System Understanding/Overview:

First, C2 loads the coordinates of the field cells to be scanned onto the UAV. The UAV will travel to these field cells in order and scan the field cells one at a time. These scans will be sent across WAN back to C2 one at a time, where the AI will process them. However, these images will be lower resolution because they were sent over WAN. After the UAV scans all field cells it was tasked to scan, it will return to C2 with the high resolution images of the field cells. During and after this process, C2 decides the best path for the UGV to take to clear mines. The UGV takes longer to traverse a path that has a mine because it takes time to deactivate it. Once the UGV has finished, the troops begin moving through the field.

The system can also be viewed as a system of systems. For example, the overall system includes a UAV, UGV, AI, etc. Each of those is a system in and of itself. We know information about the UGV and UAV system but the AI is more of a black box. The UGV system is composed of the following subsystems: Controller, Communications, Navigation, Sensor Suite, Mine Neutralization, Drivetrain, Power. The UAV system is composed of the following subsystems: Controller, Camera, GPS, Radio, Battery.
There are various losses associated with different mission outcomes:

- Common Mission Losses
    - L.1 = Loss of life or serious injury to military
        - Priority 1
    - L.2 = Loss of life or serious injury to civilian
        - Priority 1
    - L.3 = Loss of protected area assets
        - Priority 2
    - L.4 = Loss of classified mission HW/SW
        - Priority 3

There are also various mission hazards and associated hazardous actions:

- Common Mission Hazards
    - H.1 = Weapon Misfire
    - H.2 = Excessive time and/or personnel to deploy system
    - H.3 = Excessive time and/or personnel to un-deploy system
    - H.4 = Protected area improperly cleared
- Common Mission Hazardous Actions
    - HA.1 = Incorrect Fire
    - HA.2 = No Fire
    - HA.3 = Unable to Set Location
    - HA.4 = No Terminate

Rapid Safe Passage Mission (RSP):

- UAV:
    - Pre: C2 loads the UAV with coordinates of the environment "field cells" to be scanned for potential Mines.

    - The UAV travels to each field cell and scans the area using its on-board camera and sensors. The scan results are streamed back to C2 over the WAN for AI processing - may be lower resolution
    - Post: The UAV returns to C2 and uploads high resolution result of the field scan - allows for human recon
- UGV:
    - Goes to specified locations and neutralizes any found mines
    - Time associated with each move, and a greater penalty if mines need to be removed
- Traverse
    - Soldiers follow the path of the UGV when all mines are cleared

Environment:
- 10x10 grid of possible cells
- Condition vars:
    - Time, Temperature, Wind Speed, Visibility, Precipitation
- Terrain Types:
    - Grassy, Sandy, Rocky, Swampy, Wooded

Goal:

Relying on the AI system as much as possible, preprocess the low resolution UAV stream to find the highest confidence route for the UVG. The optimal route has the lowest probability of mines, minimizes the number of cells needed to be detected, and minimizes the total time needed to cross.

Ideas for future/questions about system:

- Can we change the path that the UAV will take after it leaves C2?
    - For example, if it scans the top of the first two rows of field cells and then the bottom of the first two rows and finds one side has many more mines than the other, can we no longer scan that side?
    - If we can't change its path after leaving C2, can we have it return early in order to change its path? Would this be time efficient? How long does it take for the UAV to travel from C2 to the field.

- Can troops start moving before the UGV is finished?

- How many paths can the AI analyze at one time?

- Can humans analyze the pictures sent over the WAN or only the high resolution pictures?
    - If humans can't analyze the pictures sent over the WAN, we will always (or almost always) know what the AI thinks of a field cell before we decide if a

human should analyze it. That means there will be some sort of threshold for certainty where we trust the AI.

- Can we send the UGV out before we know its whole path?

- Can we have the UGV stop short of the end?
    - If it's true that humans can't start traversing the field until the UGV is done, would it be beneficial for the UGV to stop short of the end if we are pretty certain there are no mines in the remaining path.

