverse operating systems.
- **Systematic Fault**: The Java Garbage Collector causes a delay in program execution, which results in a collision not being detected within the safety reaction time. *Mitigation:* This is less of a concern on this system where the safety reaction time is measure in seconds compared to traditional safety systems where the safety reaction time is measured in milliseconds.

Between these mitigations and due diligence in the software development process, this module will be developed to a very high degree of reliability.

Weather Module

The Weather module is responsible for ingesting weather data and sending weather reports to other modules as requested.

Module Functional Requirements Summary

The following system level functional requirements are implemented by the Weather module:

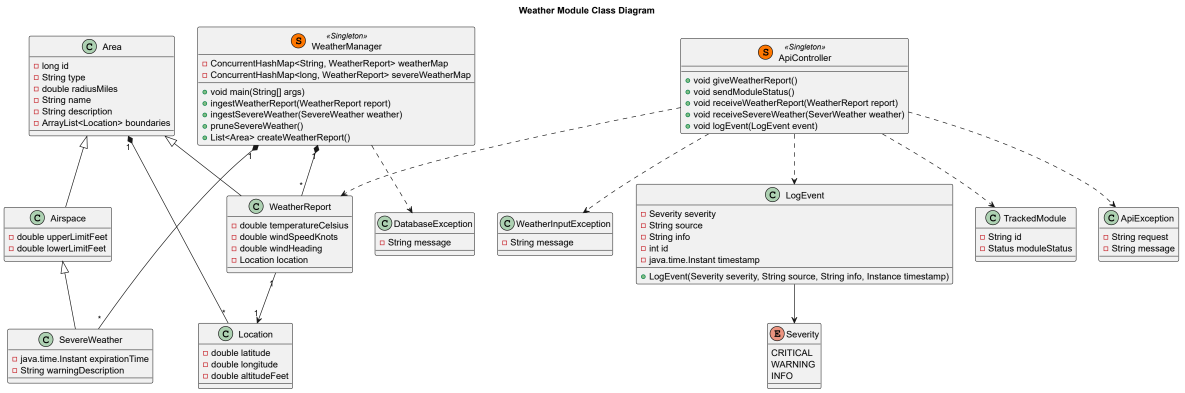
- Real-Time Weather Ingestion: The Weather module shall ingest real-time weather data from external sources.
- Weather Impacts on Trajectories: The Weather module shall report on weather conditions as requested by other modules.

Module Non-Functional Requirements Summary

- Redundance Services: The Weather module shall be deployed with redundant instances, such that in the event of a failure, another instance will automatically take over.
- Horizontal Scalability: The Weather module shall be implemented such that additional instances can be provisioned to handle additional loading.
- New Data Sources: The Weather module shall expose a REST API to enable easy integration of additional data sources.
- Module Testability: The Weather module shall be implemented in a way that enables independent testing of the module using simulated data.

Weather Module Classes

The classes that make up the Weather module are shown in the class diagram below and described in more detail in the class dictionary.


Weather Module Class Diagram
C Area
long id
String type
double radiusMiles
String name
String description
ArrayList<Location> boundaries
S «Singleton» WeatherManager
ConcurrentHashMap<String, WeatherReport> weatherMap
ConcurrentHashMap<long, WeatherReport> severeWeatherMap
void main(String[] args)
ingestWeatherReport(WeatherReport report)
ingestSevereWeather(SevereWeather weather)
pruneSevereWeather()
List<Area> createWeatherReport()
S «Singleton» ApiController
void giveWeatherReport()
void sendModuleStatus()
void receiveWeatherReport(WeatherReport report)
void receiveSevereWeather(SeverWeather weather)
void logEvent(LogEvent event)
C Airspace
double upperLimitFeet
double lowerLimitFeet
C WeatherReport
double temperatureCelsius
double windSpeedKnots
double windHeading
Location location
C DatabaseException
String message
C WeatherInputException
String message
C LogEvent
Severity severity
String source
String info
int id
java.time.Instant timestamp
LogEvent(Severity severity, String source, String info, Instance timestamp)
C TrackedModule
String id
Status moduleStatus
C ApiException
String request
String message
C SevereWeather
java.time.Instant expirationTime
String warningDescription
C Location
double latitude
double longitude
double altitudeFeet
E Severity
CRITICAL
WARNING
INFO
1
*
1
*
1
*
1
1
1
*

Class Dictionary

Location

A GPS coordinate with an altitude.

Properties

Property Name	Type	Description
latitude	double	The GPS latitude with north as positive.
longitude	double	The GPS longitude with east as positive.
altitudeFeet	double	The altitude in feet above sea level.

Area

Represents an area in the NGATC system.

Properties

Property Name	Type	Description
id	long	A globally unique ID, used as the primary key in the database.
type	String	A String indicating the type of area.
radiusMiles	double	The radius of the area in miles.
name	String	The name of the area.
description	String	A description of the area.

Associations

Association Name	Type	Description
boundaries	ArrayList	An ordered list of the boundaries of the area.

Airspace

A type of area describing a volume of airspace.

Properties

Property Name	Type	Description
upperLimitFeet	double	The upper limit of airspace altitude.
lowerLimitFeet	double	The lower limit of the airspace altitude.

SevereWeather

A type of Airspace experiencing hazardous weather conditions for flight.

Properties

Property Name	Type	Description
expirationTime	java.time.Instant	The time the weather will expire.
warningDescription	String	A description of the severe weather.

WeatherReport

A type of Area used to report the weather conditions for a Location (with resolution of 1 GPS degree).

Properties

Property Name	Type	Description
temperatureCelsius	double	The temperature in Celsius.
windSpeedKnots	double	The wind speed in knots.
windHeading	double	The wind heading in degrees.

Associations

Association Name	Type	Description
location	Location	The location for this WeatherReport, which is valid for one GPS degree of latitude and longitude.

WeatherManager

The WeatherManager class is responsible for managing incoming weather data to be used to create reports as requested.

Methods

Method Name	Method Signature	Description
main	void main(String[] args)	The main method for the module. Starts a thread to report the system status and prune severe weather every second.
ingestWeatherReport	void ingestWeatherReport(WeatherReport report)	Incorporates an incoming weather report into the weatherMap.
ingestSevereWeather	void ingestSevereWeather(SevereWeather weather)	Incorporates an incoming severe weather event into the severeWeatherMap.
pruneSevereWeather	void pruneSevereWeather()	Iterates through the active SevereWeather events and removes any that are expired.
createWeatherReport	List createWeatherReport()	Creates a weather report to be sent, including WeatherReports and SevereWeather.

