

Simulation Software Design Document v1.0

Requirements

Develop a simulation model of a lunar mining operation for extracting Helium-3. The simulation will manage trucks mining Helium-3, transporting it to unload stations, and unloading the material. The system must accommodate variable numbers of mining trucks and unload stations and provide performance and efficiency metrics.

1. Components Specification

- Define a fleet of mining trucks capable of mining, transporting and unloading Helium-3.
- Design unload stations to receive mined Helium-3 from trucks.

2. Truck Operations

- Each truck mines for a random duration between 1 to 5 hours at a mining site.
- Travel time between mining sites and unload stations is fixed at 30 minutes.
- Trucks start with empty loads at the beginning of the simulation.

3. Unload Station Operations

- Each unload station can handle one truck at a time.
- Unloading Helium-3 takes 5 minutes per truck.
- Trucks must queue at stations if all are occupied, selecting the queue with the shortest wait time.

4. Simulation Configuration

- The simulation must allow for configurable numbers of mining trucks and unload stations.
- The total simulation duration is 72 hours of continuous operation.

5. Performance and Efficiency Metrics

- Calculate and report metrics for each mining truck's performance (e.g., mining, travel time).
- Calculate and report metrics for the efficiency of each unload station (e.g., average wait time, utilization rate).

6. Simulation Execution

- The simulation must run faster than real-time to enable timely analysis.
- Ensure the system can handle a range of scenarios, from minimal to maximal numbers of trucks and stations.

Overview

This document describes the design, functionalities and implementation of the simulation system for mining operations, managing mining trucks and unload stations over a specified simulation time. The simulation tracks the status and statistics of each truck and station, processing events and collecting data throughout the simulation.

Requirements Implementation and Explanation

1. Components

- Fleet of Mining Trucks:
 - Class: MiningTruck (mining_truck.hpp)
 - Functionality: Represents trucks involved in mining, transporting, and unloading Helium-3. Each truck has state machine and states, such as Mining, TravelingToUnload, WaitingInQueue, Unloading, and TravelingToMine. The truck's state transitions are managed by methods like mine(), travel_to_unload(), queue_to_unload(), unload(), and travel_to_mine().
- Unload Stations:
 - Class: MiningUnloadStation (mining_unload_station.hpp)
 - Functionality: Represents unload stations where trucks deposit Helium-3. Each station can handle one truck at a time and manages a queue for trucks waiting to unload. Methods: add_to_queue() to enqueue trucks and process_queue() to unload trucks sequentially.

2. Truck Operations

- Mining Duration:
 - Class: RandomDurationGenerator (random_duration_generator.hpp)
 - Functionality: Generates a random mining duration between 1 to 5 hours using std::uniform_int_distribution.
- Travel Time:
 - Implementation: The MiningTruck class defines a fixed travel time of 30 minutes (TRAVEL_TIME) between mining sites and unload stations.
- Starting Condition:
 - Method: Simulation::run() in simulation.cpp
 - Functionality: At the start of the simulation, trucks are initialized in the Mining state with empty loads. The simulation advances by scheduling the events, such as mining completion or truck arrival at an unload station.

3. Unload Station Operations

- Queue Management:
 - Class: MiningUnloadStation
 - Method: add_to_queue(), process_queue()
 - Functionality: Manages a FIFO queue of trucks. Trucks waiting to unload are queued if the station is busy, to the shortest wait time queue, by Simulation::find_shortest_wait_time_station. When a station becomes available, the next truck in the queue begins unloading.
- Unloading Duration:
 - Implementation: Each truck's unload time is 5 minutes (UNLOAD_TIME), provided by the get_unload_duration() method in MiningTruck.

4. Simulation Configuration

- Configurable Trucks and Stations:

- Class: Simulation (simulation.hpp)
- Functionality: The constructor accepts parameters for the number of trucks (max_mining_trucks) and unload stations (max_unload_stations). This allows the simulation to model different scales of operation.
- Simulation Duration:
 - Method: Simulation::run()
 - Functionality: The total simulation time is set to 72 hours (max_simulation_time). The simulation loop advances the clock and processes events until the simulated time reaches this limit.

5. Performance and Efficiency Metrics

- Truck Metrics:
 - Class: MiningTruckStats (mining_truck_stats.hpp)
 - Metrics: Tracks total operation cycles, total wait time in unload queues, total travel time, and total mining time. These metrics provide insights into each truck's efficiency and utilization.
- Unload Station Metrics:
 - Class: UnloadStationStats (unload_station_stats.hpp)
 - Metrics: Records total unloads, total queue used time, and calculates the average queue time and operation-to-no-operation ratio. This data helps assess the effectiveness of unload stations.

6. Simulation Execution

- Faster than Real-Time Execution:
 - Class: Infra::SH3M_SimStepClock (infra.hpp)
 - Functionality: The chrono based simulation clock can advance in increments larger than real-time seconds, simulating long durations faster. The advance() method increments the clock, and now() provides the current simulation time.
- Scenario Handling:
 - Method: Simulation::run()
 - Functionality: The simulation framework can handle different numbers of trucks and stations, simulating various operational scenarios. The system dynamically adapts to these configurations.

Additional Infrastructure

- Infra and Logger:
 - Class: Infra (infra.hpp)
 - Functionality: A singleton class providing global access to infrastructure components like logging. The logger (logger.hpp) records simulation events and states to file or outputs to stdout, and provides two types of timestamps (real time us and simulated clock) which is useful in debugging and performance analysis.
- Assertions:
 - Files: sh3m_assert.hpp, assert_with_log.hpp
 - Functionality: Provide macros for assertions that log failures and abort the simulation, and trace information for debug log messages instrumented with timestamp, filename, line#.