- If the UGV traverses the whole path before the soldiers do, is there ever any risk of soldiers hitting a mine? If not we can disregard the value of human lives unless we have the UGV stop short of the end.

- Do soldiers have to follow the path of the UGV?
    - Would there ever be a case where the UGV would be faster taking a path, but soldiers would be faster taking another path?

- Does the UGV have to start at the beginning of the field? Can we drop it in the middle?

- We can create multiple decision models for different scenarios/terrains. These can be places where the US are likely to go to war in the future.

- Can we send the UGV out before we decide its whole path?
    - If we are uncertain about the back half of the grid and need humans to analyze it, can the UGV start clearing the first parts of a path that the AI was confident about before continuing to the back half of the path that humans will have analyzed by that point?

- How close together are paths/ will the soldiers always stay on the given path?
    - If they are not guaranteed to stay on a path, are there scenarios where we want the UGV to clear more paths around the main path?
    - That could be done if the UGV is done and has extra time before soldiers get to that part of the path.

- How is battery usage determined for the UGV and UAV? If the UAV is sent out to analyze 5 cells but that drops the battery by 50% is that better than analyzing 3 with a 30% drop given it might take a while to recharge.

- Can we use Bayesian logic to inform the AI's analysis? Can we "learn as we go"?

- What expected mission success rate from the AI or the human analyst is sufficient to risk lives/resources?

- Does the UAV routing have time associated, or can we scan all cells with no penalty
- Are all maps 10x10 grids of possible cells
- Is there a designated start and finish location, or does this change
- Will we have access to all aspects of the simulation in a configurable way during the competition
- Time to traverse three cells without mines is equal to one with mines
- Can the UGV move diagonally
- Can AI / human process in parallel

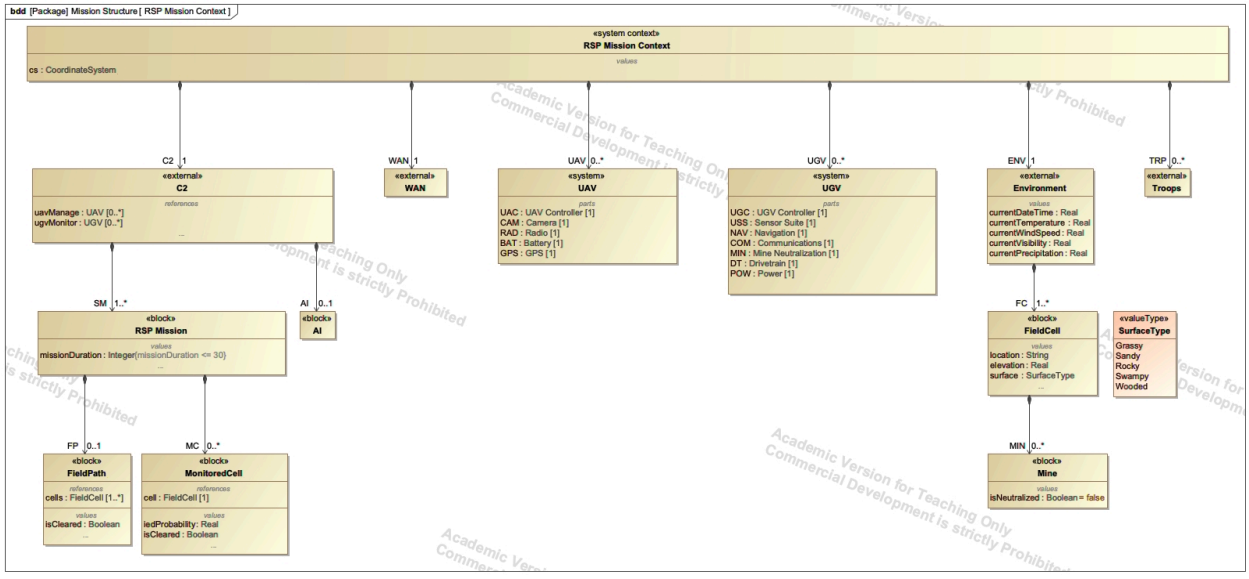
Future Ideas:

- Regression to determine the confidence for each cell scanned
    - By collecting data through interactions with the simulation across various cells with differing environmental variables and terrain types, build a regression model to predict the accuracy of the AI and human system for each specific case. These regressions should provide a probability or confidence score for each cell, offering an accuracy metric for every cell scanned.
    - Factors:
        - Environmental and terrain conditions
        - Maybe adjacent conditions?
- MDP formulation:
    - State:
        - Current cell being processed
        - Accuracy of adjacent cells for human and AI - maximum of 8 adjacent cells
        - State of any previously scanned adjacent cells (mines detected or confidence - maximum of 8
        - Direction to target (0-7 for each cardinal direction)
        - …
    - Action:
        - Scan cells (0-7)
            - Human, AI, or neither for each
        - Move (0-7)
            - Could have this just be heuristic, always go to cell with highest confidence and no mine detected
    - Reward:
        - Negative reward for time deduction
        - Positive reward for moving closer to the target without detecting a mine

    - Maybe a minor reward for just moving closer to target?

- Reinforcement Learning
    - Apply RL to the MDP to find optimal routing
    - Maybe factor in the environment conditions into the state vs just the accuracy heuristic
    - Downside:
        - Requires a lot of simulations to be run and a good simulator

#	Use Case ID	Name	Pre Condition	Basic Flow of Events	Post Condition
1	RSP.1	Perform Rapid Safe Passage (RSP) Mission	C2 requires troop movement through a potentially mined field.	In order to rapidly clear a field path of Mines, C2 uses a UAV to perform a reconnaissance scan for each field cell. Using AI, C2 analyzes the UAV scan stream and determines the probability of a Mines for each field cell. Based on the results of the field scan, C2 determines a field path for UGV clearing that minimizes UGV neutralization time. NOTE: The UGV takes time t1 to search and traverse a field cell with no found Mine. The UGV takes time t2 to search, neutralize and traverse a field cell with a found Mine (t2 > t1). C2 deploys the UGV to clear the field path. Upon completion of the UGV clearing, C2 instructs troops to traverse the field path.	C2 has successfully moved troops to the field path destination within the mission duration time constraint.
2	S.UAV.1	Perform Field Reconnaissance	C2 loads the UAV with coordinates of the environment "field cells" to be scanned for potential Mines.	The UAV travels to the each field cell and scans the area using its on-board camera and sensors. The scan results are streamed back to C2 over the WAN. NOTE: scan stream resolution is adapted based on WAN capacity.	The UAV returns to C2 and uploads high resolution result of the field scan.
3	S.UGV.2	Clear Field	C2 loads the field path (list of field cells) for the UGV to visit and clear of Mines. Each field cell includes a probability of Mine measure.	The UGV travels to each field cell, in the order prescribed by the field path, and neutralizes any found Mines.	The UGV returns to C2 and uploads the results of the Mines neutralized along field path.
4	Z.1	Traverse Field	The C2 field path has been cleared of Mines.	The troops traverse the field path.	The troops safely arrive at the field path destination.



UGV and UAS Ground Rules and Assumptions

- Unmanned Ground Vehicle (UGV)
  - UGV receives direction from Command and Control on where to go
  - The troops seeking safe passage will always follow the UGV
    - The speed of the UGV limits how fast people can traverse the terrain
  - UGV is 100 percent effective at detecting mines and clearing mines
  - Regardless of the type of terrain, the UGV takes:
    - 20 minutes to traverse the terrain
    - An additional 40 minutes to clear an mines, if a mine is detected
  - UGV has unlimited battery life

- Unmanned Aerial Vehicle (UAV)
  - UAV receives direction from Command and Control on where to go
  - Regardless of type of terrain, UAV takes one minute to capture and transmit imagery to Command Control
  - UAV has unlimited battery life