ApiController

The ApiController class is a singleton class used to send and receive messages through the module's REST API.

Methods

Method Name	Method Signature	Description
giveWeatherReport	void giveWeatherReport()	Reports the weather to another module using a list of JSON encoded WeatherReport and SevereWeather objects.
sendModuleStatus	void sendModuleStatus()	Reports the status of the module to the System Monitor module.
receiveWeatherReport	void receiveWeatherReport(WeatherReport report)	Receives a weather report from an external source and incorporates it into the WeatherManager.
receiveSevereWeather	void receiveSevereWeather(SeverWeather weather)	Receives a severe weather report and incorporates it into the WeatherManager.
logEvent	void logEvent(LogEvent event)	Logs a notable event with the System Monitor module.

Service API

The Flight Tracker module implements the follow REST API interface:

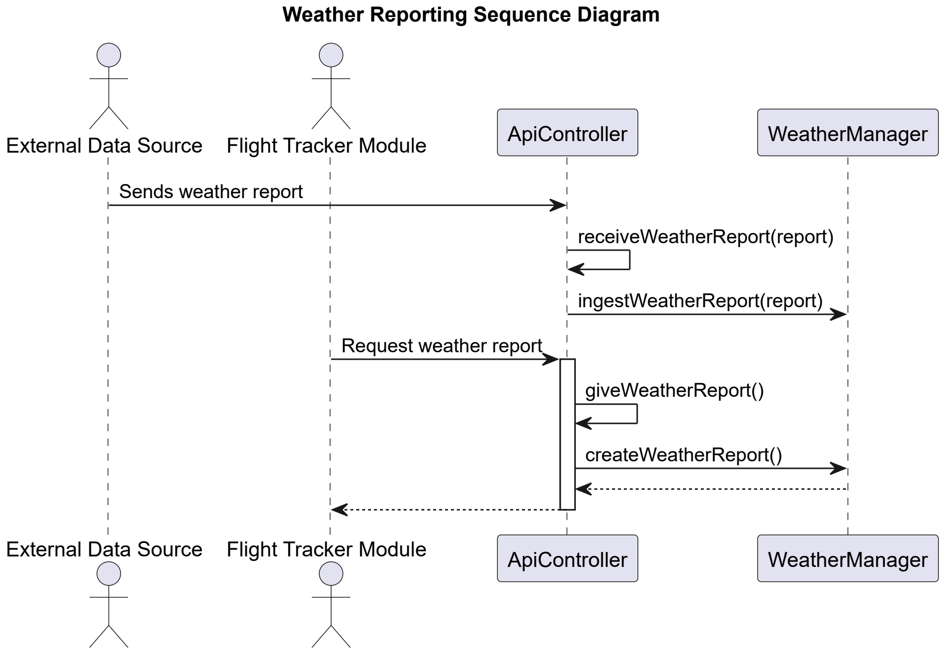
- Give Weather Report: Receives a request for a weather report.
    - Path: GET/weather
    - Inputs:
        - Access Token: Requires an internal module role
    - Output: A JSON encoded list of WeatherReport and SevereWeather objects.
- Receive Weather Report: Receives a weather report from an external source.
    - Path: PUT/report
    - Inputs:
        - Report: A JSON encoded WeatherReport object.
        - Access Token: Requires a Trusted Data Source role

- Output: An HTTP status.

- Receive Severe Weather: Receives a severe weather report from an external source.
  - Path: PUT/severe
  - Inputs:
    - Report: A JSON encoded SevereWeather object.
    - Access Token: Requires a Trusted Data Source role
  - Output: An HTTP status.

Sequence Diagram

The following sequence diagram illustrates the process of receiving a weather report and sending a report to an external module.



Entitlement Service Integration

The entitlement service is used to ensure that access for all API calls are protected. For receiving data from external sources, the trusted data source role is used. For other calls, the internal module role is used.

Object Persistence

Object persistence is handled through the Hibernate framework with primary keys for the database noted in the class dictionary.

Testing Strategy

The module testing strategy for the Weather module is as follows:

- Weather Report Test:
  - Ingest WeatherReports
  - Ingest SevereWeather events
  - Let some, but not all of the SevereWeather events expire
  - Receive some WeatherReports to override existing ones
  - Receive a request for a weather report and verify it is correct.

Exception Handling

Exceptions for the Weather module are handled primarily through the DatabaseException, WeatherInputException and ApiException classes. These exception classes are unchecked exceptions and are logged for future auditing.

Risks

The two risks for the Weather module are that a weather report is incorrect, or that a malicious actor could do damage to the NGATC system through this module. The first risk is mitigated by allowing for diverse weather data sources by providing a simple and well defined API. The second risk is mitigated by using the Entitlement Service to control access to the module's API.

Static Map Module

The Static Map module is responsible for reporting to other modules the locations of static objects such as airports, terrain, restricted airspace and buildings.

Module Functional Requirement Summary

The Static Map module implements the following system level functional requirements:

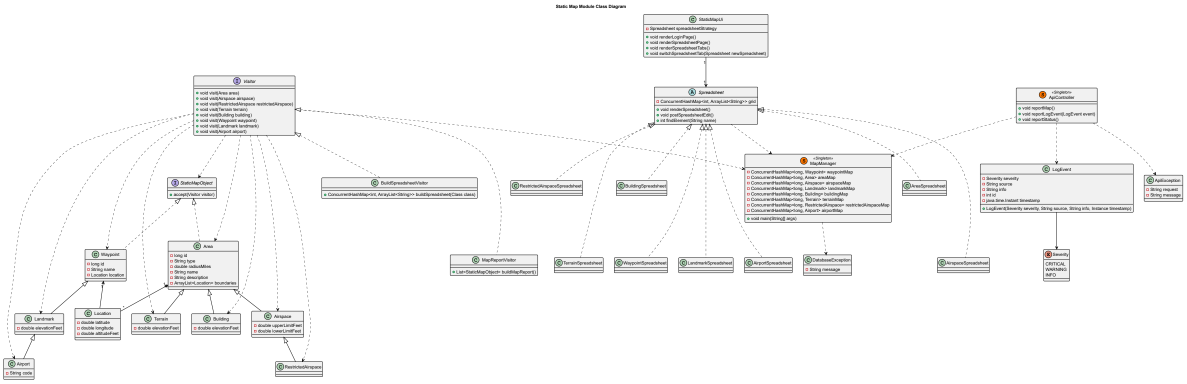
- Loss of Separation Detection: The Static Map module shall provide information on static hazards on a request from another module.
- Restricted Airspace Alerts: The Static Map module shall include restricted airspace in its reports to other modules.
- Event Logging: The Static Map module shall log relevant system events to the System Monitor.
- Module Health Monitoring: The Static Map module shall report its status to the System Monitor module every second.
- Role Based Access: The Static Map module shall only allow UI access to administrator users and API access to internal module users.