Clock and Simulation Time Progression

In the simulation, time management is handled by the SimStepClock class (infra.hpp), which simulates time advancement faster than real-time.

1. Time Advancement: The SimStepClock::advance() method increments the current simulation time (current_time) by a specified duration. This allows the simulation to proceed in discrete time steps, accelerating the passage of time.
2. Event-Driven Progression: The simulation follows an event-driven model. Events are scheduled and processed based on their occurrence time, with the simulation clock advancing to the next event's time. This method efficiently skips periods of inactivity.
3. Faster than Real-Time Execution: The simulation clock can be stepped forward in large increments, allowing the simulation to run significantly faster than real-time.

Software Design

This is a single-threaded design architecture. Multi-threaded version can be provided in the v2.0. The simulation's software design utilizes object-oriented principles such as ownership, inheritance, composition, and event-driven control flow:

1. Class Dependencies and Ownership:
 - Simulation Class (simulation.hpp): The main controller, responsible for initializing and managing MiningTruck and MiningUnloadStation instances. It controls the simulation, events, simulation clock and gathers statistics.
2. Inheritance:
 - Statistics Classes: SimulationStats, MiningTruckStats, and UnloadStationStats provide a common interface for collecting and reporting statistics, inherited by the main components.
3. Composition:
 - MiningTruck and MiningUnloadStation: Composed within the Simulation class, handles specific operations like mining, driving and unloading. The Infra class manages system-wide services like logging.
4. Control Flow:
 - The simulation operates on an event-driven model. The Simulation::run() method processes events scheduled by the EventSequencer, coordinating activities and state transitions. The SimStepClock synchronizes time progression, maintaining order across components.

Diagram - Simulation Class (ownership, inheritance, composition)

