Designing Emergency Management Training Sessions
for C3Fire – Prioritization & Information Searching

by

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Tehman Pervaiz

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Supervisor: Rego Granlund
Examiner: Arne Jönsson
Dedication

To our parents and teachers . . .

Who always pray for us, without their prayers we were not able to do our projects and also to our elder brothers who always encouraged us to work hard and guided us towards right destination.
Abstract

C3Fire is an emergency management system. The purpose of this simulation system is to develop team decision making skills and to provide an opportunity for researchers to perform research in a controlled environment. Training is a crucial task for developing skills to tackle with emergency situation. The purpose of this thesis is to develop decision making by keeping focus on two major areas, namely; making prioritizations and information searching using UAV & Non UAV. Success of dealing with emergency management situation mostly depends on these training factors.

The methodology which we adapt to achieve these two training goals are as follow; first we design training sessions based on the literature study and research work. These training sessions are fully capable of achieving desired goals (i.e. prioritization & information searching). Finally we test the session by playing game with the participants from the real life.

In this thesis, theory part discusses literature about C3Fire and theoretical framework explains different terminologies and methods used in emergency management. Training sessions and their analysis is explained using theoretical framework. Better ways of communication and prioritization while taking decisions in emergency situation are discussed.

Keywords: C3Fire, Simulation System, Micro World, Teamwork, Situational Awareness, OODA, Prioritization, Information Searching, UAV, Non-UAV
Acknowledgement

We have no words to express the deepest sense of Gratitude to ALMIGHTY ALLAH, the most merciful, WHO enable us to finish this project developed in best possible manner. This project is not an accomplishment of a person or group alone. Many cooperative people have helped and contributed to realize this report, all in their own ways. Our project supervisor Mr. Rego Granlund has helped us by providing guidance at each and every phase of the project; his generous suggestions, timely guidance, sincere cooperation, encouragement and technical advice were greatly useful in bringing the task in to exercise. Consequently we would like to offer thanks to all those who directly and indirectly helped motivated and guided us through the long and arduous writing process. We also pay our gratitude to our parents who provided their full support and provided us new ideas and advice for filling up this project. We are grateful to them for the help which they provided us in completing this project.

Regards:
Muteer Arshad.
Tehman Pervaiz.
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<td>Command Control &amp; Communication</td>
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<td>SA</td>
<td>Situational Awareness</td>
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<td>DM</td>
<td>Decision Making</td>
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<tr>
<td>OODA</td>
<td>Observe Orient Decide Act</td>
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<tr>
<td>DOODA</td>
<td>Dynamic Observe Orient Decide Act</td>
</tr>
<tr>
<td>UAV</td>
<td>Unmanned Armed Vehicle</td>
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<td>FRAM</td>
<td>Functional Resonance Analysis Method</td>
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<td>COA</td>
<td>Course of Action</td>
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<td>GIS</td>
<td>Global Information System</td>
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<td>RPD</td>
<td>Recognition Primed Decision</td>
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Chapter 1  
Introduction

The term training can be defined as the teaching of professionals or practical dexterity and knowledge about a specific domain, in order to acquire certain skills and competencies. It plays a vital role to develop, maintain, and update skills throughout life time of a certain event. Along with training the teamwork also plays a very imperative role while working in groups. However the personal abilities and characteristics of an individual cannot be ignored at any cost; because these individuals are combined to form a group and group only operates in successful manner when each individual contribute to the group work according to his competency.

In our daily life there exist a lot of situations that requires teamwork for their successful completion. Hence it is very necessary to train teams, so that the teams would be able to successfully complete their tasks. One of the usages of training is to train team decision making skills by using an Emergency management system; the purpose of this training is to build some abilities inside teams in order to achieve various outcomes. In this study we have used the C3Fire simulation system for training team decision making; which is one of the applications of emergency management systems

C3Fire is a simulation system where group of people collaborate and coordinate to obtain an overview of the situation to extinguish forest fire. This simulation system is mainly used to train team decision making and to conduct research on Command, Control & Communication. The training can also be referred as collaboration training (group of peoples are trained to work together to extinguish forest fire) and research can be referred as the controlled studies of cooperation and coordination in dynamic environment.

C3Fire Simulation system operates by generating a dynamic task environment which represents a real world scenario where there are buildings (houses, schools etc.), vegetations (pine trees, oak trees etc.), computer simulated agents (fire fighting units, water truck etc.), fire and players (part of fire fighting organization). These all entities co-operate to extinguish fire by taking different roles (manager, observer, fire fighting unit chief etc.)

Disclaimer: - All the information presented in this whole chapter (chapter 1) and the coming chapter (chapter 3) is based on the information gathered from the official website of C3Fire system [1]. However the figures lacking references are contribution of authors to this thesis.

1.1  C3Fire

1.1.1 Idea behind the name “C3Fire”
The name of the simulation system i.e. C3Fre, reflects the whole idea behind its development. The first word “C3” represent the three different words starting from C i.e. Command, Control and Communication, (these three would be described in the upcoming section) and the second word “Fire” represents the forest fire fighting domain, this domain is chosen because it creates a good dynamic task environment for its users, where user have to keep variety of issues into his mind while making a certain decision and in this ways user learns more. This domain enables researchers to get most out of research
studies on Command, Control and communication and also helps trainee to train staff more effectively. Following are the description of the three words:

**Command:**
In general, the word “command” refers to a certain authoritative order to perform certain operation. In C3Fire the word “command” reflects the same meanings as in military domain. Command represents a collection of units or a group of people working under the control of single person. The main aim to make such grouping is to achieve a certain tactical requirement. The example of unit working under the control of single person is some fire fighter units (F1, F2, F3 etc.) controlled by a single fire fighter player (X, Y etc.). Similarly, the common example of group under the control of a specific person, is that different (fire fighter, water tank, fuel tank, fire break etc.) persons controlled by a single person (manager).