Module Non-Functional Requirements

- Redundance Services: The Static Map module shall be deployed with redundant instances, such that in the event of a failure, another instance will automatically take over.
- Horizontal Scalability: The Static Map module shall be implemented such that additional instances can be provisioned to handle additional loading.
- New Data Sources: The Static Map module shall expose a REST API to enable easy integration of additional data sources.
- Module Testability: The Static Map module shall be implemented in a way that enables independent testing of the module using simulated data.

Static Map Module Classes

The classes that make up the Static Map module are shown below with greater detail given in the class dictionary.


Static Map Module Class Diagram
StaticMapUi
Spreadsheet spreadsheetStrategy
void renderLoginPage()
void renderSpreadsheetPage()
void renderSpreadsheetTabs()
void switchSpreadsheetTab(Spreadsheet newSpreadsheet)
1
1
Spreadsheet
ConcurrentHashMap<int, ArrayList<String>> grid
void renderSpreadsheet()
void postSpreadsheetEdit()
int findElement(String name)
«Singleton»
ApiController
void reportMap()
void reportLogEvent(LogEvent event)
void reportStatus()
Visitor
void visit(Area area)
void visit(Airspace airspace)
void visit(RestrictedAirspace restrictedAirspace)
void visit(Terrain terrain)
void visit(Building building)
void visit(Waypoint waypoint)
void visit(Landmark landmark)
void visit(Airport airport)
StaticMapObject
accept(Visitor visitor)
BuildSpreadsheetVisitor
ConcurrentHashMap<int, ArrayList<String>> buildSpreadsheet(Class class)
RestrictedAirspaceSpreadsheet
BuildingSpreadsheet
«Singleton»
MapManager
ConcurrentHashMap<long, Waypoint> waypointMap
ConcurrentHashMap<long, Area> areaMap
ConcurrentHashMap<long, Airspace> airspaceMap
ConcurrentHashMap<long, Landmark> landmarkMap
ConcurrentHashMap<long, Building> buildingMap
ConcurrentHashMap<long, Terrain> terrainMap
ConcurrentHashMap<long, RestrictedAirspace> restrictedAirspaceMap
ConcurrentHashMap<long, Airport> airportMap
void main(String[] args)
AreaSpreadsheet
LogEvent
Severity severity
String source
String info
int id
java.time.Instant timestamp
LogEvent(Severity severity, String source, String info, Instance timestamp)
ApiException
String request
String message
Waypoint
long id
String name
Location location
Area
long id
String type
double radiusMiles
String name
String description
ArrayList<Location> boundaries
1
*
MapReportVisitor
List<StaticMapObject> buildMapReport()
TerrainSpreadsheet
WaypointSpreadsheet
LandmarkSpreadsheet
AirportSpreadsheet
DatabaseException
String message
AirspaceSpreadsheet
Severity
CRITICAL
WARNING
INFO
Landmark
double elevationFeet
Location
double latitude
double longitude
double altitudeFeet
Terrain
double elevationFeet
Building
double elevationFeet
Airspace
double upperLimitFeet
double lowerLimitFeet
Airport
String code
RestrictedAirspace

Class Dictionary

Location

A GPS coordinate with an altitude.

Properties

Property Name	Type	Description
latitude	double	The GPS latitude with north as positive.
longitude	double	The GPS longitude with east as positive.
altitudeFeet	double	The altitude in feet above sea level.

Waypoint

Describes a location augmented with a name.

Properties

Property Name	Type	Description
id	long	A globally unique ID of the waypoint, used as the primary key in the database.
name	String	The name of the waypoint.

Associations

Association Name	Type	Description
location	Location	The location of the waypoint.

Area

Represents an area in the NGATC system.

Properties

Property Name	Type	Description
id	long	A globally unique ID, used as the primary key in the database.
type	String	A String indicating the type of area.
radiusMiles	double	The radius of the area in miles.
name	String	The name of the area.
description	String	A description of the area.

Associations

Association Name	Type	Description
boundaries	ArrayList	An ordered list of the boundaries of the area.

Airspace

A type of area describing a volume of airspace.

Properties

Property Name	Type	Description
upperLimitFeet	double	The upper limit of airspace altitude.
lowerLimitFeet	double	The lower limit of the airspace altitude.

RestrictedAirspace

A type of Airspace that is restricted for civil aviation.

MapManager

The MapManager contains references to hash maps for each type of object that can be created in the Static Map module, as well as getters for each of these maps (not shown for readability). The hash key for each element is its ID.

Methods

Method Name	Method Signature	Description
main	void main(String[] args)	Starts a thread to report the system status to the System Monitor module every second.

Associations

Association Name	Type	Description
waypointMap	ConcurrentHashMap<long, Waypoint>	A map containing the Waypoints in the module.
areaMap	ConcurrentHashMap<long, Area>	A map containing the Areas in the module.
airspaceMap	ConcurrentHashMap<long, Airspace>	A map containing the Airspaces in the module.
landmarkMap	ConcurrentHashMap<long, Landmark>	A map containing the Landmarks in the module.
buildingMap	ConcurrentHashMap<long, Building>	A map containing the Buildings in the module.
terrainMap	ConcurrentHashMap<long, Terrain>	A map containing the Terrains in the module.
restrictedAirspaceMap	ConcurrentHashMap<long, RestrictedAirspace>	A map containing the RestrictedAirspaces in the module.
airportMap	ConcurrentHashMap<long, Airport>	A map containing the Airports in the module.

StaticMapUi

The StaticMapUi is the base class for the UI administrators will interact with to input static objects. It uses the strategy design pattern to maintain a reference for the correct spreadsheet for the objects the user is interacting with.

Methods

Method Name	Method Signature	Description
renderLoginPage	void renderLoginPage()	Renders a panel for users to login.
renderSpreadsheetPage	void renderSpreadsheetPage()	Renders the current spreadsheet page, or the login page if the spreadsheetStrategy is null.
renderSpreadsheetTabs	void renderSpreadsheetTabs()	Renders the tabs for each spreadsheet page.
switchSpreadsheetTab	void switchSpreadsheetTab(Spreadsheet newSpreadsheet)	Switches the spreadsheet page when another tab is selected.

Associations

Associations

Association Name	Type	Description
spreadsheetStrategy	Spreadsheet	A reference to the type of spreadsheet to display using the strategy design pattern.