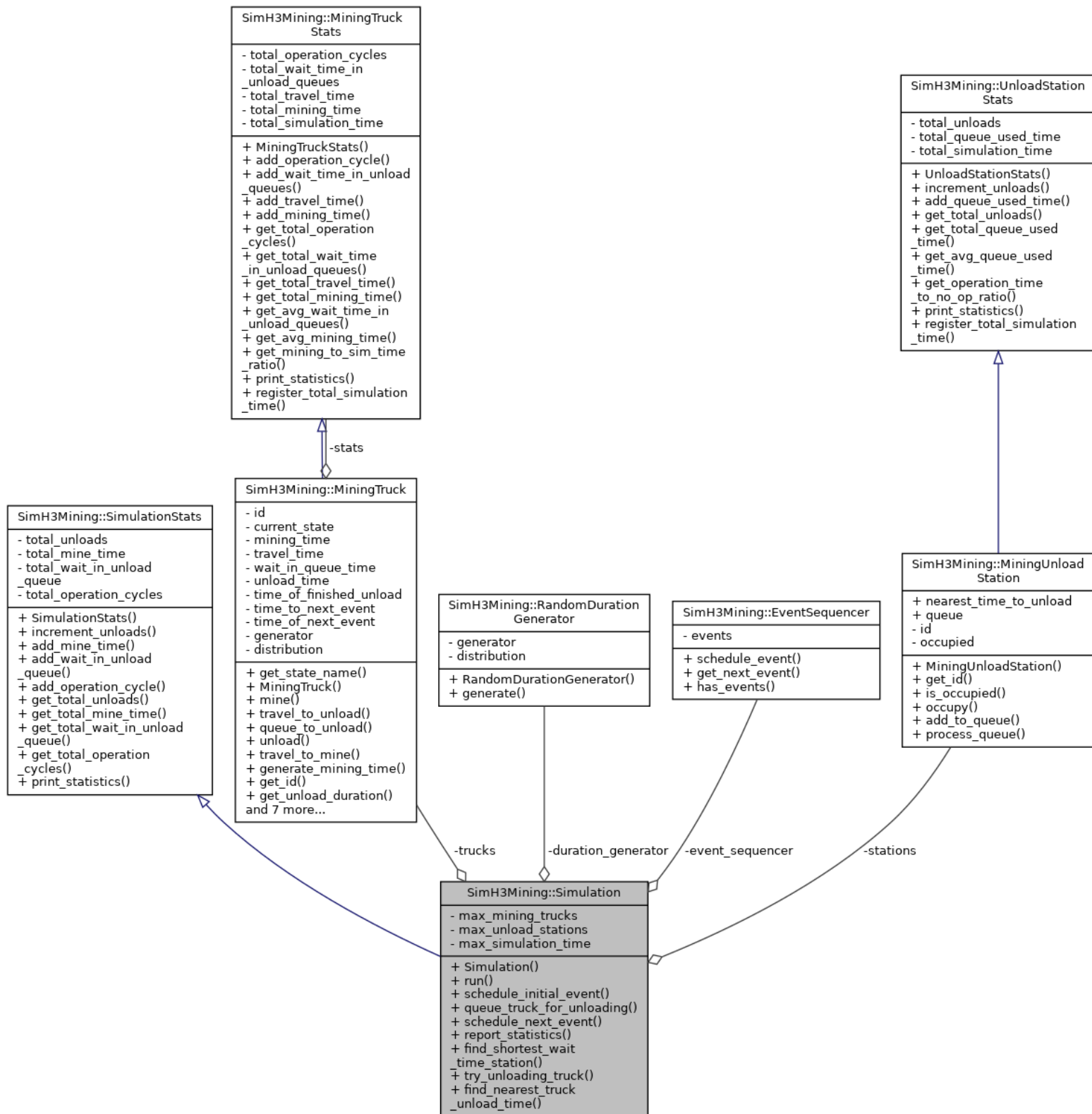


Diagram - Simulation Class

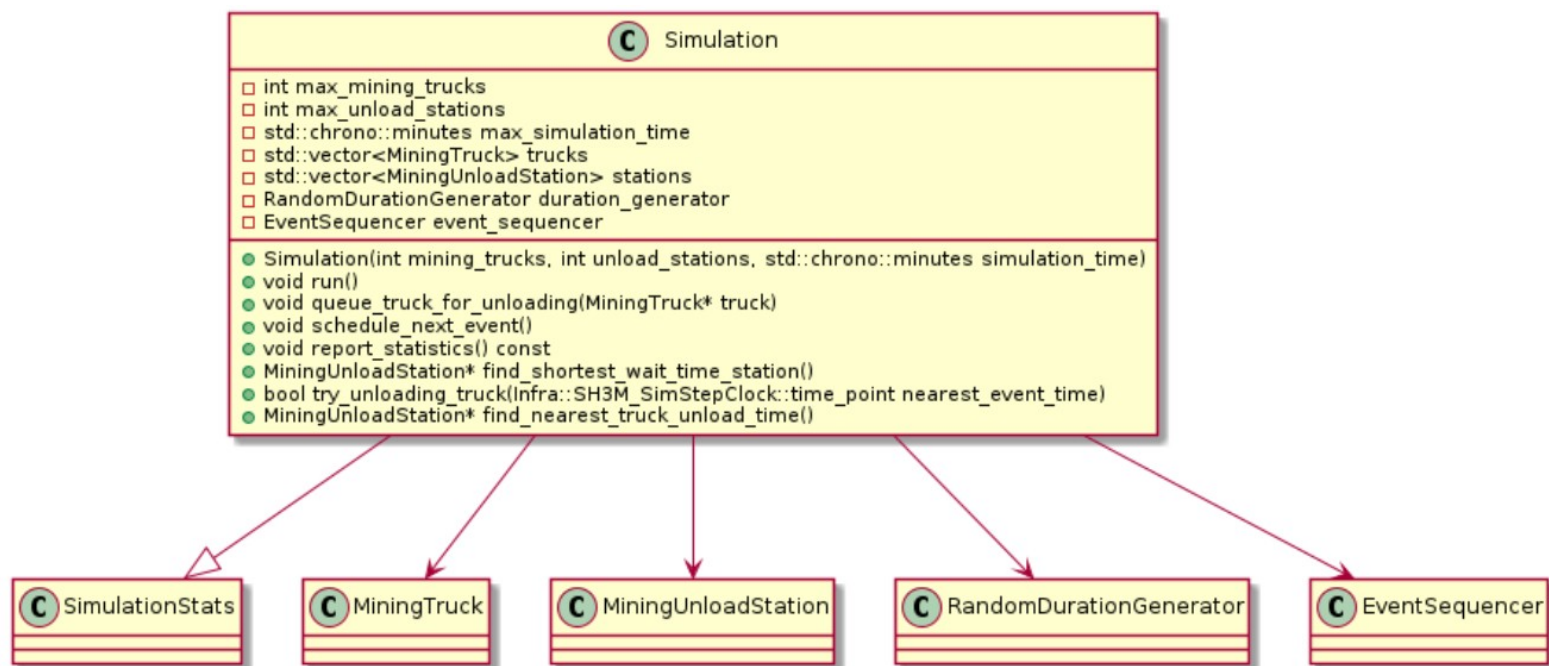
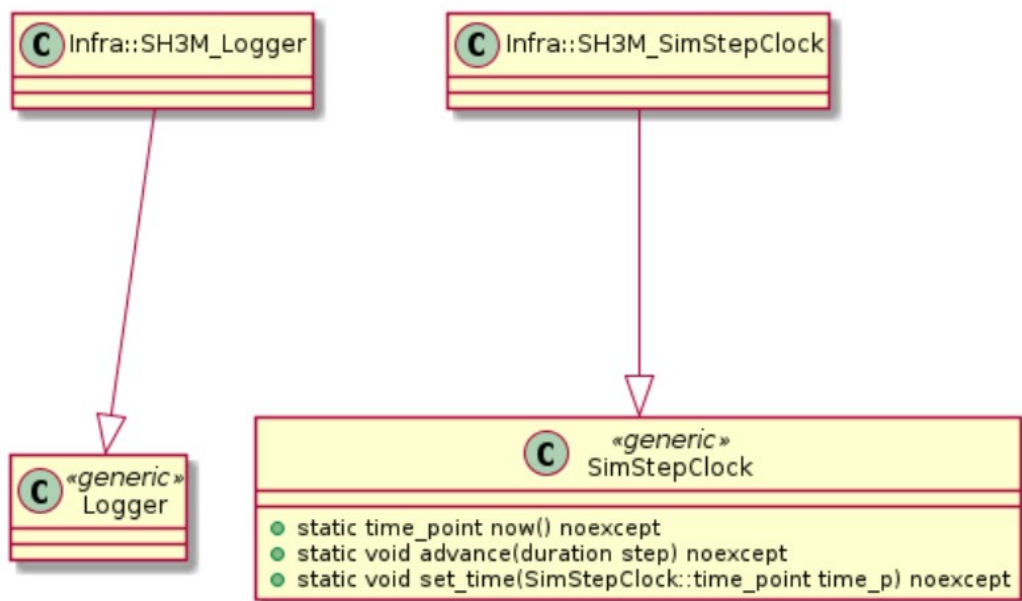


Diagram - Infrastructure and specializations (SH3M_Logger, SimStepClock)



Proposed Testing Strategies

Testing strategy should include unit testing, integration testing, system testing, and performance testing. The logging functionality, which provides real-time clock timestamps and simulated stepped clock timestamps, can be used in validating the simulation's behavior and timing accuracy.

