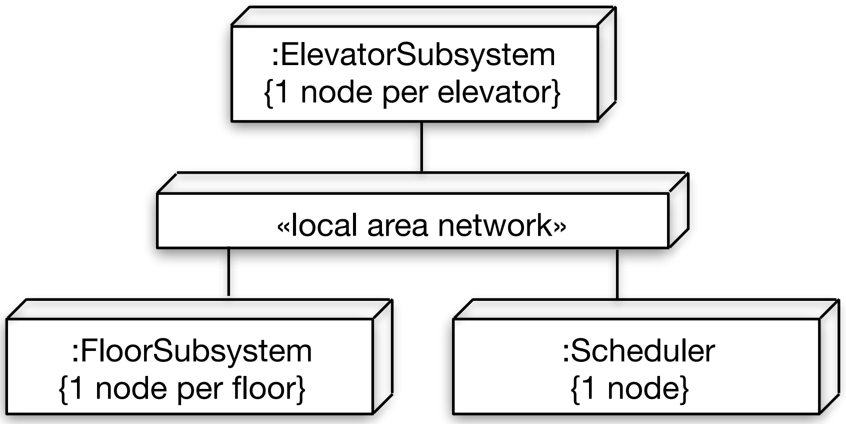
Carleton University
Department of Systems and Computer Engineering
SYSC 3303 RealTime Concurrent Systems Winter 2019

Project Specification 1.2

Teams will design and implement an elevator control system and simulator. The system will consist of an elevator controller (the Scheduler), a simulator for the elevator cars (which includes, the lights, buttons, doors and motors) and a simulator for the floors (which includes, buttons, lights and last, but not least, people who are too lazy to take the stairs). The elevator controller will have to be multi-threaded since it is expected to handle more than one car at a time. The simulation will eventually run on multiple computers as part of the project will involve running the controller on its own machine with the simulator(s) running on a separate computer. The code will be written in Java, using the Eclipse IDE. *You must design your code to work in the lab environment provided!*



Note that there will be three separate programs: the Elevator Subsystem (the cars), the Floor Subsytem (the simulated users), and the Scheduler. Each program will run as a separate Win32 process, and the programs will communicate via DatagramSocket objects. These three components should run on three separate computers in the lab.

One part of the project will involve measuring the Scheduler Subsystem code using Java Visaul VM (or another Java Profiler of your choice). You will then use this information to determine whether your scheduler can run four elevators at the same time. Your project is also expected to behave in "real-time" which means that elevators take time to more from floor to floor. I suggest you pick your favourite elevator (!) and time a few runs to determine the average time it takes a car to move between floors. You can assume that the elevator cars can accelerate and decelerate instantaneously, though I for one would not want to be a passenger on such an elevator!

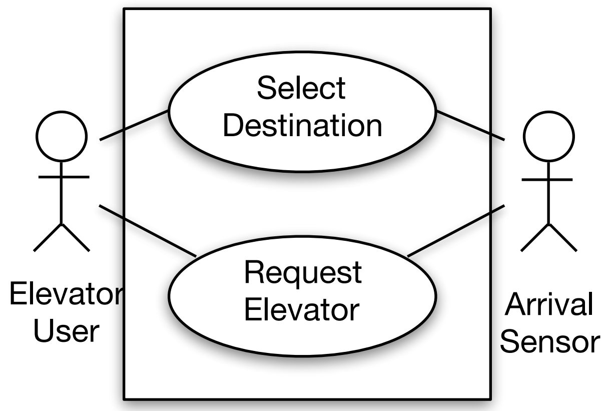
You must be able to run multiple main programs (projects) concurrently as the three components should be able to run on three computers. You can decide whether each elevator and floor is run as a separate instance, or that the elevator and floor subsystems are one program that can simulate multiple cars and floors simultaneously. See the Reference Material on the course web site for hints in doing this in Eclipse.

Your team's code must demonstrate good programming style, and be well documented. For examples of "industrial quality" Java code, have a look at Sun's Java coding conventions, which can be found on the Oracle Web site. Unit testing using JUnit should be included for each subsystem. Java Doc documentation should also be provided.

All team members should be familiar with all aspects of the code and diagrams for your group. Working in (at least) pairs for the programming, debugging, and developing the diagrams is recommended. If any team members are not pulling their weight, please notify the TAs and/or instructor as early in the term as possible so that this can be remedied.