**Control:**
By definition control means “To suggest or dictate”. In C3fire the term “Control” refers to activity of managing the task environment, means that group of people cooperate and coordinate in structured manner to extinguish forest fire. Control can also be looked as the state of executing commands.

**Communication:**
In general communication means to exchange information between entities. In C3Fire it is not possible for a subject to extinguish a forest fire standalone, so for this the subject has to communicate with other subjects. The tools which enable communication in C3Frie system are mail and dairy.

1.1.2 Why Micro World?
A micro world is a kind of a simulation system that represents or maps a certain kind of real world. It is created on the basis of some of the important characteristic of a real world. It is also referred to as the scaled world because apart from being small and well controlled it is scaled with respect to real world entities. The major advantage of micro world is that it serves as a bridge between the lab work and the industrial work, independent of time and cost.

In other words there are some things lacking in both the lab environment and in natural work environment. For instance the thing which lacks in lab environment is the absence of natural work environment and the things which lack in the field work are control & difficulties in finding causal interpretations of the results. The micro world overcomes all these problems by providing a controlled simulation environment.

C3Fire system is also a micro world or a simulation system that simulates the forest fire fighting domain. It does so by retaining some of the important characteristics of real world and then generates a task environment based on those characteristics. Figure 1.1 reflects the C3Fire simulation system by mapping some real world entities with the C3Fire system. Following are the major properties of micro world:

**Complex:**
One of the main attribute of C3Fire task environment is that it is complex, means that subject is required to keep various factors in mind, firstly there are many goals and subject has to keep all goals in mind with aim of achieving all the goals, secondly there are many parallel process that subject has to manage.
by keeping in mind that all processes also have side effects, and due to parallel processes there are many alternative course of actions as well.

**Dynamic:**
Another important feature of C3Fire task environment is that it is dynamic. Means that task environment changes his behavior based on subject’s action. The system’s dynamic nature can be calculated from the fact that it changes in response to subjects’ behavior.

**Opaque:**
The task environment generated by C3Fire is also opaque, means that all the things are not visible or some things are not what they look like. So in such situations the subject has to perform hypotheses to solve the task. This provides an opportunity for researchers and training staff to perform their work in an optimal manner.

1.1.3 **Training in C3Fire**
Apart from above three major properties, another important property of micro world is that it provides means present different problems rather than focusing or presenting a single task only. The following list describes some the task that subject has to perform in the micro world:

**Exploring Micro world:**
The first and foremost task of the subject is to learn about the micro world by identifying the properties, behavior and relationship different objects of the system. It also requires subject to perform some hypothesis, so that he must collect information about insights of micro world.
Goal Analysis:
Goal Analysis is another important task that a subject performs i.e. analyzing the goal of the task. It includes prioritization of the task goal, identification of the sub goals and resolving conflicts that arises during the session.

Learning Decision Making:
The subject also needs to learn about decision making. They also learn about creating, considering and evaluating their own strategies to achieve a goal in the task environment. Despite of the above all tasks the subject must be able to propose the future development for the system along with the action alternatives.

While performing the above task the subject might make some typical errors. The first major mistake that a subject can do is that he can’t understand the regularities in the time frame means that he often interprets linear growth as non-linear growth. Similarly the subject is also unaware of the side effects of their actions. Another common mistake they do is that instead of following a structured way to achieve a certain goal, they follow ad hoc approach.

1.2 Aim
Our task in this thesis is related to team training. We would design emergency management training session by keeping focus on two major areas; first area is to train team decision making in such a manner that the team will be able to develop strategies and prioritize tasks in emergency situations, while having major focus on task prioritization. The second area of training is information searching in which the focus is on gathering the information about the emergency situation by using UAVs and non UAVs. For both of these training tasks, we would define training goals, organization structure and session scenario.

1.3 Outline
The work in report is organized as:
- Second chapter describes the different theories which were applied in various sessions.
- Third chapter describes the systematic working of the system (C3Fire) that was used to create session and to conduct experiments.
- Fourth and fifth chapters are dedicated to two major tasks (prioritization & information searching) which were performed in this thesis.
- Sixth chapter presents the analysis of whole work
- Seventh chapter concludes the report.
- Finally there are appendices in the end, containing the instructions for players and managers.
Chapter 2  Theoretical Framework

In this chapter we will take an overview of different theories which helps in decision making in emergency management situations. Below is the list of theories discussed in this chapter.

- Decision making
  - Naturalistic Decision Making
  - Normative Decision Making
- Recognition Primed Decision (RPD) Model
- Teamwork
- Situational Awareness
- Observe Orient Decide Act (OODA) Loop
- Dynamic Observe Orient Decide Act (DOODA) Loop
- Functional Resonance Analysis Method (FRAM)

2.1 Decision Making (DM)

"Decision making can be regarded as an outcome of mental processes (cognitive process) leading to the selection of a course of action among several alternatives" [10].