- Unit Testing

Verify the correctness of individual components and functions.

- RandomDurationGenerator:
 - Test the distribution of generated durations to ensure they fall within the expected range (1 to 5 hours).
- MiningTruck:
 - Test state transitions (e.g., from Mining to TravelingToUnload) and validate the timing of each state.
- MiningUnloadStation:
 - Test the queue management functionality, ensuring that trucks are correctly added, processed, and removed.
- EventSequencer:
 - Validate the scheduling and execution order of events and correct clock progression.

Tools: Use a unit testing framework such as Google Test (gtest) and log analysis.

- Integration Testing

Objective: Verify the interactions between integrated components.

- Simulation Initialization:
 - Test different configurations (varying numbers of trucks and stations) to ensure the simulation initializes correctly.
- Event Handling:
 - Ensure that events are scheduled and processed in the correct sequence.
 - Validate that the Simulation class correctly manages the progression of time and state transitions across components.

Tools: Integration tests can also use the gtest framework, with combined component functionality.

- System Testing

Objective: Validate the system's behavior as a whole, including edge cases and overall performance.

- End-to-End Simulation:
 - Run the simulation for the full 72-hour duration with various configurations, ensuring correct overall behavior.
- Edge Cases:
 - Test scenarios such as zero trucks, maximum capacity of trucks and stations, single station and many trucks.
 - Additionally test different failure modes (e.g., truck breakdowns, station overloads) – fault injections.

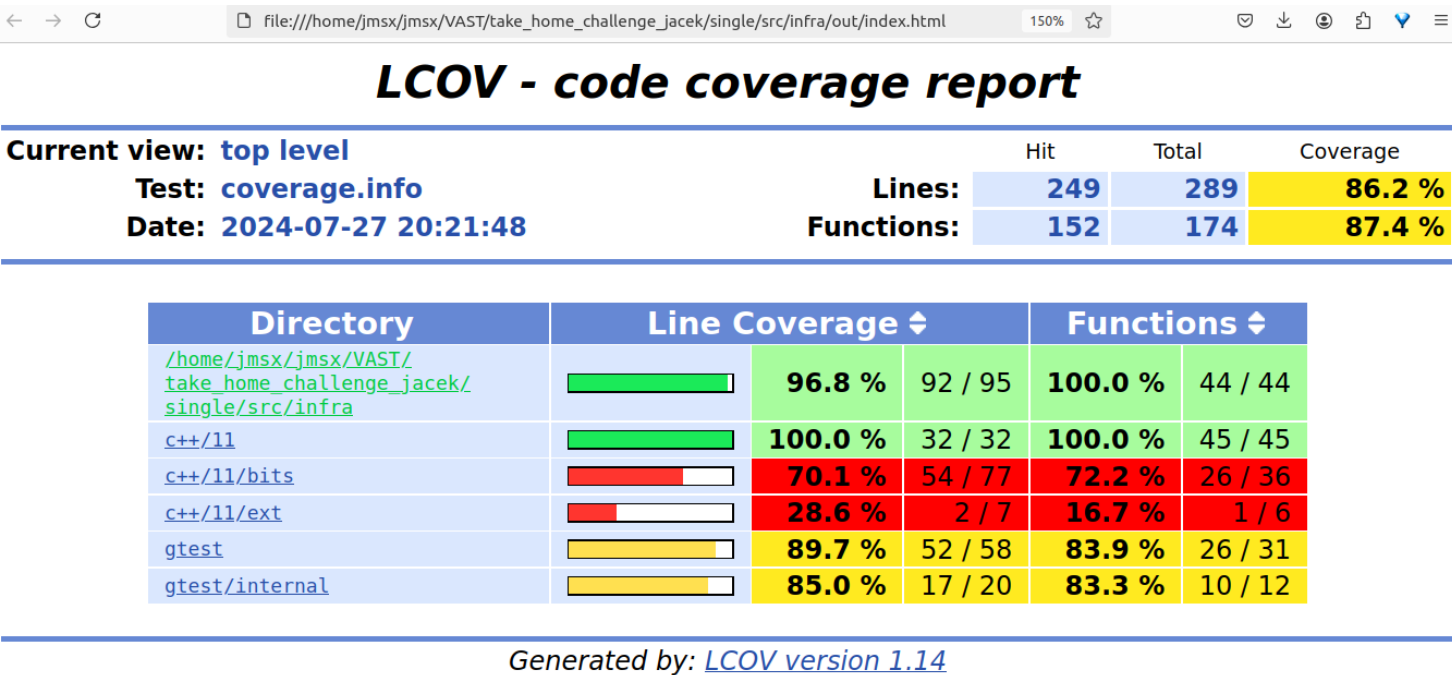
Tools: System tests may include custom scripts or testing frameworks capable of simulating user interactions.

- Logging-Based Testing

Objective: Utilize logs for detailed analysis and verification.

- Timestamp Validation:
 - Compare real-time clock timestamps and simulated stepped clock timestamps to validate time progression accuracy.
 - Validate that events are logged with the correct sequence and timing, verifying that the simulation's clock advances correctly.
- Log Analysis:
 - Implement log parsing scripts to automate the verification of expected events and states. For example, checking that the transition from Mining to TravelingToUnload occurs after the expected mining duration.