Please note that this project specification may be revised as necessary.

Use Cases



Select Destination Use Case

Actors: Elevator User (primary), Arrival Sensor
Precondition: User is in the elevator
Description:

1. User presses an elevator floor button. The elevator button sensor sends the elevator button request to the system, identifying the destination floor the user wishes to visit.
2. The new request is added to the list of floors to visit. If the elevator is stationary; the system determines in which direction the system should move in order to service the next request. The system commands the elevator door to close. When the door has closed, the system commands the motor to start moving the elevator, either up or down.
3. As the elevator moves between floors, the arrival sensor detects that the elevator is approaching a floor and notifies the system. The system checks whether the elevator should stop at this floor. If so, the system commands the motor to stop. When the elevator has stopped, the system commands the elevator door to open.
4. If there are other outstanding requests, the elevator visits these floors on the way to the floor requested by the user. Eventually, the elevator arrives at the destination floor selected by the user.

Alternatives:

- If the elevator is at a floor and there is no new floor to move to, the elevator stays at the current floor, with the door open.
  Postcondition: Elevator has arrived at the destination floor selected by the user.

Request Elevator Use Case

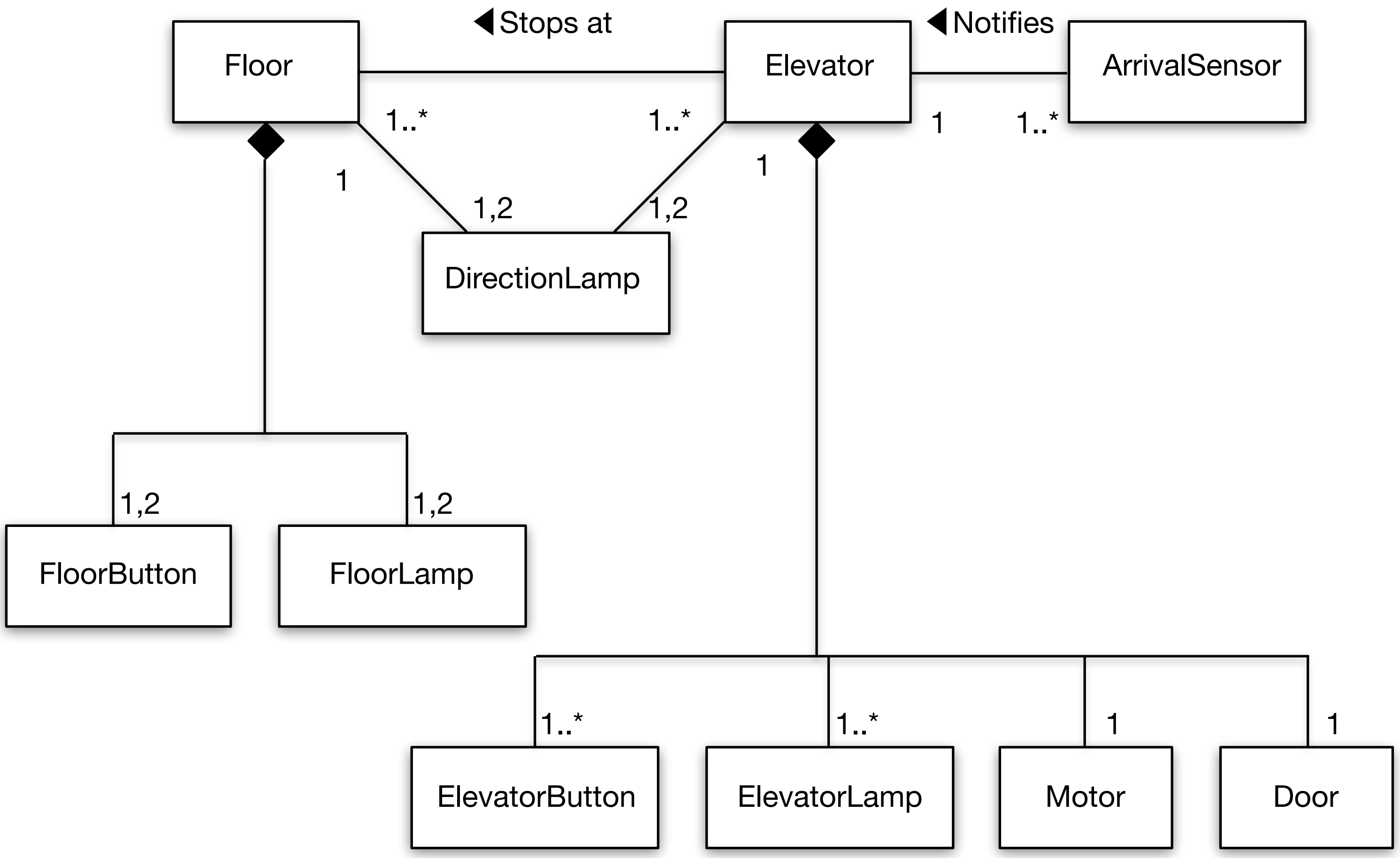
Actors: Elevator User (primary), Arrival Sensor
Precondition: User is at a floor and wants an elevator.
Description:

1. User presses the up floor button. The floor button sensor sends the user request to the system, identifying the floor number.
2. The system selects an elevator to visit this floor. The new request is added to the list of floors to visit. If the elevator is stationary, the system determines in which direction the system should move in order to service the next request.The system commands the elevator door to close. After the door has closed, the system commands the motor to start moving the elevator, either up or down.
3. As the elevator moves between floors, the arrival sensor detects that the elevator is approaching a floor and notifies the system. The system checks whether the elevator should stop at this floor, if so, the system commands the motor to stop. When the elevator has stopped, the system commands the elevator door to open.
4. If there are other outstanding requests, the elevator visits these floors on the way to the floor requested by the user. Eventually, the elevator arrives at the floor in response to the user request.

Alternatives:

- User presses the down floor button to move down. System response is the same as for the main sequence.
- If the elevator is at a floor and there is no new floor to move to, the elevator stays at the current floor, with the door open.

Postcondition: Elevator has arrived at the floor in response to user request.



Static Model of the Problem Domain

Each elevator has:

- **A set of elevator buttons:** The user presses one to select a floor.
- **A set of elevator lamps:** The lamps indicate the floor(s) which will be visited by the elevator.
- **An elevator motor:** The motor moves the elevator between floors.
- **An elevator door:** The elevator door also opens and closes the floor doors.

Each floor has:

- **Up and down floor buttons:** The user presses a button to request an elevator. Note that the top and bottom floors will only have one button.
- **Floor lamps**: The lamps indicated which buttons have been pushed.
- **Direction lamps:** Each elevator has a set of lamps to denote the arrival and direction of an elevator at a floor.
- **Arrival sensors**: Each elevator shaft at each floor has a sensor to detect the presence of an elevator.

Floor Subsystem Simulation

The floor subsystem is used to simulate the arrival of passengers to the elevators and for simulating all button presses and lamps. It should also test for the proper operation of the elevator, i.e., a passenger arrives, presses the elevator request button, waits for the arrival of an elevator (signalled by a lamp), then presses a floor button. The elevator chosen should eventually arrive at the floor selected.

Your floor subsystem should read an input file using the format shown below:

Time	Floor	Floor Button	Car Button
hh:mm:ss.mmm	n	Up/Down	n
14:05:15.0	2	Up	4

i.e., a time stamp, white space, an integer representing the floor on which the passenger is making a request, white space, a string consisting of either “up” or “down”, more white space, then an integer representing floor button within the elevator which is providing service to the passenger. For example, in the table above, a passenger arrives at 2:05pm on the second floor of the building and wants to go up to the fourth floor. It is strongly advisable to maintain separate queues for each floor and direction for service requests since passengers may arrive at other floors prior to an elevator reaching the floor currently being serviced. If several requests are pending for an elevator, they can all be serviced at the same time once an elevator arrives. You can assume that each elevator has infinite capacity (if only that were true in Dunton!) so you do not have to keep track of the number of passengers in an elevator car.

You can assume that there is no “down” button at the lowest floor, nor is there an “up” button at the highest. Furthermore, you can assume that are as many floor buttons in an elevator car as there are floors serviced by the elevator, no more and no less. You should assume that roughly one half of all passengers arrive at the ground floor (although you could also assume that people can enter a building at more than one floor like here at Carleton if you so like). You should also assume that people choose floors somewhat randomly when they enter the elevator at a ground floor. Finally, not all passengers who enter an elevator at a non-ground floor will exit at a ground floor (i.e., some passengers will go from floor 6 to floor 2).