Spreadsheet

The Spreadsheet abstract class is used to render and interact with spreadsheets for the objects users can create in the Static Map module. A concrete class is created for each of the objects that can be created (not shown in the class dictionary for brevity).

Methods

Method Name	Method Signature	Description
renderSpreadsheet	void renderSpreadsheet()	Renders the spreadsheet to the user.
postSpreadsheetEdit	void postSpreadsheetEdit()	Updates the objects in the MapManager with the information in the spreadsheet.
findElement	int findElement(String name)	Finds the element by name and returns the row of the element in the spreadsheet.

Associations

Association Name	Type	Description
grid	ConcurrentHashMap<int, ArrayList> grid	A representation of the cells of the spreadsheet and their contents.

StaticMapObject

The StaticMapObject interface is used to enable the visitor design pattern on the objects that users can create in the Static Map module. It is implemented by the classes that users can create.

Methods

Method Name	Method Signature	Description
accept	void accept()	Performs some visitor specific action on the object.

Visitor

The visitor interface is used to enabled the visitor design pattern for a variety of interactions with the objects created in the Static Map module. The interface contains a visit() method for each type of object created by users in this module.

BuildSpreadsheetVisitor

Used to build the contents of a spreadsheet for a specific class.

Methods

Method Name	Method Signature	Description
buildSpreadsheet	ConcurrentHashMap<int, ArrayList> buildSpreadsheet(Class class)	Uses the MapManager to build the contents of the spreadsheet for the specified class.

MapReportVisitor

Used to build a report of objects to other modules.

Methods

Method Name	Method Signature	Description
buildMapReport	List buildMapReport()	Uses the MapManager to build a report of all created objects in this module.

ApiController

The ApiController class is a singleton class used to send and receive messages through the module's REST API.

Methods

Method Name	Method Signature	Description
reportMap	void reportMap()	Builds a map report to send to another module.
reportLogEvent	void reportLogEvent(LogEvent event)	Reports an event, such as a FlightWarning or failure to the System Monitor module.
reportStatus	void reportStatus()	Report's the module's status to the System Monitor module every second.

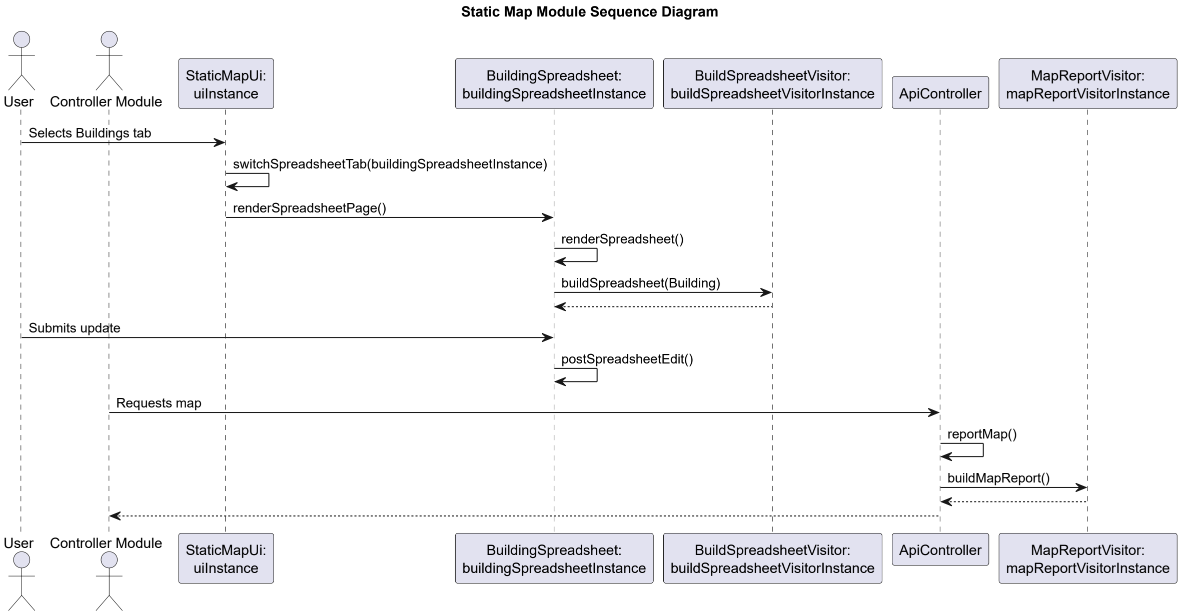
Service API

The Flight Tracker module implements the follow REST API interface:

- Report Map: Build a map report of all the StaticMap objects in this module.
    - Path: GET/map
    - Inputs:
        - Access Token: Requires an internal module role
    - Output: A JSON encoded list of all the objects in this module.

Sequence Diagram

The following sequence diagram illustrates the process editing and returning a report of StaticMapObjects.


Static Map Module Sequence Diagram
User
Controller Module
StaticMapUi: uiInstance
BuildingSpreadsheet: buildingSpreadsheetInstance
BuildSpreadsheetVisitor: buildSpreadsheetVisitorInstance
ApiController
MapReportVisitor: mapReportVisitorInstance
Selects Buildings tab
switchSpreadsheetTab(buildingSpreadsheetInstance)
renderSpreadsheetPage()
renderSpreadsheet()
buildSpreadsheet(Building)
Submits update
postSpreadsheetEdit()
Requests map
reportMap()
buildMapReport()

This diagram illustrates how the Static Map module communicates through the UI and its REST interface to maintain its objects and respond to API map requests.

Entitlement Service Integration

The Static Map module requires users of the UI to have the administrator role and login through the UI and users of the API to have the internal module role. The Static Map module does not support user creation, which must be done through the Controller module UI.

Object Persistence

The Static Map module uses the Hibernate framework for object persistence with primary keys noted in the class dictionary.

Testing Strategy

The module testing strategy for the Static Map module is as follows. UI interactions will be automated through Functionize.

- Static Map Test:
  - A map report is requested with no objects to verify this works properly
  - Objects are added to the Static Map module
  - A map report is requested and verified to be correct
  - Some objects are deleted from the Static Map module
  - A map report is requested and verified to be correct
  - Some objects are edited in the Static Map module
  - A map report is requested and verified to be correct

Exception Handling

Exceptions for the Static Map module are handled primarily through the DatabaseException and ApiException classes. These exception classes are unchecked exceptions and are logged for future auditing.