Example gtest and coverage report (src/infra/tests/test_logger.cpp)



Example execution and output

```
$ ./build/sim_h3_mining 15 3 120
Usage: ./build/sim_h3_mining [num_mining_trucks] [num_simulation_time] [num_simulation_time_minutes]
num_mining_trucks=15
num_unload_stations=3
num_simulation_time=120 minutes
```

Example log file

Real time cl, sim clock, sim clock in messages
microseconds, minutes, message time values in minutes

59168620918, 0, Log started. Output to file='SH3M_Log.txt'

59168620970, 0, Timestamp unit [us]

59168621130, 0, Truck0 [Mining] till time=272 (for 272)

59168621153, 0, Truck1 [Mining] till time=101 (for 101)

59168621179, 0, Truck2 [Mining] till time=75 (for 75)

59168621197, 0, Truck3 [Mining] till time=50 (for 50)

59168621212, 0, Truck4 [Mining] till time=199 (for 199)

59168621232, 0, Truck5 [Mining] till time=175 (for 175)

59168621249, 0, Truck6 [Mining] till time=82 (for 82)

59168621266, 0, Truck7 [Mining] till time=141 (for 141)

59168621299, 0, Truck8 [Mining] till time=57 (for 57)

59168621316, 0, Truck9 [Mining] till time=167 (for 167)

59168621330, 0, Truck10 [Mining] till time=83 (for 83)

59168621343, 0, Truck11 [Mining] till time=234 (for 234)

59168621356, 0, Truck12 [Mining] till time=246 (for 246)

59168621375, 0, Truck13 [Mining] till time=111 (for 111)

59168621388, 0, Truck14 [Mining] till time=208 (for 208)

59168621442, 0, Sim: time now=0 < end=120

59168621451, 0, Sim: Truck3 nearest event in state [Mining] time=50

59168621461, 0, Sim: time now=0 < end=120

59168621465, 0, Sim: Time step now=0 new_time=50

59168621496, 50, Truck3 mined for 0.8 hours.

59168621503, 50, Truck3 state [Mining] transition to [TravelingToUnload]

59168621510, 50, Truck3 [TravelingToUnload] till time=80 (for 30)

59168621513, 50, Sim: Truck3 executed event in [TravelingToUnload] state

59168621519, 50, Sim: Truck8 nearest event in state [Mining] time=57

59168621524, 50, Sim: time now=50 < end=120

59168621529, 50, Sim: Time step now=50 new_time=57

59168621534, 57, Truck8 mined for 0.9 hours.

59168621539, 57, Truck8 state [Mining] transition to [TravelingToUnload]

59168621545, 57, Truck8 [TravelingToUnload] till time=87 (for 30)

59168621549, 57, Sim: Truck8 executed event in [TravelingToUnload] state

59168621560, 57, Sim: Truck2 nearest event in state [Mining] time=75

59168621566, 57, Sim: time now=57 < end=120

59168621571, 57, Sim: Time step now=57 new_time=75

59168621575, 75, Truck2 mined for 1.2 hours.

59168621578, 75, Truck2 state [Mining] transition to [TravelingToUnload]
59168621582, 75, Truck2 [TravelingToUnload] till time=105 (for 30)
59168621585, 75, Sim: Truck2 executed event in [TravelingToUnload] state
59168621596, 75, Sim: Truck3 nearest event in state [TravelingToUnload] time=80
59168621603, 75, Sim: time now=75 < end=120
59168621608, 75, Sim: Time step now=75 new_time=80
59168621612, 80, Truck3 traveling to unload station.
59168621617, 80, Truck3 state [TravelingToUnload] transition to [WaitingInQueue]
59168621623, 80, Truck3 [WaitingInQueue] till time=80 (for 0)
59168621625, 80, Sim: Truck3 executed event in [WaitingInQueue] state
59168621631, 80, Sim: Station0 queue add Truck3, nearest unload start time=0
59168621639, 80, Sim: To Station0 not occupied QLen=0 ADD Truck3 [WaitingInQueue] unload finish time=85
59168621644, 80, Truck3 waiting in queue to unload.
59168621648, 80, Truck3 state [WaitingInQueue] transition to [Unloading]
59168621654, 80, Truck3 [Unloading] till time=85 (for 5)
59168621666, 80, Sim: Truck6 nearest event in state [Mining] time=82
59168621673, 80, Sim: time now=80 < end=120
59168621677, 80, Sim: Time step now=80 new_time=82
59168621680, 82, Truck6 mined for 1.4 hours.
59168621683, 82, Truck6 state [Mining] transition to [TravelingToUnload]
59168621688, 82, Truck6 [TravelingToUnload] till time=112 (for 30)
59168621693, 82, Sim: Truck6 executed event in [TravelingToUnload] state
59168621702, 82, Sim: Truck10 nearest event in state [Mining] time=83
59168621710, 82, Sim: time now=82 < end=120
59168621716, 82, Sim: Time step now=82 new_time=83
59168621723, 83, Truck10 mined for 1.4 hours.
59168621726, 83, Truck10 state [Mining] transition to [TravelingToUnload]
59168621729, 83, Truck10 [TravelingToUnload] till time=113 (for 30)
59168621732, 83, Sim: Truck10 executed event in [TravelingToUnload] state
59168621739, 83, Sim: Truck3 nearest event in state [Unloading] time=85
59168621749, 83, Sim: Station0 Unloaded Truck3 state [Unloading] time=85
59168621755, 85, Sim: time now=85 < end=120
59168621760, 85, Sim: Time step now=85 new_time=85
59168621865, 85, Truck3 waiting in queue and unloading for 5.
59168621871, 85, Truck3 state [Unloading] transition to [TravelingToMine]
59168621877, 85, Truck3 [TravelingToMine] till time=115 (for 30)
59168621882, 85, Sim: Truck3 executed event in [TravelingToMine] state
59168621892, 85, Sim: Truck8 nearest event in state [TravelingToUnload] time=87
59168621898, 85, Sim: time now=85 < end=120