Scheduler Specification

The scheduler is responsible for accepting input from all of the sensors shown in the diagram above, and sending indications (to devices such as lamps) and commands (to devices such as the motor and door). It is responsible for routing each elevator to requested floors and coordinating elevators in such a way to minimize waiting times for people moving between floors (hint: observe where the elevators are in the Canal Building). You definitely don't want to serve requests in a first-come, first-served order, but you do want to make sure that all requests are served in a timely fashion (i.e., prevent starvation).
The scheduler system also has to be prepared to handle possible faults and failures in the system. Some of these faults include, but are not limited to, doors not opening or closing, elevator cars getting stuck between floors, and packets being lost on the LAN.

Elevator Subsystem Specification

The elevator subsystem consists of the buttons and lamps inside of the elevator used to select floors and indicate the floors selected, and to indicate the location of the elevator itself. The elevator subsystem is also used to operate the motor and to open and close the doors. Each elevator has its own elevator subsystem.

For the purpose of this project, the elevator subsystem listens for packets from the scheduler to control the motor and to open the doors. The elevator subsystem also has to monitor the floor subsystem for destination requests (button presses inside of the elevator car, rather than button presses at the floors) from the input file. Button presses are to be rerouted to the scheduler system. Lamp (floor indications) from button pushes do not have to originate from the scheduler. Rather, when the elevator subsystem detects a button request, it can then light the corresponding lamp. When the elevator reaches a floor, the scheduling subsystem signals the elevator subsystem to turn the lamp off.

User Interface

Not much of a user interface is needed initially. For the final project iteration, you will have to have some sort of output to show the position of all of the elevators in the system at any given time. Full marks will be awarded for graphical output.

The only other user interface is to load the input file into the system. You should also be able to provision the number of elevators and the number of floors before your simulation starts. Start up the three parts, then load the trace into the system. Must be able to configure the number of floors and the number of elevators. Stress test to see when it breaks (I.e, how many elevators can run at the same time? Maybe you'll be lucky and you won't hit a limit).

Development Process

The project will be developed using an iterative, incremental process. The result of each iteration will be the release of an executable piece of software that constitutes a subset of the final elevator controller and simulator. The software will be grown incrementally from iteration to iteration to become the final system. Note that when submitting iteration "*n*", it is absolutely not acceptable to include code for iteration "*n*+1", etc.

Iteration 0 – Establish Connections between the three subsystems.

For this part, assume that no errors occur. Using Assignment 1 (or the simple echo server example), create three programs, one for each subsystem identified above. The Floor subsystem is to send and receive from the Scheduler, and the Scheduler is to send and receive from the Elevators. The Floor subsystem is to read in events using the format shown above: Time, floor or elevator number, and button. Each line of input is to be sent to the Scheduler who will then pass it on to the Elevator. The Elevator will then send the data back to the Scheduler who will then send it back to the Floor. Note that in a future iteration, there will be multiple elevator cars, all running independently of each other, so be sure that you allow for this configuration when you design your code, or you will have to refactor your design at a later point in time.

You probably don't want to pass text strings from the Floor subsystem to the rest of the system. You should develop a data structure which only passes then necessary information representing the hardware device (floor button, elevator button, etc.) to the scheduler.

Your project should also be configurable in terms of the number of floors, the number number of elevators, the time it takes to open and close the doors, and the time it takes to move between floors. In order to populate some of these values, your team should pick your favourite (set of) elevator(s) and measure the times. However, once you pick an elevator or set of elevators(s), e.g., Minto, Dunton, Canal (or the pokey freight elevator in the Unicentre), stick with it. Collect data for several trips then decide whether the mean, median, or perhaps even the mode is best for your project (but be prepared to justify your choice).

Work Products for Iteration #0:

- None your first submission is Iteration #1 (below) which includes Iteration #0.

Iteration 1 – Adding the Scheduler and Elevator Subsystems.