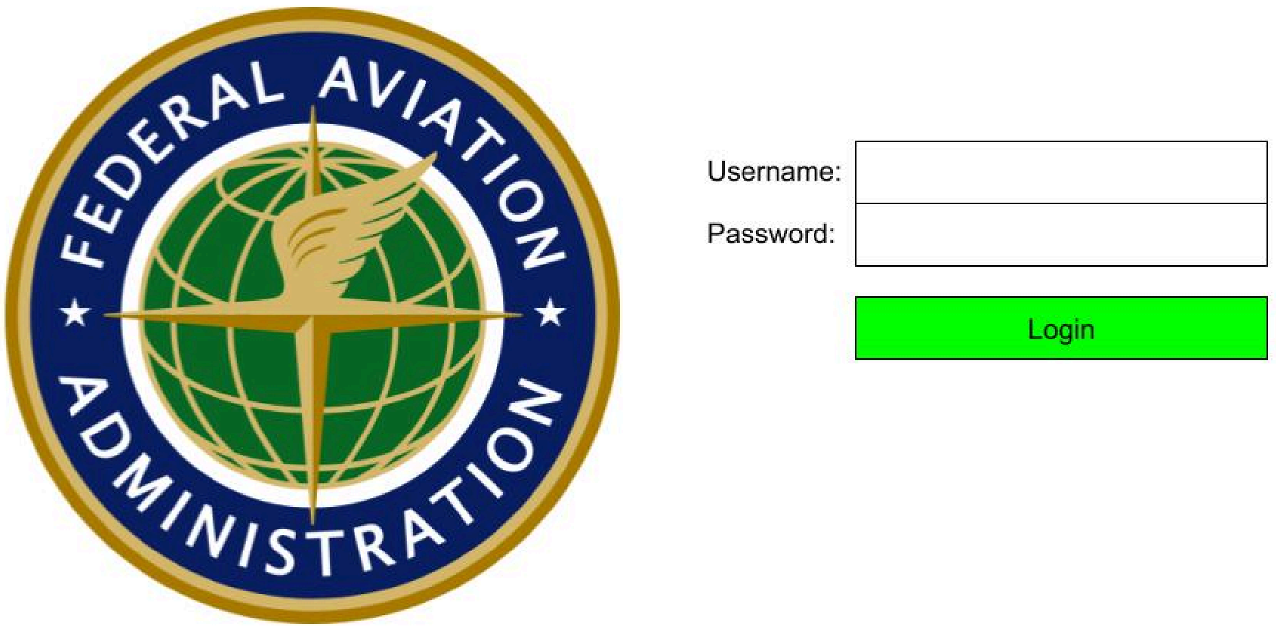
Risks

The primary risk for this module is the security risk for a malicious actor making changes in this module, or potentially using this module to gain greater access to the rest of the NGATC system. For this reason, the Entitlement Service is used to control access to the module through the UI and the API.

UI Wireframes

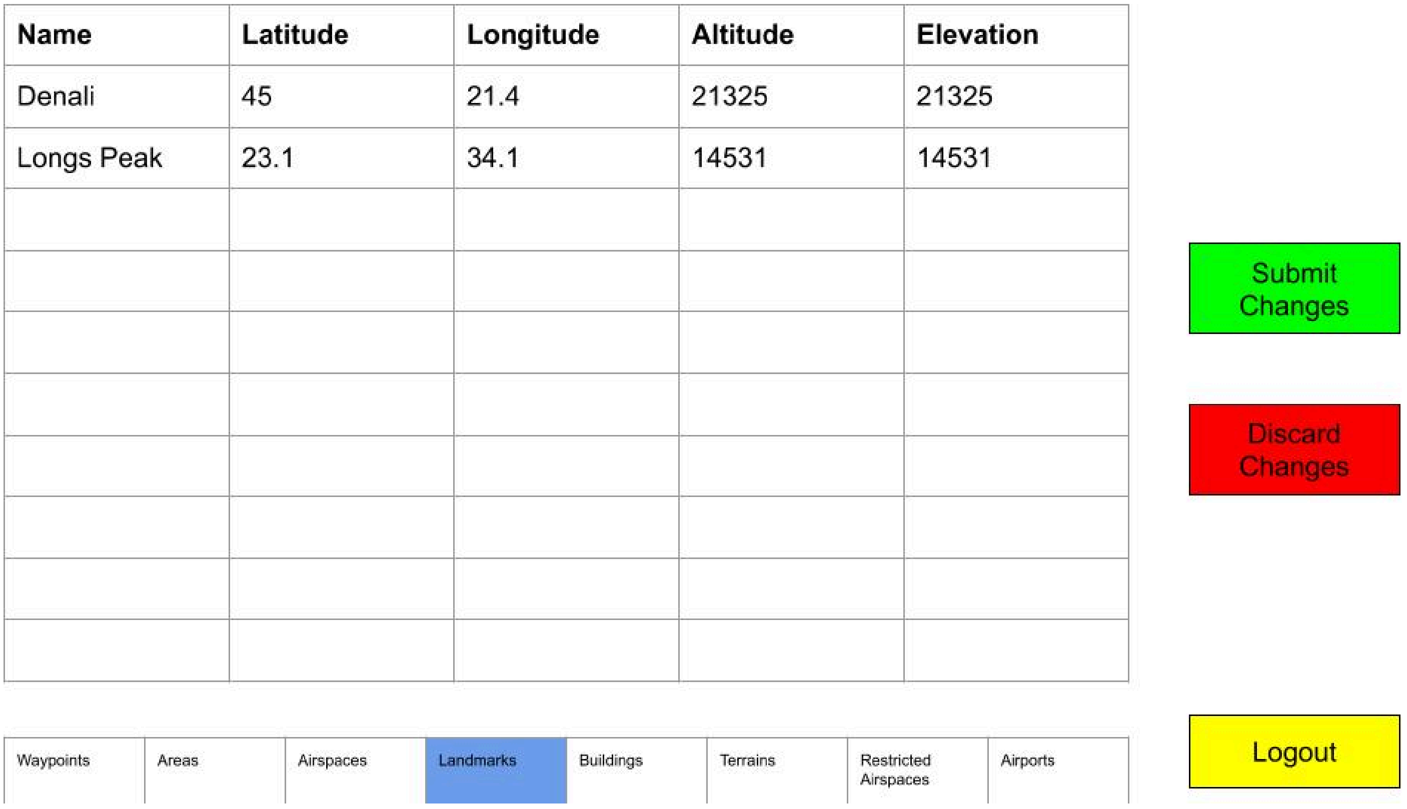
Login Page

When a user is not logged in, the following page will appear prompting the user to login.