59168621902, 85, Sim: Time step now=85 new_time=87
59168621904, 87, Truck8 traveling to unload station.
59168621907, 87, Truck8 state [TravelingToUnload] transition to [WaitingInQueue]
59168621913, 87, Truck8 [WaitingInQueue] till time=87 (for 0)
59168621918, 87, Sim: Truck8 executed event in [WaitingInQueue] state
59168621925, 87, Sim: Station1 queue add Truck8, nearest unload start time=0
59168621933, 87, Sim: To Station1 not occupied QLen=0 ADD Truck8 [WaitingInQueue] unload finish time=92
59168621937, 87, Truck8 waiting in queue to unload.
59168621942, 87, Truck8 state [WaitingInQueue] transition to [Unloading]
59168621947, 87, Truck8 [Unloading] till time=92 (for 5)
59168621953, 87, Sim: Truck8 nearest event in state [Unloading] time=92
59168621959, 87, Sim: Station1 Unloaded Truck8 state [Unloading] time=92
59168621964, 92, Sim: time now=92 < end=120
59168621970, 92, Sim: Time step now=92 new_time=92
59168621973, 92, Truck8 waiting in queue and unloading for 5.
59168621979, 92, Truck8 state [Unloading] transition to [TravelingToMine]
59168621983, 92, Truck8 [TravelingToMine] till time=122 (for 30)
59168621989, 92, Sim: Truck8 executed event in [TravelingToMine] state
59168621998, 92, Sim: Truck1 nearest event in state [Mining] time=101
59168622002, 92, Sim: time now=92 < end=120
59168622006, 92, Sim: Time step now=92 new_time=101
59168622011, 101, Truck1 mined for 1.7 hours.
59168622016, 101, Truck1 state [Mining] transition to [TravelingToUnload]
59168622022, 101, Truck1 [TravelingToUnload] till time=131 (for 30)
59168622027, 101, Sim: Truck1 executed event in [TravelingToUnload] state
59168622036, 101, Sim: Truck2 nearest event in state [TravelingToUnload] time=105
59168622044, 101, Sim: time now=101 < end=120
59168622050, 101, Sim: Time step now=101 new_time=105
59168622052, 105, Truck2 traveling to unload station.
59168622055, 105, Truck2 state [TravelingToUnload] transition to [WaitingInQueue]
59168622059, 105, Truck2 [WaitingInQueue] till time=105 (for 0)
59168622062, 105, Sim: Truck2 executed event in [WaitingInQueue] state
59168622067, 105, Sim: Station2 queue add Truck2, nearest unload start time=0
59168622075, 105, Sim: To Station2 not occupied QLen=0 ADD Truck2 [WaitingInQueue] unload finish time=110
59168622079, 105, Truck2 waiting in queue to unload.
59168622084, 105, Truck2 state [WaitingInQueue] transition to [Unloading]
59168622089, 105, Truck2 [Unloading] till time=110 (for 5)
59168622100, 105, Sim: Truck2 nearest event in state [Unloading] time=110

59168622105, 105, Sim: Station2 Unloaded Truck2 state [Unloading] time=110
59168622108, 110, Sim: time now=110 < end=120
59168622112, 110, Sim: Time step now=110 new_time=110
59168622115, 110, Truck2 waiting in queue and unloading for 5.
59168622120, 110, Truck2 state [Unloading] transition to [TravelingToMine]
59168622125, 110, Truck2 [TravelingToMine] till time=140 (for 30)
59168622130, 110, Sim: Truck2 executed event in [TravelingToMine] state
59168622139, 110, Sim: Truck13 nearest event in state [Mining] time=111
59168622146, 110, Sim: time now=110 < end=120
59168622152, 110, Sim: Time step now=110 new_time=111
59168622155, 111, Truck13 mined for 1.9 hours.
59168622159, 111, Truck13 state [Mining] transition to [TravelingToUnload]
59168622162, 111, Truck13 [TravelingToUnload] till time=141 (for 30)
59168622165, 111, Sim: Truck13 executed event in [TravelingToUnload] state
59168622176, 111, Sim: Truck6 nearest event in state [TravelingToUnload] time=112
59168622183, 111, Sim: time now=111 < end=120
59168622188, 111, Sim: Time step now=111 new_time=112
59168622193, 112, Truck6 traveling to unload station.
59168622197, 112, Truck6 state [TravelingToUnload] transition to [WaitingInQueue]
59168622269, 112, Truck6 [WaitingInQueue] till time=112 (for 0)
59168622274, 112, Sim: Truck6 executed event in [WaitingInQueue] state
59168622282, 112, Sim: Station0 queue add Truck6, nearest unload start time=85
59168622289, 112, Sim: To Station0 not occupied QLen=0 ADD Truck6 [WaitingInQueue] unload finish time=117
59168622292, 112, Truck6 waiting in queue to unload.
59168622294, 112, Truck6 state [WaitingInQueue] transition to [Unloading]
59168622297, 112, Truck6 [Unloading] till time=117 (for 5)
59168622303, 112, Sim: Truck10 nearest event in state [TravelingToUnload] time=113
59168622308, 112, Sim: time now=112 < end=120
59168622311, 112, Sim: Time step now=112 new_time=113
59168622313, 113, Truck10 traveling to unload station.
59168622318, 113, Truck10 state [TravelingToUnload] transition to [WaitingInQueue]
59168622323, 113, Truck10 [WaitingInQueue] till time=113 (for 0)
59168622328, 113, Sim: Truck10 executed event in [WaitingInQueue] state
59168622332, 113, Sim: Station1 queue add Truck10, nearest unload start time=92
59168622336, 113, Sim: To Station1 not occupied QLen=0 ADD Truck10 [WaitingInQueue] unload finish time=118
59168622338, 113, Truck10 waiting in queue to unload.
59168622343, 113, Truck10 state [WaitingInQueue] transition to [Unloading]
59168622347, 113, Truck10 [Unloading] till time=118 (for 5)