It is a very important task to take right decision in emergency management at right time. There are several principles which apply in emergency operations. 1) As emergency situation is something which requires quick response which may be in the form helping others by critically analyzing the situation. 2) One who implements the sound decisions faster often gets its reward by saving others in emergency situations. 3) Emergency decisions are not just mathematical calculations rather it requires a lot of analysis of the situation and suggest a practical solution. This ability is based on several factors including education, experience, perceptions etc. 4) In emergency management every situation may be different from other situation so it becomes quite difficult to predict whether particular solution will be fruitful in that uncertain situation. So we should adopt several actions instead of one with an acceptable degree of risk rather one get harmed by the situation which cause emergency [11].

Uncertainty and time put a significant influence on decision making in emergency management system. Humans make decision on the basis of knowledge so as the knowledge increases, ability to make right decisions also increases. So we can say that right information available at right time increase the effectiveness of decisions.

Below is the review of the decision theories developed. These theories addresses following key issues [16].

- **Assessment of the situation**: On the basis of information crew matches the presented situation with closet fit situation on the basis of their experience. If the situation is not similar more information is gathered to improve the situation awareness [16].
- **Awareness of the situation**: In order to make right decision crew must have right understanding of the situation. If there is any problem, they have to reassess the situation to reveal a clear picture.
• **Knowledge of the appropriate course of action:** The team will take action or handle the situation on the basis of their mental representations. Training, experience and procedures dictates appropriate actions.

• **Awareness of potential consequences of action(s)/inaction:** Team performs some type of mental simulation and evaluates their actions to assess outcome and check for expectancies. Feedback is received on expectancies, goals, information input and so on.

Several decision making theories are available. Each is having certain strengths and weaknesses and which is better depends on the situation and information available. Two most popular theories are

1) Analytical process
2) Intuition process

**Decision making as an analytical process:**
In this case several options are generated, certain criteria for evaluating these options is also made and certain values are assigned to each evaluation criteria. This evaluation criterion is then assigned to the options generated. The idea behind this approach is to compare multiple options and reached to an optimal solution. This approach is comprehensive and thorough but it takes a lot of time. An advantage of this approach is that experience is not necessary in this case, but it requires a good reasoning power [11].

**Decision making as an intuition process:**
This approach is based on the experience involves recognizing the key elements of a problem, rapidly integrate them, and make proper decisions. So intuition decision making is different from analytical decision in the fact that it replaces analysis with expert judgment. This model is based on the assumption that by using personal experience, one can generate workable solution earlier and there is no need for several options. It is the function of time if it is available, one may evaluate his/her decision; if he finds any problem he may move to another reasonable solution [11]. The two major types of decision making are normative and naturalistic decision making.

**2.1.1 Normative DM**
In normative decision making individuals make decisions on the basis of rationality and logic of decision making and it leads to unvarying choices [12]. The classical model of decision making process is expected utility theory. This theory contains the steps of

1) Definition of the goal
2) Generation of all possible options that help in achieving the goal
3) The probability of success of each option
4) The evaluation of utility of these options
5) The multiplication of probability and utility of these options, and finally
6) The selection of the option with the highest expected utility for execution.

Expected utility theory explains decision making as a sequence of well defined mathematical operations. This theory is considered to be normative. This theory also explains that there exists some constraints in which the decisions are made. The point which needs to be noted is that often goals, options,
probability and utility of options and outcome can’t be identified in actual complex dynamic work environments. There are some problems when we wish to make decisions using this theory [18].

1) Goals are not defined clearly.
2) The generation of all possible options is problematic.
3) There are several difficulties while estimating probabilities.
4) Time is a major constraint.

2.1.2 Naturalistic DM

There are many models of human decision making the most successful ones are based on naturalistic decision making [16]. Naturalistic decision making refers to how people actually make decisions in real world and perform cognitively complex functions in demanding situations [14]. There are several features that help in defining naturalistic decision making setting i.e. time, pressure, high stakes, experienced decision makers, inadequate information, poorly defined goals, ill defined procedures, team coordination etc [13]. They help us understanding how team can act in particular situation, how they react as a result of that situation and how they make decisions. One of the models for naturalistic decision making is Recognition Primed Decision (RPD) model.

2.1.2.1 RPD Model

One of the forms of Naturalistic decision making models is the Recognition-Primed Decision model. The “The RPD model asserts that decision makers draw upon their experience to identify a situation as representative of or analogous to a particular class of problem” [15]. This analogy then helps in directing appropriate course of action (COA). Now there are two cases either the two situations are similar or they are not similar. When they are similar follow the COA already practiced and when different then by adopting previous approaches. Figure 2-1 illustrates the process that how decision makers evaluate the course of action through mental simulation.

Recognition-Primed Decision (RPD) model combines two process first is the way decision makers’ size up the situation to recognize which COA is reasonable and second is the way they evaluate the COA by imagining it [13]. Figure 2-2 is showing the RPD model in simple form on the left and with option evaluation on the right. In simple form decision makers recognize the situation as typical and known i.e. like a fire in a building and proceed to take action. They recognize which goals are important so that they can be prioritized, which cues are important so that there is not an overload of information, what to expect next so that they can prepare themselves, and the ways of responding in given situation. By understanding the situation they recognize certain COA to succeed or at least likely to succeed. The identification of goals, cues, expectancies, and action are the means to understand the situation [13].

In Recognition-Primed Decision (RPD) model with optional evaluation decision makers evaluate many options by imagining, what will be the result of course of action (COA). If there is any problem then decision maker have to revise the course of action (COA), or have to replace it with another option.

There are several advantages of RPD model as compared to classical approaches of decision making [13].

1) Comprehensively pictures a wide range of options
2) Analyze a full range of objectives
3) Carefully presents the costs, risk and benefits of all options
4) Incorporate all new information
5) Presents the positive and negative results of each option.
6) Carefully plan to include contingencies if various risks occur.