Main Page

During normal operation, the Static Map UI will appear as follows. This will allow administrators to submit changes to objects. CTRL+F find functionality, as well as scrolling is also available to users.



Name	Latitude	Longitude	Altitude	Elevation
Denali	45	21.4	21325	21325
Longs Peak	23.1	34.1	14531	14531

Simulator Module

The Simulator module is used for testing and training purposes to simulate external inputs into the NGATC. The module allows administrators to enter mock inputs into the system using a command line interface and to view the data that would be sent to pilots. The general principal behind the design of this module is that inputs should be able to be sent through the Simulator module if and only if they would come from an external source in "real life".

Module Functional Requirements Summary

The Simulator module shall implement the following system level requirements:

- Simulation Mode: Users with an administrator role shall have access to send the following information to the NGATC through the Simulator module CLI. Additionally, these users shall be able to view information sent to pilots through the Simulator module CLI.
  - New flight proposals
  - Flight plan updates
  - Surveillance Inputs
  - Weather Data

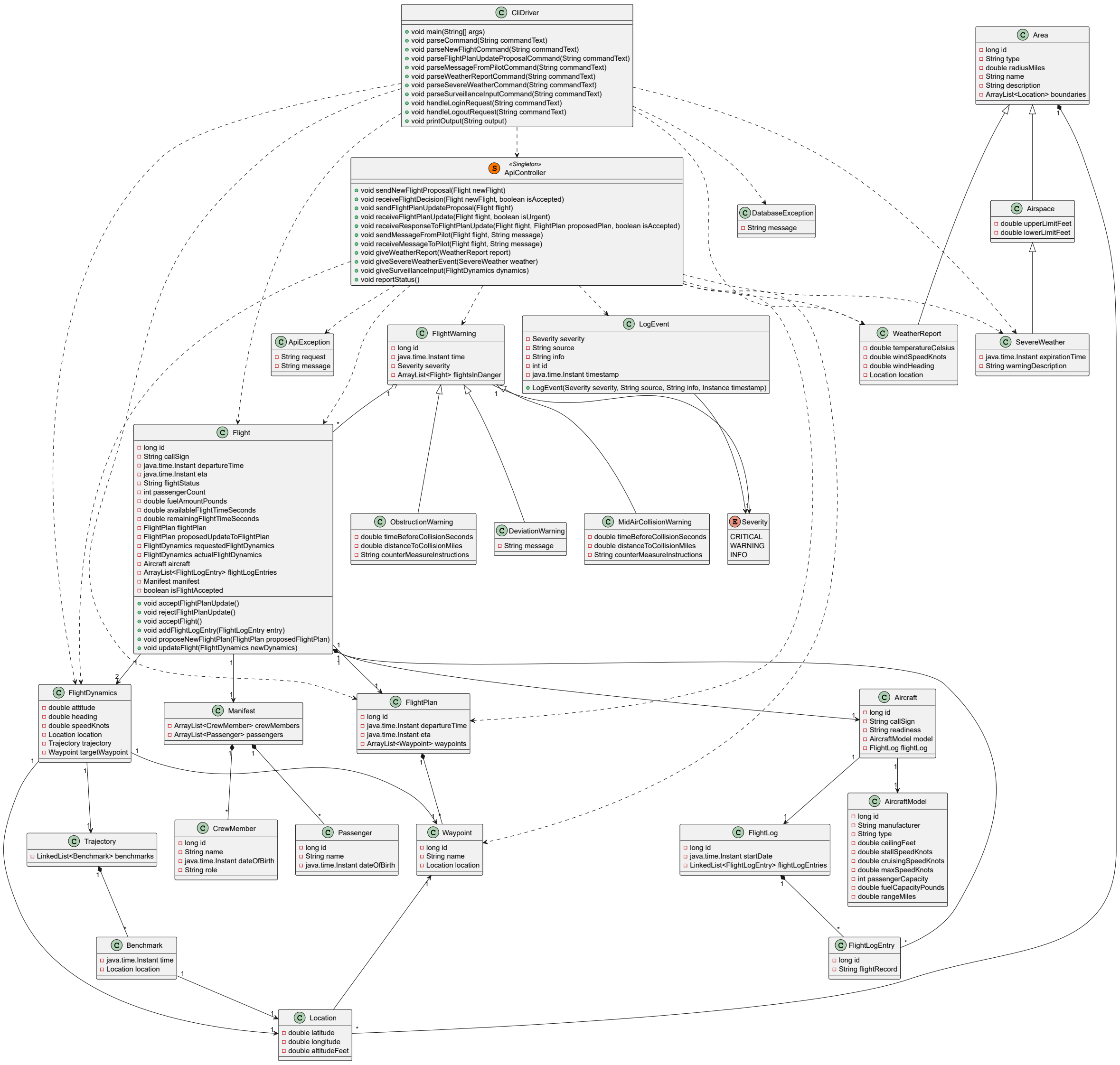
Module Non-Functional Requirements Summary

- Role-Based Authentication: The Simulator module shall require the administrator role to access its CLI.
- Simulation Testing: The Simulator module shall be configured with a CLI such that it can be used for system level testing.

Simulator Module Classes

The following classes make up the Simulator module. More details about these classes are presented in the class dictionary.