59168622354, 113, Sim: Truck3 nearest event in state [TravelingToMine] time=115
59168622362, 113, Sim: time now=113 < end=120
59168622367, 113, Sim: Time step now=113 new_time=115
59168622371, 115, Truck3 traveling to mining site.
59168622376, 115, Truck3 state [TravelingToMine] transition to [Mining]
59168622382, 115, Truck3 [Mining] till time=192 (for 77)
59168622384, 115, Sim: Truck3 executed event in [Mining] state
59168622389, 115, Sim: Truck6 nearest event in state [Unloading] time=117
59168622393, 115, Sim: Station0 Unloaded Truck6 state [Unloading] time=117
59168622395, 117, Sim: time now=117 < end=120
59168622397, 117, Sim: Time step now=117 new_time=117
59168622398, 117, Truck6 waiting in queue and unloading for 5.
59168622400, 117, Truck6 state [Unloading] transition to [TravelingToMine]
59168622402, 117, Truck6 [TravelingToMine] till time=147 (for 30)
59168622404, 117, Sim: Truck6 executed event in [TravelingToMine] state
59168622407, 117, Sim: Truck10 nearest event in state [Unloading] time=118
59168622411, 117, Sim: Station1 Unloaded Truck10 state [Unloading] time=118
59168622412, 118, Sim: time now=118 < end=120
59168622414, 118, Sim: Time step now=118 new_time=118
59168622416, 118, Truck10 waiting in queue and unloading for 5.
59168622418, 118, Truck10 state [Unloading] transition to [TravelingToMine]
59168622420, 118, Truck10 [TravelingToMine] till time=148 (for 30)
59168622421, 118, Sim: Truck10 executed event in [TravelingToMine] state
59168622425, 118, Sim: Truck8 nearest event in state [TravelingToMine] time=122
59168622427, 118, Sim: time now=118 < end=120
59168622429, 118, Sim: Time step now=118 new_time=122
59168622430, 122, Truck8 traveling to mining site.
59168622432, 122, Truck8 state [TravelingToMine] transition to [Mining]
59168622434, 122, Truck8 [Mining] till time=263 (for 141)
59168622436, 122, Sim: Truck8 executed event in [Mining] state
59168622439, 122, Sim: Truck1 nearest event in state [TravelingToUnload] time=131
59168622442, 122, Simulation done after 120 min

//NOTE: stats are not yet fully connected to data

59168622443, 122, ===== STATISTICS =====
59168622445, 122, Simulation
59168622602, 122, Total Unloads: 0
59168622604, 122, Total Mine Time: 0 minutes

59168622605, 122, Total Wait in Unload Queue: 0 minutes
59168622606, 122, Total Operation Cycles: 0
59168622608, 122, Truck0
59168622610, 122, Total Operation Cycles: 0
59168622612, 122, Total Wait Time in Unload Queues: 0 minutes
59168622617, 122, Average Wait Time in Unload Queues: 0.00 minutes
59168622618, 122, Total Travel Time: 0 minutes
59168622619, 122, Total Mining Time: 0 minutes
59168622621, 122, Average Mining Time: 0.00 minutes
59168622623, 122, Mining to Simulation Time Ratio: 0.00%
59168622675, 122, Truck1
59168622677, 122, Total Operation Cycles: 0
59168622679, 122, Total Wait Time in Unload Queues: 0 minutes
59168622681, 122, Average Wait Time in Unload Queues: 0.00 minutes
59168622682, 122, Total Travel Time: 0 minutes
59168622683, 122, Total Mining Time: 0 minutes
59168622685, 122, Average Mining Time: 0.00 minutes
59168622687, 122, Mining to Simulation Time Ratio: 0.00%
59168622688, 122, Truck2
59168622690, 122, Total Operation Cycles: 0
59168622691, 122, Total Wait Time in Unload Queues: 0 minutes
59168622692, 122, Average Wait Time in Unload Queues: 0.00 minutes
59168622694, 122, Total Travel Time: 0 minutes
59168622695, 122, Total Mining Time: 0 minutes
59168622697, 122, Average Mining Time: 0.00 minutes
59168622698, 122, Mining to Simulation Time Ratio: 0.00%
59168622700, 122, Truck3
59168622701, 122, Total Operation Cycles: 0
59168622702, 122, Total Wait Time in Unload Queues: 0 minutes
59168622704, 122, Average Wait Time in Unload Queues: 0.00 minutes
59168622705, 122, Total Travel Time: 0 minutes
59168622706, 122, Total Mining Time: 0 minutes
59168622708, 122, Average Mining Time: 0.00 minutes
59168622710, 122, Mining to Simulation Time Ratio: 0.00%
59168622711, 122, Truck4
59168622712, 122, Total Operation Cycles: 0
59168622714, 122, Total Wait Time in Unload Queues: 0 minutes
59168622715, 122, Average Wait Time in Unload Queues: 0.00 minutes
59168622716, 122, Total Travel Time: 0 minutes