![Image of Recognition-Primed Decision (RPD) Model](Figure 2-1 Recognition-Primed Decision (RPD) Model [15])

### 2.2 Teamwork

“Teams are social entities composed of members with high task interdependency and shared and valued common goals [18]”. Teams are organized in a hierarchy and they may be dispersed all over the world; a team has to integrate, synthesize and share information; they also need to coordinate and cooperate in order to achieve the mission. Individual task work is the components of individual performance and that don’t require interdependency of other team members. Teamwork is defined as the interdependent components of performance required to effectively coordinate the performance of multiple individuals.

“Team performance is defined as a multilevel process (and not a product) arising as team members engage in managing their individuals and team level task work and teamwork processes [18]”

### 2.3 Situation Awareness

Situation awareness can be defined as “the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future” [17]. The term situation awareness is basically from the military pilot world, where achieving high level of situation awareness was considered to be more important and challenging in the earlier aviation history.
The individual elements in the above definition of situation awareness can vary from domain to domain. Situation awareness is considered to be as foundation of decision making and performance in almost every field. The definition of situational awareness can be divided into three levels [17].

- **Level 1**: Perception of the elements in the environment
- **Level 2**: Comprehension of the current situation, and
- **Level 3**: Projection of future status

### 2.3.1 Level 1: Perception of the elements in the environment:
This is the first level in achieving the situational awareness. This involves perceiving the status, attributes and dynamics of relevant elements in the environment. This level is the most basic level of SA which leads to an awareness of multiple situational elements like objects, event, people, environmental factors etc and their current status like location, condition, modes etc by monitoring, cue detection and simple recognition.

### 2.3.2 Level 2: Comprehension of the current situation
This is the second level in obtaining SA, is by understanding what the data and cues perceived mean in relation to relevant goals and objectives. Comprehension is based on a synthesis of disjointed level 1 elements, and a comparison of that information to one’s goals. This level consists of combining the information to recognize how it impact on individual’s goals and objectives. This also includes developing a detailed image of the situation or of that portion of the situation that is concerned to the individual.

### 2.3.3 Level 3: Projection of future status
Once it becomes clear that what the elements are and what they mean in relation to the current goal, level 3 of SA is the ability what those elements will do in the future. Level 3 of SA can be achieved through knowledge of the status and dynamics of the elements and comprehension of the situation and then extrapolating this information forward in time to determine how it will affect future states of the operational environment.

Figure 2-2 (on next page) shows the Endsley’s model of SA, illustrating several variables that can affect the development and maintenance of SA. These variables are individual, task and environmental factors [18].

### 2.3.4 Situation awareness in team operations
Mostly in organizations people work in team. It is important to consider the Situation Awareness of team but not just individual members of the team.

#### 2.3.4.1 Team Situational Awareness
It is defined as “the degree to which every team member possesses the SA required for his or her responsibilities [22] [23]”. According to this terminology the success or failure of the team depends on the success of the each individual member of the team. If any member of the team has the poor situation awareness, it can affect the overall performance of the entire team.
So on the basis of this every member of the team must have high level SA on those factors that are relevant for his occupation. It is also insufficient for one member of the team to be aware of all important information, instead the member of the team who need that information is unaware. One of the forms of team SA can be as shown in figure 2-3.

![Figure 2-2 Model of situation awareness in dynamic decision making](image1)

![Figure 2-3 Team situation awareness](image2)
Chapter 2  Theoretical Framework

Every member in the team have specific role for achieving specific goal that is added up in the overall team goal. There are a set of SA elements that are concerned with each member’s sub goal. Team members are depending on each other in achieving the overall goal; figure 2-3 is presenting the overlap between each member’s sub goal and SA requirements.

2.3.4.2  Shared Situational Awareness
It is defined as “the degree to which team members possess the same SA on shared SA requirements [24] [25]”. There are requirements that are related to several members of the team. Most of the teamwork is in the area where SA requirements overlap. In a poorly functioning team, members have different point of view on share SA requirements while in good functioning team, each member of the team have common understanding of SA requirements. In figure 2-4, white areas is showing that every team member need not to know the every information about other team members. It is only that information that is related to the SA requirements of every team member that is required.

2.4  OODA (Observe Orient Decide & Act) loop
The OODA loop was developed as a part to explain why American fighter pilots were more successful than their adversaries in the Korean War [19]. OODA loop describes fighter combat in four stages. These four stages are

1) Observe
2) Orient
3) Decide &
4) Act

Observe involves getting some information about features of the environment i.e. detection of enemy aircraft. The second step is Orient which refers pointing one’s aircraft towards adversary so that to get better data for entering in Decide stage. Decide stage helps in making decision of what doing next. The final step is Act, which involves implementing that has been decided in previous stage. One of the decisions may be pressing the trigger.
According to OODA loop as shown in figure 2-5 there is a new observation after Act stage i.e. there are no consideration given for exiting from the loop. There should be consideration that if the act stage is successful then there may be nothing more to Observe. So in this case loop will exists. Boyd also noted that the American pilots and their aircrafts were better than their adversaries in all the four aspects as explained by the OODA loop [20].

Further work on OODA loop by Boyd, he developed a more general model for success and failure. It is shown in figure 2-6 that Boyd achieved generalization of the OODA loop by explaining the Orient stage from representing a physical orientation to representing a mental orientation and by introducing a number of feedback loops, thus actually placing the OODA loop in the cybernetic camp.