Simulator Module Class Diagram


CliDriver
void main(String[] args)
void parseCommand(String commandText)
void parseNewFlightCommand(String commandText)
void parseFlightPlanUpdateProposalCommand(String commandText)
void parseMessageFromPilotCommand(String commandText)
void parseWeatherReportCommand(String commandText)
void parseSevereWeatherCommand(String commandText)
void parseSurveillanceInputCommand(String commandText)
void handleLoginRequest(String commandText)
void handleLogoutRequest(String commandText)
void printOutput(String output)
«Singleton»
ApiController
void sendNewFlightProposal(Flight newFlight)
void receiveFlightDecision(Flight newFlight, boolean isAccepted)
void sendFlightPlanUpdateProposal(Flight flight)
void receiveFlightPlanUpdate(Flight flight, boolean isUrgent)
void receiveResponseToFlightPlanUpdate(Flight flight, FlightPlan proposedPlan, boolean isAccepted)
void sendMessageFromPilot(Flight flight, String message)
void receiveMessageToPilot(Flight flight, String message)
void giveWeatherReport(WeatherReport report)
void giveSevereWeatherEvent(SevereWeather weather)
void giveSurveillanceInput(FlightDynamics dynamics)
void reportStatus()
DatabaseException
String message
Area
long id
String type
double radiusMiles
String name
String description
ArrayList<Location> boundaries
Airspace
double upperLimitFeet
double lowerLimitFeet
ApiException
String request
String message
FlightWarning
long id
java.time.Instant time
Severity severity
ArrayList<Flight> flightsInDanger
LogEvent
Severity severity
String source
String info
int id
java.time.Instant timestamp
LogEvent(Severity severity, String source, String info, Instance timestamp)
WeatherReport
double temperatureCelsius
double windSpeedKnots
double windHeading
Location location
SevereWeather
java.time.Instant expirationTime
String warningDescription
Flight
long id
String callSign
java.time.Instant departureTime
java.time.Instant eta
String flightStatus
int passengerCount
double fuelAmountPounds
double availableFlightTimeSeconds
double remainingFlightTimeSeconds
FlightPlan flightPlan
FlightPlan proposedUpdateToFlightPlan
FlightDynamics requestedFlightDynamics
FlightDynamics actualFlightDynamics
Aircraft aircraft
ArrayList<FlightLogEntry> flightLogEntries
Manifest manifest
boolean isFlightAccepted
void acceptFlightPlanUpdate()
void rejectFlightPlanUpdate()
void acceptFlight()
void addFlightLogEntry(FlightLogEntry entry)
void proposeNewFlightPlan(FlightPlan proposedFlightPlan)
void updateFlight(FlightDynamics newDynamics)
ObstructionWarning
double timeBeforeCollisionSeconds
double distanceToCollisionMiles
String counterMeasureInstructions
DeviationWarning
String message
MidAirCollisionWarning
double timeBeforeCollisionSeconds
double distanceToCollisionMiles
String counterMeasureInstructions
Severity
CRITICAL
WARNING
INFO
FlightDynamics
double attitude
double heading
double speedKnots
Location location
Trajectory trajectory
Waypoint targetWaypoint
Manifest
ArrayList<CrewMember> crewMembers
ArrayList<Passenger> passengers
FlightPlan
long id
java.time.Instant departureTime
java.time.Instant eta
ArrayList<Waypoint> waypoints
Aircraft
long id
String callSign
String readiness
AircraftModel model
FlightLog flightLog
AircraftModel
long id
String manufacturer
String type
double ceilingFeet
double stallSpeedKnots
double cruisingSpeedKnots
double maxSpeedKnots
int passengerCapacity
double fuelCapacityPounds
double rangeMiles
Trajectory
LinkedList<Benchmark> benchmarks
CrewMember
long id
String name
java.time.Instant dateOfBirth
String role
Passenger
long id
String name
java.time.Instant dateOfBirth
Waypoint
long id
String name
Location location
FlightLog
long id
java.time.Instant startDate
LinkedList<FlightLogEntry> flightLogEntries
Benchmark
java.time.Instant time
Location location
FlightLogEntry
long id
String flightRecord
Location
double latitude
double longitude
double altitudeFeet

Class Dictionary

Note: *Business domain classes used in the NGATC are omitted from this class dictionary for the sake of brevity. Please consult the implementing modules for more information about these classes.*

CliDriver

The CliDriver class is responsible for interacting with the Simulator module command line interface. It handles incoming commands, handles login requests and prints information received from the REST API.

Methods

Method Name	Method Signature	Description
main	void main(String[] args)	The main method for the module. This method listens for new input to the CLI and starts a thread that runs every second to report the module's status to the System Monitor module.
parseCommand	void parseCommand(String commandText)	The top level command parsing method. This method is responsible for receiving a command and delegating its handling to a more specific method.
parseNewFlightCommand	void parseNewFlightCommand(String commandText)	Parses a command to propose a new flight and passes the information received to the ApiController for input into the NGATC system.
parseFlightPlanUpdateProposalCommand	void parseFlightPlanUpdateProposalCommand(String commandText)	Parses a command to propose a flight plan update and passes the information received to the ApiController for input into the NGATC system.
parseMessageFromPilotCommand	void parseMessageToPilotCommand(String commandText)	Parses a command to receive a mock message from a pilot and passes the information received to the ApiController for input into the NGATC system.
parseWeatherReportCommand	void parseWeatherReportCommand(String commandText)	Parses a command to receive a weather report and passes the information received to the ApiController for input into the NGATC system.
parseSevereWeatherCommand	void parseSevereWeatherCommand(String commandText)	Parses a command to receive a severe weather event and passes the information received to the ApiController for input into the NGATC system.

Method Name	Method Signature	Description
parseSurveillanceInputCommand	void parseSurveillanceInputCommand(String commandText)	Parses a command to receive a surveillance input and passes the information received to the ApiController for input into the NGATC system.
handleLoginRequest	void handleLoginRequest(String commandText)	Parses a command to login to the Simulator module and passes the information to the Entitlement Service.
handleLogoutRequest	void handleLogoutRequest(String commandText)	Parses a command to logout of the Simulator module and passes the information to the Entitlement Service.
printOutput	void printOutput(String output)	Outputs the text to the CLI.

ApiController

The ApiController class is responsible for interacting with the other modules of the NGATC through a REST API in the same manner as external data sources.

Methods

Method Name	Method Signature	Description
sendNewFlightProposal	void sendNewFlightProposal(Flight newFlight)	Sends a new flight proposal to the Controller module in the same manner as a pilot.
receiveFlightDecision	void receiveFlightDecision(Flight newFlight, boolean isAccepted)	Receives an accept/reject decision for a new flight proposal from the Controller module in the same manner as a pilot and forwards this information to the CLI.
sendFlightPlanUpdateProposal	void sendFlightPlanUpdateProposal(Flight flight)	Sends a flight plan update proposal to the Controller module in the same manner as a pilot.
receiveFlightPlanUpdate	void receiveFlightPlanUpdate(Flight flight, boolean isUrgent)	Receives an update flight plan from the Controller module in the same manner as a pilot and forwards this information to the CLI.
receiveResponseToFlightPlanUpdate	void receiveResponseToFlightPlanUpdate(Flight flight, FlightPlan proposedPlan, boolean isAccepted)	Receives an accept/reject decision for a flight plan update proposal from the Controller module in the same manner as a pilot and forwards this information to the CLI.
sendMessageFromPilot	void sendMessageFromPilot(Flight flight, String message)	Sends a pilot message to the Controller module in the same manner as a pilot.

Method Name	Method Signature	Description
receiveMessageToPilot	void receiveMessageToPilot(Flight flight, String message)	Receives a messages meant for a pilot and forwards this information to the CLI.
giveWeatherReport	void giveWeatherReport(WeatherReport report)	Sends a weather report to the Weather module in the same manner as an external data source.
giveSevereWeatherEvent	void giveSevereWeatherEvent(SevereWeather weather)	Sends a severe weather event to the Weather module in the same manner as an external data source.
giveSurveillanceInput	void giveSurveillanceInput(FlightDynamics dynamics)	Sends a surveillance input to the Flight Tracker module in the same manner as an external data source.
reportStatus	void reportStatus()	Reports the module's status to the System Monitor module.