The goal of this iteration is to add the state machines for the scheduler and elevator subsystems assuming that there is only one elevator. However, you should bear in mind that for the next iteration, your system is expected to coordinate between the elevators in order to maximize the number of passengers carried over time (i.e., the throughput). Note that the floor subsystem is used to notify the scheduler that an elevator has reached a floor, so that once an elevator has been told to move, the floor subsystem also has to be informed so that it can send out messages back to the scheduler to denote the arrival by an elevator. You can either maintain a single event list or have separate tasks for each elevator. Perhaps you can think of another way of doing it too.

Work Products for Iteration #1:

- "README.txt" file explaining the names of your files, set up instructions, etc.
- Breakdown of responsibilities of each team member for this iteration
- UML class diagram
- State machine diagram for the scheduler and elevator subsystems.
- Detailed set up and test instructions, including test files used
- Code (.java files, all required Eclipse files, etc.)

Iteration 2 – Implementation of Planning Subsystem for Multiple Cars

For this iteration, you are to coordinate the movement of cars such that each car carries roughly the same number of passengers as all of the others and so that the waiting time for passengers at floors is minimized. Hint: if a passenger wants to go down and there is an elevator above the passenger, then that elevator should service the passenger rather than having a second elevator go up instead. The state machines for each car should execute independently of each other, but they will all have to share their position with the scheduler. The scheduler will choose which elevator will be used to service a given request.

Work Products for Iteration #2:

- "README.txt" file explaining the names of your files, set up instructions, etc.
- Breakdown of responsibilities of each team member for this and previous iterations
- Any unchanged diagrams from the previous iterations UML class diagram
- Timing diagrams showing the error scenarios for this iteration
- Detailed set up and test instructions, including test files used
- Code (.java files, all required Eclipse files, etc.)

Iteration 3 – Adding Error detection and correction.

For this iteration, you will be adding code for detecting and handling faults. To this end, you will have to add timing events so that if the timer goes off before an elevator reaches a floor, then your system should assume a fault (either, the elevator is stuck between floors, or the arrival sensor at a floor has failed). Similarly, you should detect whether a door opens or not, or is stuck open. In iteration 5 below, your elevator status output should show these faults. A door which has not closed should be regarded as a transient fault, so your system should be able to handle this situation gracefully. However, the floor timer fault should be regarded as a hard fault and should shut down the corresponding elevator.

You must submit code to enable us to see that your elevator scheduler can deal properly with the faults shown above (i.e., you must be able to inject these faults into the system). I suggest that you inject these faults using the input file (so you will have to modify its format and be able to show to us how it works).

Work Products for Iteration #3:

- "README.txt" file explaining the names of your files, set up instructions, etc.
- Breakdown of responsibilities of each team member for this and previous iterations
- Any unchanged diagrams from the previous iterations UML class diagram
- Timing diagrams showing the error scenarios for this iteration
- Detailed set up and test instructions, including test files used
- Code (.java files, all required Eclipse files, etc.)

Iteration 4 – Measuring the Scheduler and predicting the performance.

For this part, you will have to measure the performance of the scheduler subsystem. To do so, you will have to run the scheduler on a separate computer than the floor and elevator subsystems. You will have to repeat the measurements several times and with sufficient traffic in order to find, minimally, the mean and variance of the time the scheduler takes to service a request. Using these numbers, use Rate Monotonic Analysis to assign priorities to tasks as necessary. Deadlines for various events are as follows:

Task	Period
Arrival Sensors Interface	50
Elevator Buttons Interface	100

Task	Period
Floor Buttons Interface	200

Work Products for Iteration #4:

- "README.txt" file explaining the names of your files, set up instructions, etc.
- Breakdown of responsibilities of each team member for this and previous iterations
- Any unchanged diagrams from the previous iterations UML class diagram
- Timing diagrams showing your measured values.
- Rate Monotonic Analysis using your measured values.
- Detailed set up and test instructions, including test files used
- Code (.java files, all required Eclipse files, etc.)

Iteration 5 – Adding a GUI to the floor subsystem.

The last stage of the project is to add a display console showing where each of the elevators is in real time and displaying any faults (if any). The idea is to have output suitable for the concierge sitting at the desk in the front lobby to refer to. This part of the project can be part of the floor subsystem if you so choose, or you may want to develop a separate subsystem altogether.

Project Demonstration – Iteration #4 or #5

Your team will give a 15 minute demo to a TA of iteration #4 or iteration #5 (your choice). The goal of the demo is to give you feedback to improve your project before the final submission. Ensure that you have soft copies of all the work products to hand during the demo.