After the modification by Boyd in OODA loop it is now no longer a loop rather it is a stage model with multiple loops. Boyd also introduced a number of factors that affect the orientation achieved by the decision maker in Orient stage i.e. cultural traditions, generic heritage and previous experience, also mental process of analysis and synthesis [20]. These are all except analysis and synthesis are factors that affect the outcome of the orientation stage.

2.5 DOODA (Dynamic Observe Orient Decide & Act) loop(s)

Brehmer identified two problems in OODA loop: 1) The rendering representation of the delays in C2 is impossible due to the absence of representation of the effects of the ACT stage and 2) the lack of detail in its description of the requisite functions for effective C2. A DOODA stand for Dynamic OODA was developed by Brehmer to overcome shortcomings in OODA loop. The basic DOODA loop for research in
normative C2 science is the F-DOODA stands for functional DOODA, which represents the functions that need to be performed to achieve the mission as shown in FIGURE.

The C2 system consists of three functions and the sensors. Three functions are sense making, data collection and planning. The sense making function gives an understanding of the mission based on the action and the situation at hand in the form of Course of Action (COA), and takes data accordingly as it inputs the mission and the data acquired by the function data collection. Course of Action (COA) are translated in to orders by the planning function, which is considered to be the most important output of the C2 system. The outcome from the last step i.e. orders is translated into practical (emergency management) activity i.e. moving and extinguishing fire. These actions are then passed through frictions, which resulted in effects that are detected by sensors and passed into the data collection function [19].

Brehmer stress that sense making is a collective process of commander and staff together testing hypotheses whether it is explicit or implicit, using data, supervised by the mission. In the planning phase data will be hunted to check hypothesis whether COA will work in the execution phase, data will be sought to check whether the current plan needs change and if new COA need to be generated. Brehmer is of the view that there is no ultimate understanding of the truth; the sense making process refines the understanding that is continually needed to be revised by testing it against data. The original value of understanding can only be obtained from the results, the outcome of actions taken, and therefore what the outcome of actions taken must be part of understanding, According to Brehmer action is a component of sense making. On the basis of this model it is very difficult to assess sense directly, since most of it is implicit, and since outcome of actions may also be successful with incorrect understanding or unsuccessful for reasons other than truth of understanding, because of numerous factors external to the C2 system [19].

2.6 Functional Resonance Analysis Method (FRAM)

The functional resonance accidental model describes systems involving social and technical aspects, by functions rather than by structure. The aim is to capture the dynamics of these systems by modeling non-linear dependencies and variability with which functions are performed. FRAM states that both normal and failure are evolving phenomena that can’t be attributed to specific system components. The variability of performance in these systems is natural to enable people to cope with uncertainty and complexity. Every function is having normal weak variability. In FRAM functional resonance is an undesirable event that emerges from weak variability of many signals. This model was suggested by
Hollnagel (2004) for accidental modeling and for the purpose of complex system analysis; But the FRAM has over time also become to mean functional resonance analysis method. Following are the steps of FRAM [19].

1) Identifying functions
2) Characterizing variability
3) Defining functional resonance
4) Identifying barriers and indicators

2.6.1 Step 1: Identifying functions
There are six aspects that a FRAM module addresses for each identified function. These aspects are

1) Input: This presents what the function uses or transforms or in simple words, inputs.
2) Output: This presents what the function produces or in simple words, output
3) Precondition: This presents the conditions that must be fulfilled to execute the function.
4) Resources: This presents the resources which are required, when the function is carried out.
5) Time: This is the time available as a special kind of resource or constraint.
6) Control: This presents the supervisions for adjusting the function like plan, controller etc

In order to find the modules of the FRAM one may start with the top-level goal. This goal is then translated in to top-level function then starting with any function one may move to the related functions. Figure 2-8 presenting the FRAM presentation of the function.

![The hexagonal function representation](image)

2.6.2 Step 2: Characterizing variability
In order to elicit potential or actual variability eleven common performance conditions (CPCs) are identified in the FRAM method [19]. These CPCs are:

1) Availability of personnel and equipment,
2) Training, preparation, competence,
3) Communication quality,
4) Human machine interaction, operational support,
5) Availability of procedures,
6) Work conditions,

7) Goals, number and conflicts,  
8) Available time,  
9) Circadian rhythm, stress,  
10) Team collaboration, and  
11) Organizational quality.

These CPCs address the combined technological, human and organizational aspects of each function. After determining CPCs, the variability is to be determined in a qualitative way and to be expressed in terms of sufficiency, predictability, stability and boundaries of performance [20].

2.6.3 Step 3: Defining functional resonance
Step 1 result in a list of functions and each having its six aspects. These functions are then linked with their aspects. For example, the input given into a function produces output which is used as input for another function, fulfill a pre-condition, or produce a resource, or enforce a control or time constraint. When these links between functions are found, then through thorough analysis of functions and common or related aspects these links may be combined with the results of step 2 i.e. for characterizing the variability. The links together with common performance conditions specify where the variability of one function may have an impact, or may propagate. This analysis helps in determining how a resonance can occur of variability across functions in the system. For example if the output of a function is a unpredictable variable, another function that requires this output as a resource or as an input may be performed unpredictably as a consequence. Thus resonance is affected by the many such occurrences and propagation of variability. Also the additional variability under the normal detection threshold becomes a signal, i.e. a high risk or vulnerability.