Service API

The Simulator module implements the following API services:

- New Flight Proposal Response
  - Path: GET/newFlightResponse
  - Inputs:
    - Flight: The Flight in JSON encoding
    - Is Accepted: A boolean indicating whether the new flight has been accepted
    - Access Token: Requires an internal module role
  - Output: HTTP Status
- Update Flight Plan:
  - Path: PUT/flightPlanUpdate
  - Inputs:
    - Flight: The Flight in JSON Encoding
    - Is Urgent: Whether updating the Flight Plan is urgent (e.g. emergency conflict resolution)
    - Access Token: Requires an internal module role
  - Output: HTTP status
- Flight Plan Update Response:
  - Path: PUT/flightPlanUpdateResponse
  - Inputs:
    - Flight: The Flight in JSON Encoding
    - Flight Plan: The proposed flight plan in JSON encoding
    - Is Accepted: Whether the flight plan update was accepted
    - Access Token: Requires an internal module role
  - Output: HTTP status
- Receive Pilot Message:
  - Path: GET/pilotMessage
  - Inputs:
    - Flight: The Flight in JSON encoding
    - Message: The message to be sent
    - Access Token: Requires an internal module role
  - Output: HTTP status

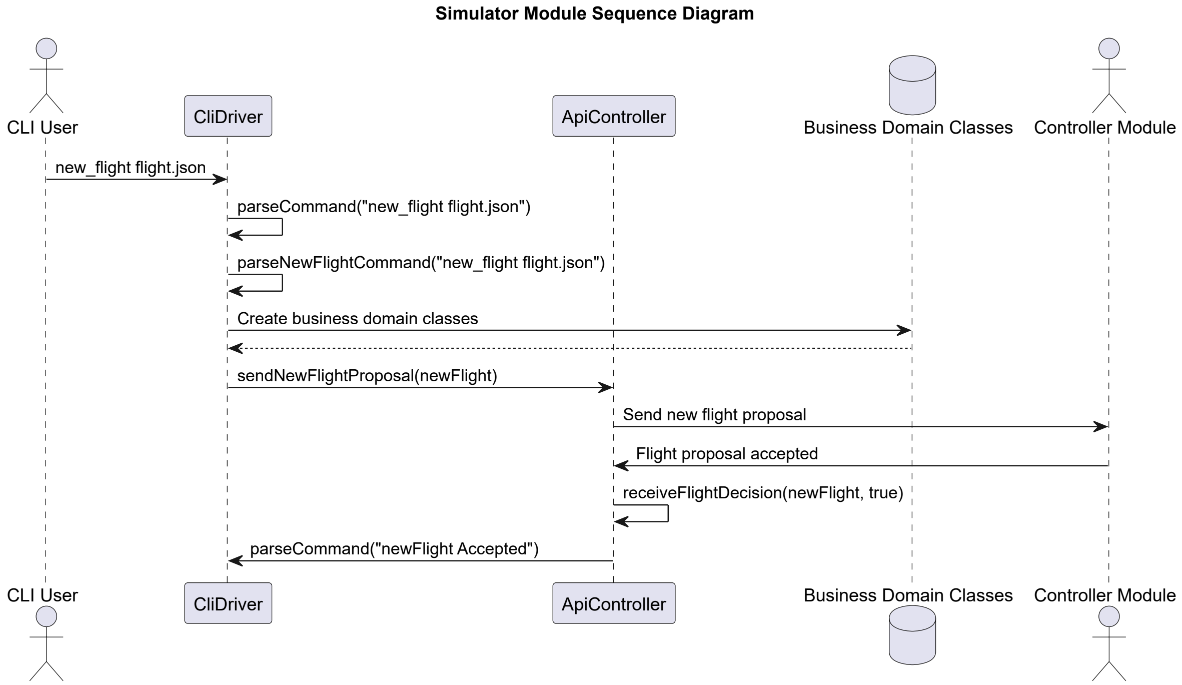
CLI Documentation

The Simulation module CLI shall support the following commands:

- New Flight:
  `new_flight <path to flight JSON file>`
- Flight Plan Update Proposal:
  `propose_flight_plan <path to flight JSON file>`
- Send Pilot Message:
  `send_pilot_message <path to flight JSON file> "<Message Text>"`
- Send Weather Report:
  `send_weather_report <path to weather report JSON file>`
- Send Severe Weather Event:
  `send_severe_weather_event <path to severe weather JSON file>`
- Send Surveillance Input:
  `send_surveillance_input <path to flight dynamics JSON file>`
- Login User:
  `login <username> <password>`
- Logout User:
  `logout`

Sequence Diagram

The following sequence diagram illustrates how the Simulator module interacts with the CLI and the rest of the NGATC to provision a flight.


Simulator Module Sequence Diagram
CLI User
CliDriver
ApiController
Business Domain Classes
Controller Module
new_flight flight.json
parseCommand("new_flight flight.json")
parseNewFlightCommand("new_flight flight.json")
Create business domain classes
sendNewFlightProposal(newFlight)
Send new flight proposal
Flight proposal accepted
receiveFlightDecision(newFlight, true)
parseCommand("newFlight Accepted")

This diagram illustrates how the CLI stands in for pilots or other external data sources and communicates information to the rest of the NGATC in the same manner as these data sources.

Entitlement Service Integration

The Simulator module requires authentication to interact with the CLI and with its API. Interacting with the CLI requires the administrator role and interacting with the API requires the internal module role.

Object Persistence

Object persistence is achieved through the Hibernate framework, with database primary keys matches those of the implementation modules.

Testing Strategy

The module level testing strategy for the Simulator module is as follows:

- CLI input test:
  - Send a variety of CLI inputs and ensure the module sends the correct REST API requests as a response
- CLI output test:
  - Send a variety of REST API requests to the module and ensure the module prints the correct response to the CLI

Exception Handling

Exceptions for the Simulator module are handled primarily through the DatabaseException and ApiException classes. These exception classes are unchecked exceptions and are logged for future auditing.

Risks

The primary risk of the simulator module is that a user or the system would mistakenly use this module instead of the real system. For this reason, authenticated access is tightly controlled to administrator users. Additionally, a risk with all "non-core" modules is that the module could be used as a gateway into the system for a malicious user. To guard against this, authentication is required to access the CLI and the module's REST API.