Work Products for Project Demonstration – Iteration #4 or #5:

- "README.txt" file explaining the names of your files, set up instructions, etc.
- Breakdown of responsibilities of each team member for each iteration
- All diagrams
- Detailed set up and test instructions, including test files used
- Code (.java files, all required Eclipse files, etc.)

Final Project Presentation – Iteration #5

Your team will give a 15 minute presentation to a TA of iteration #5. It must show four elevators running with 22 floors with arrivals at levels one and two (i.e., the Dunton Tower). It must also demonstrate stuck doors on one elevator and a stuck elevator on a second. It is not necessary to demonstrate annoyed passengers typically found in Dunton. The goal of the presentation is to show us how awesome your team and project are, and to submit your final copy of your work using CULearn.

Final Project Presentation Work Products:

You must submit all of the following:

1. A report consisting of:
    - Team number and team members

- Table of contents
- Breakdown of responsibilities of each team member for each iteration
- All diagrams:
  - UML class diagrams for the three components.
  - A State Machine diagram for the scheduler.
  - Sequence diagrams showing all the error scenarios.
  - Timing diagrams for the scheduler.
- Detailed set up and test instructions.
- Results from your measurements.
- Analysis of your system for schedulability.
- Reflection on your design - what parts do you like and what parts should be redone.

2. Test files for all iterations.
3. Code (.java files, all required Eclipse files, etc.)

Submission and Grading:

Please refer to CULearn for all submission dates.

Work products for each iteration are to be submitted using cuLearn. Submit using your project team's number, (one submission per team) by the date/time specified. You can include any number of files in your submission. Ensure that all your files are accepted. Please submit PDF instead of Word, LibreOffice, Pages, etc. documents.

The project is worth 25% of your final grade. Iterations #1 through #4, and the demo are worth two marks each (total of 10 marks). 10 project marks are for the final deliverables. These 20 marks are for the team. However, based on the participation of each member, each individual's mark could be higher, the same, or lower than the team mark. The final five marks are assigned to each individual for their participation in the biweekly meetings (see below). In addition, any student who does not complete a project peer assessment will have a deduction of 1 mark from their individual project mark.

BiWeekly Meetings:

Each team will have an approximately biweekly 20 minute meeting with a TA to discuss their progress. The meetings are mandatory, and will be held during the labs. The meeting schedule will be posted on the web site.

The teams will be graded using the following rubric:

Graduate Attrirbute		Performance Level	Level 1	Level 2	Level 3	Level 4
		Level Descriptor	**Beginning**	**Developing**	**Accomplished**	**Exemplary**
6	**Individual and team work**	6.1 Personal and group time management	*Deadlines often missed. Several projects or assignments appear hurried or inadequately addressed. No evidence of time management planning.*	*Some deadlines missed. Some tasks or assignments appear hurried or inadequately addressed. Some evidence of time management planning.*	*No important deadlines missed. Few tasks or assignments appear hurried or inadequately addressed. Good time management planning.*	*No deadlines missed. Tasks and assignments always excellently prepared and presented. Tasks occasionally completed ahead of schedule. Leadership in time planning.*
		6.2 Group culture, group dynamics	*Not dependable. Little or no trust from teammates. Dishonest or evasive interactions with teammates. Poor conflict resolution.*	*Usually dependable and trusted by teammates. Mostly ethical behavior towards project and teammates. Minor conflicts.*	*Dependable and trusted by teammates. Ethical open interactions with teammates. Good conflict resolution.*	*Dependable and trusted by team mates. Ethical and open interactions with teammates. Leads team in ethical and responsive behavior. Leadership in conflict resolution.*
		6.3 Leadership: initiative and mentoring, areas of expertise, and interdisciplinary teams	*No initiative. No effort to mentor group members or take ownership of an area of expertise.*	*Some initiative. Some effort to mentor group members and take ownership of an area of expertise.*	*Good initiative and self-motivation. Regular effort to mentor group members. Clear command of an area of expertise.*	*Self-motivated, with regular demonstration of initiative. Constructively directs other team members and helps them to improve at their tasks. High degree of knowledge in an area of expertise.*

Change Log

1.0: Initial version
1.1: Revise Submission and Grading. Add rubric for Biweekly Meetings.
1.2: Add deadlines for the inputs.