2.6.4 Step 4: Identifying barriers and indicators
Barriers and indicators are to prevent unwanted events to take place or to prevent the consequences of unwanted events. Barriers can be described in terms of barrier systems and barrier functions. Barrier system presents the physical and/or organizational structure of the barrier while barrier functions present the manner by which barriers achieve their purpose. In FRAM four categories of FRAM are identified (each with their potential barrier functions) [19]:

**Physical barrier systems:** These barrier systems block the movement of mass, energy, or information. For example filters, safety belts and fuel tanks.

**Functional barrier systems:** These barrier systems establish a pre-condition that need to be met before an action to be taken by human and/or machines. For example locks, passwords, sprinklers etc.

**Symbolic barrier systems:** These barrier systems are indications of constraints on action that are physically present. For example signs, alarms, checklists etc.

**Incorporeal barrier systems:** These barrier systems are indications of constraints on action that are not physically present. For example ethical norms, group pressure, rules and laws etc.


FRAM is aimed at specifying recommendations for monitoring the performance and variability, to be able to detect undesired variability. Performance indicators may thus be developed for every function and every link between functions.
3 C3Fire

One of the most useful characteristics of C3Fire is that it is highly configurable, meaning researchers are able to generate any sort of dynamic environment by developing a session configuration file. The researcher selects some of the important features of the real world and inputs these features to the C3Fire simulation system. The simulation system retains these features and then generates a small and well-controlled simulated task environment that has complex, dynamic and opaque characteristics. Moreover, the task environment generated by the C3Fire system resembles very much with the cognitive tasks that people normally face in routine life. Figure 3.1 illustrates the above concept graphically.

3.1 Task Environment Requirements in C3Fire

In order to get the most out of the C3Fire simulation system, it is very necessary to generate such a task environment which reflects the team collaboration task. In order to create such an environment, the C3Fire simulation system must be input with dynamic context that demands distributed decision making. It is also possible to configure the task environment in such a way that it supports specific training and research goals.

3.1.1 Dynamic Context

In order to understand the concept of dynamic context, forest fire fits as a best example to describe this concept. The two major properties of forest fire are that it changes with respect to the subject’s actions, and secondly, it shows autonomous behavior. Similarly, fire-fighting organizations reflect dynamic autonomous systems, which can be governed by a group of decision makers in the organization. The dynamic context is reflected from this view of fire and fire fighting organization.

3.1.2 Distributed Decision-making

In C3Fire, the task of extinguishing a forest fire is distributed among the group of people. More specifically, the subjects are assigned different roles and they work in their own domain by coordinating with other subjects in the environment in order to fulfill the given task. In such kind of situations, the decision making process can be reviewed as a team decision making, because a single person doesn’t decide at its own rather a group of people decides after coordinating with each other.
3.1.3 Time Scales
The concept of working on different time scale exists in all most all hierarchical organizations, where decision makers work on different time scales. Same is the case with C3Fire simulation system that subject works on different time scales. There are two time scales in C3Fire short and high time scale. Low level operations like extinguishing a fire are done on short time scale, whereas people responsible for coordination tasks work on high level time scale.

3.2 Organization
In C3Fire the term “organization” is defined by the configuration of player definition and the communication structure of game participants. In C3Fire a player is defined by name (used to uniquely identify a player), the communication tools (mail or diary) that player is allowed to use, interface layout and the number of units which a player operates. Similarly the communication structure specifies the communication possibilities between the players and is configured by communication tools and the distributed map tools. Figure 3.2 provides the graphical representation of an organization in C3Fire.

Organizations in C3Fire can be setup in many different ways depending upon the training and research goals. C3Fire allows configuring organization for any number of players less than twenty, depending upon the processing capacity of the equipment used. Following are the two types of organization;

3.2.1 Hierarchic Organization
In such kind of organization group of people perform task under a certain hierarchic manner, means that all the operations are performed in a structured manner. This concept can be better understood by mapping it with a typical office environment, where there is a boss, then managers and then worker. Same is the case in hierarchic organization of C3Fire, where on the top is an administrator, then staff and fire fighting unit chiefs and so on. In such type of organizations the decision is made on top layers and persons on the lower layer receives commands from upper layer and perform actions on the basis of those decisions.

3.2.2 Flat Organization
In this type of organization all the people work by coordinating with each other. It is also referred as network based organization. On contrary to hierarchic organization there is no structured communication channel, hence all the people have to coordinate with each other in order to achieve a certain common goal. It reflects a true distributed decision making organization, where decision making process is split among different players. Figure 3.3 shows a typical structure of flat organization.

3.2.3 Organization Example
The typical C3fire environment is normally split among four layer organization, namely; emergency alarm centre, command and control staff, fire-fighting unit chiefs and the grounded units. Figure 3.5 gives the illustrative view of four layer organization example.
First layer helps staff to acquire information by sending them textual messages. This is computer controlled layer and can also be known as task assignor. Second layer comprises of staff which works on high level time scale, hence they are performing strategic task to understand the situation. More specifically they command and control the fire fighting organization. They work as decision maker and get information from the upper layer and make a bidirectional communication with the fire fighting unit chiefs, residing on the third layer. Fire fighting unit chiefs are responsible to control the ground units on the basis of the commands they receive from the staff. The last layer comprises of computer simulated units, these units move around the environment to extinguish forest fire.

### 3.2.4 Modeling Notation

Modeling notations describes the graphical way of representing the organization. In thesis we use two diagrams to represent a single organization, the control structure diagram and the communication structure diagram. Table 3.1 shows a typical example of an organization control structure.