59168622718, 122, Total Mining Time: 0 minutes
59168622719, 122, Average Mining Time: 0.00 minutes
59168622721, 122, Mining to Simulation Time Ratio: 0.00%
59168622722, 122, Truck5
59168622723, 122, Total Operation Cycles: 0
59168622725, 122, Total Wait Time in Unload Queues: 0 minutes
59168622726, 122, Average Wait Time in Unload Queues: 0.00 minutes
59168622727, 122, Total Travel Time: 0 minutes
59168622729, 122, Total Mining Time: 0 minutes
59168622730, 122, Average Mining Time: 0.00 minutes
59168622732, 122, Mining to Simulation Time Ratio: 0.00%
59168622733, 122, Truck6
59168622735, 122, Total Operation Cycles: 0
59168622736, 122, Total Wait Time in Unload Queues: 0 minutes
59168622737, 122, Average Wait Time in Unload Queues: 0.00 minutes
59168622739, 122, Total Travel Time: 0 minutes
59168622740, 122, Total Mining Time: 0 minutes
59168622741, 122, Average Mining Time: 0.00 minutes
59168622743, 122, Mining to Simulation Time Ratio: 0.00%
59168622744, 122, Truck7
59168622746, 122, Total Operation Cycles: 0
59168622747, 122, Total Wait Time in Unload Queues: 0 minutes
59168622749, 122, Average Wait Time in Unload Queues: 0.00 minutes
59168622750, 122, Total Travel Time: 0 minutes
59168622751, 122, Total Mining Time: 0 minutes
59168622753, 122, Average Mining Time: 0.00 minutes
59168622754, 122, Mining to Simulation Time Ratio: 0.00%
59168622756, 122, Truck8
59168622757, 122, Total Operation Cycles: 0
59168622758, 122, Total Wait Time in Unload Queues: 0 minutes
59168622760, 122, Average Wait Time in Unload Queues: 0.00 minutes
59168622761, 122, Total Travel Time: 0 minutes
59168622762, 122, Total Mining Time: 0 minutes
59168622764, 122, Average Mining Time: 0.00 minutes
59168622766, 122, Mining to Simulation Time Ratio: 0.00%
59168622767, 122, Truck9
59168622768, 122, Total Operation Cycles: 0
59168622769, 122, Total Wait Time in Unload Queues: 0 minutes
59168622771, 122, Average Wait Time in Unload Queues: 0.00 minutes

59168622772, 122, Total Travel Time: 0 minutes
59168622773, 122, Total Mining Time: 0 minutes
59168622775, 122, Average Mining Time: 0.00 minutes
59168622777, 122, Mining to Simulation Time Ratio: 0.00%
59168622778, 122, Truck10
59168622780, 122, Total Operation Cycles: 0
59168622781, 122, Total Wait Time in Unload Queues: 0 minutes
59168622782, 122, Average Wait Time in Unload Queues: 0.00 minutes
59168622784, 122, Total Travel Time: 0 minutes
59168622785, 122, Total Mining Time: 0 minutes
59168622786, 122, Average Mining Time: 0.00 minutes
59168622788, 122, Mining to Simulation Time Ratio: 0.00%
59168622789, 122, Truck11
59168622791, 122, Total Operation Cycles: 0
59168622817, 122, Total Wait Time in Unload Queues: 0 minutes
59168622819, 122, Average Wait Time in Unload Queues: 0.00 minutes
59168622820, 122, Total Travel Time: 0 minutes
59168622821, 122, Total Mining Time: 0 minutes
59168622823, 122, Average Mining Time: 0.00 minutes
59168622825, 122, Mining to Simulation Time Ratio: 0.00%
59168622826, 122, Truck12
59168622827, 122, Total Operation Cycles: 0
59168622829, 122, Total Wait Time in Unload Queues: 0 minutes
59168622830, 122, Average Wait Time in Unload Queues: 0.00 minutes
59168622831, 122, Total Travel Time: 0 minutes
59168622833, 122, Total Mining Time: 0 minutes
59168622834, 122, Average Mining Time: 0.00 minutes
59168622836, 122, Mining to Simulation Time Ratio: 0.00%
59168622837, 122, Truck13
59168622838, 122, Total Operation Cycles: 0
59168622840, 122, Total Wait Time in Unload Queues: 0 minutes
59168622841, 122, Average Wait Time in Unload Queues: 0.00 minutes
59168622843, 122, Total Travel Time: 0 minutes
59168622844, 122, Total Mining Time: 0 minutes
59168622845, 122, Average Mining Time: 0.00 minutes
59168622847, 122, Mining to Simulation Time Ratio: 0.00%
59168622848, 122, Truck14
59168622850, 122, Total Operation Cycles: 0
59168622851, 122, Total Wait Time in Unload Queues: 0 minutes

59168622852, 122, Average Wait Time in Unload Queues: 0.00 minutes
59168622854, 122, Total Travel Time: 0 minutes
59168622855, 122, Total Mining Time: 0 minutes
59168622857, 122, Average Mining Time: 0.00 minutes
59168622858, 122, Mining to Simulation Time Ratio: 0.00%
59168622860, 122, Station0
59168622861, 122, Total Unloads: 0
59168622863, 122, Total Queue Used Time: 0 minutes
59168622865, 122, Average Queue Used Time: 0.00 minutes
59168622866, 122, Operation Time to No-Op Ratio: 0.00%
59168622868, 122, Station1
59168622869, 122, Total Unloads: 0
59168622871, 122, Total Queue Used Time: 0 minutes
59168622872, 122, Average Queue Used Time: 0.00 minutes
59168622874, 122, Operation Time to No-Op Ratio: 0.00%
59168622875, 122, Station2
59168622876, 122, Total Unloads: 0
59168622877, 122, Total Queue Used Time: 0 minutes
59168622879, 122, Average Queue Used Time: 0.00 minutes
59168622881, 122, Operation Time to No-Op Ratio: 0.00%