<table>
<thead>
<tr>
<th>Fire Fighting Unit Chiefs</th>
<th>Fire Fighting Units &amp; Reconnaissance Persons</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>F1, F2, F3, F4, F5, F6, W7, W8, G9, G10</td>
</tr>
</tbody>
</table>

Table 3-1 Modeling Organization Command & Control Structure
3.2.4.1 Control Structure Diagram
The control diagram is used to define the players along with their relevant units in the session environment. This diagram presents the control structure of each individual player i.e. which player is controlling which units. The players are represented by stick man and their corresponding unit lies right below them in form of square. If a player doesn’t control any unit then there is no square underneath him e.g. Staff. Basically the square contains the name of the player which is also used as a unique identifier. The name format is:

\[
\text{<A Single Character><Unique Numeric Value>}
\]
The single character represents the role of the player. A complete list of all current roles along with their character code and color is shown in table 3.2.

<table>
<thead>
<tr>
<th>Role</th>
<th>Character Code</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire Fighter</td>
<td>F</td>
<td>Red</td>
</tr>
<tr>
<td>Gasoline</td>
<td>G</td>
<td>Yellow</td>
</tr>
<tr>
<td>Water</td>
<td>W</td>
<td>Blue</td>
</tr>
<tr>
<td>Fire Break</td>
<td>B</td>
<td>Gray</td>
</tr>
<tr>
<td>Helicopter</td>
<td>H</td>
<td>Green</td>
</tr>
</tbody>
</table>

Note: It is also possible to add new roles, above are the only existing roles

The second section of the unit name is a unique numeric value; normally it starts from one and represents the total number of players.

3.2.4.2 Communication Structure Diagram
The second figure is used to represent the communication structure among the player in this figure the players are represented by a circle containing their names and communication among players is represented by a straight line connecting two players. Table 3.3 shows an example of two different alternatives of an organization communication structure.

![Mechanisms (Coordination & Communication)](image)

Table 3-3 Modeling Organization Communication Structure

3.3 How to Create a Session
Session represents a task environment which is used for either training or research and is generated by C3Fire system, which retains some of the important characters of real world selected by the trainee or researcher and then generate a task environment based on those characteristics. Since C3Fire is highly configurative system, so a trainee or a researcher is able to specify all the characteristics by developing
configuration files. All the configuration files are written in XML. In order to create a proper session following configuration files are required:

3.3.1 Session configuration file
This is one of the major files for generating C3Fire task environment; this file contains the static configuration values used to define the organization and elements of task environment. More specifically this file specifies the setting for the subject, including their roles and the simulated units that they should control. Along with this information the session designer also defines the parameters for user interface layout and geographical environment. This file is saved by the .con extension.

3.3.2 Scenario Definition file
On contrary to the session configuration the scenario definition file helps session designer to define the dynamic characteristics of the session. It contains the events that will be triggered at a specific time during the life time of session. These events are also called as time stamped events. This file is saved by .sce extension.

3.4 The Monitoring Module
Among the important features of C3Fire monitoring is also one major feature. It enables researchers to analyze the collaborative work in the C3Fire system. The type of monitoring that C3Fire provides is computer based monitoring. This feature is available in the simulation system, which automatically logs all the events that are occurred during the session.

The backbone of this feature is the session log files which are automatically created when a session starts. This log file maintains a log of all the events occur during the session, along with all the computer mediated activities. There are four major sources of information, namely; simulation system, GIS Module, Mail and Diary. The information gathered from simulation environment is related to current activities and the simulation world. The GIS module adds to information by providing personal information in terms of marks on the personal map. Finally the mail and diary tool provides information about collaborative work. The information fetched from these sources are classified in to three major categories, namely; Operational information, Collaborative information and Personal work information. This information is then stored in log file and log file is centralized by saving the log file on the C3Fire server. Once the information is centralized then it is further used for performing quantitative analysis or in replaying the old session. Figure 3.6 illustrates this above concept in graphical form.

The information obtained from simulation environment is mainly used to measure the performance of a subject. Similarly the information obtained from GIS is mainly used to observe the situation awareness and situation distribution parameters. In comparison with the GIS and simulation information the information obtained from communication tools (mail and diary) is bit harder to use for qualitative analysis because it requires information parsing.
Qualitative analysis is used to analyze the performance of each player and how collaboratively they work together. The information that is used to perform qualitative analysis is mainly obtained from the simulation environment and the communication tools.

The replay feature acquaints the C3Fire user with the facility of playing back the complete session, which has already been conducted. This feature shows all the simulated activities and events held during the original session. It is one of the most important features and is helpful in many ways by satisfying the needs of different audiences, it helps students to observe and then students start presenting their
views. Similarly it helps researchers to observe and analyze the activities performed in the simulation environment.

3.5 Objectives of C3Fire
The prime objectives of C3Fires simulation system are to train team decision making and to conduct research in team collaboration. In this section both of these objectives are discussed in detail. Figure 3.7 gives the abstract view of C3Fire objective.
3.6 Training
The first objective of C3Fire is to train team for performing various tasks. This objective is accomplished by generating a dynamic task environment where group of people co-operate to extinguish a forest fire.

3.6.1 Training Goals
After a successful team training a team is able to perform:

- Distributed planning and decision making
  - The planning and the decision making process is distribute among a group of people
- Coordinated actions
  - Group of people coordinate in an effective manner to achieve a common goal
- Communication and tactical reasoning
  - Tactical reasoning is among one of the desired goals, when the team is trained about avoiding the common reasoning errors such as decreasing willingness to make decisions etc.

The major focus of training is on the following three subareas:

- Emergency management systems
- Decision Making (discussed in chapter 2)
- Forest fire fighting domain training

3.6.2 Emergency Management Systems
Emergency management is defined as the set of measures that has taken to deal with and to avoid disasters or unforeseen. It involves preparation for the disaster (before its occurrence), responding to disaster (once it has occurred) and then recovering from disaster. In general the term “emergency management” represents a process in which entities manage to avoid or reduce the impact of hazardous events.

Emergency Management Systems are classified as social dynamic systems, in which the goal of decision maker is to define and organize a set of actions in order to achieve a given task by reducing the negative consequences as much as possible. These systems are often so complex that some type of hierarchical organization is required, to operate such systems.

These systems are composed of three entities; target system, controlling system and the staff. The target system represents the target area of emergency management organization’s operations. The example of target is forest fire and the example of operation is extinguishing forest fire. The controlling system refers to the entities that help staff to control the target system; they directly operate on the system based on the commands from the staff. Whereas the staff works only as a decision maker and doesn’t directly operate the system, their task is to only command and control their subordinates based on the situation.

3.6.2.1 Complex Dynamic Systems:
The two major properties of both emergency mgmt system and military systems are that they are complex dynamic system and are controlled on the basis of distributed decision making. Along with these properties such systems also depicts autonomous behavior. These characteristics make such system difficult to predict and control, because system changes it states both autonomously and on the
basis of subjects actions. One of the important task is to train the subject about understanding the current state of the system.

3.6.2.2 Emergency Management Training

Knowledge of a person about his task and system can be classified into two categories; theoretical knowledge (the knowledge that is gained from theoretical studies) and the experience-based knowledge (knowledge that can be learned from experience). This kind of knowledge is referred as “compiled conceptual knowledge” and is considered as a good target for simulation based learning environment. This knowledge can also be illustrated in graphical form (figure 3.8) by the help of “Rasmussen’s three levels of human action control”.

Human behaviors are classified into three main categories; knowledge base, skill based and rule based. The knowledge based represents activities activated from explicit goals and mental models. The rule based behavior represents the activities that are controlled by rules or procedures and the skill based behavior represents the activities based on intentions.

The purpose of using emergency management system is to let the trainee experience the system so that they make concrete knowledge of their task. Secondly it is sometimes too expensive or impossible in terms of human resources to perform in real life situation. So in such cases these emergency management systems are used.

![Figure 3.8 A Three level description of human action control [6]](image-url)
**Training Goals:**
In general the goal of training is to let trainee be aware with the dynamic nature of the task environment, and enable them to learn that how to perform in an emergency situation. The training goals of a typical emergency management system are classified into four types, namely; Targets System, Controlling System, Tactical Reasoning and Work situations. The goals regarding target systems are to learn about the target system, its concepts and the relation between the concepts of those systems. The goal of controlling system is to get an understanding of the emergency organization.

The training strategies used in such type of systems are normally based on briefing, debriefing. Briefing reflects the activity of informing the staff in advance that what they are supposed to do. Whereas the debriefing represents the process where the teacher and the staff discusses various activities performed during the training session.

**Simulation of surrounding world:**
One important factor to consider in emergency management system is the simulation of the surroundings, that it should be as realistic as possible. So that it generate the same behavior pattern as in real world. This behavior pattern is used by the staff in the development of mental model of real world. Some major problems in the simulation include the interaction in natural language, complex activity description of actors in organization and target system.

### 3.6.3 Forest fire fighting domain training

The training of forest fire fighting domain is based on the forest fire concepts. Along with those concepts C3Fire is used for the simulation of the forest fire, so it helps trainee to experience the fire behavior, organization working, situation assessment and communication infrastructure, under a controlled and well defined simulation environment. The basic training strategies that are used in C3fire are briefing and debriefing. The knowledge that a trainee can obtain during a training session is classified into three types the knowledge about the target system, knowledge about the controlling system and finally the tactical reasoning knowledge. These three sorts of knowledge enable staff to command and control forest fire operation in an effective manner.

#### 3.6.3.1 Forest Fire fighting Concepts

Another aim of training is to familiarize the organization with the fire fighting domain. So that the organization should be able to command and control forest fire extinguish operations. This section describes the fire fighting domain, by discussing the target system, controlling system of forest fire fighting and the tactical reasoning (discussed in chapter 2)

**Target System:**
The target system in forest fire fighting domain is forest fire and the environment in which fire is burning. In order to extinguish the fire in an effective manner the fire fighting organization must have the knowledge of fire concepts, types of fire and fire behavior.

- **Fire Concepts:** The forest fire always spread in doughnut shaper (an oval like shape hollow from inside) from a point where it starts burning. It is classified into four different areas; head, rear, left and right flank. Figure 3.9 shows these parts of fire.

![Figure 3-9 Parts of Forest Fire](image-url)
• Classifications of fire: Forest fires are classified into the following four types, Figures 3.10 demonstrates these four types of fire:
  o Surface Fire: Surface fire includes the fire on the ground surface like in the grass or bushes. This fire spreads more rapidly as compared to any other natural fuel.
  o Mid-level Fire: Mild level fire is bit intensive than surface fire, but less than two meters in total height. It generates a lot of smoke.
  o Crown Fire: On contrary to the mid level fire, this fire is in the upper portion of forest like in foliage, twigs and smaller branches. This fire can have high spread rate.
  o Ground Fire: Ground fire is a type of fire that is under the ground in roots and in fallen material produces no smoke and usually spread slowly.

![Figure 3-10 Forest Fire Classifications](image)

• Forest Fire Behavior: This subsection presents the behavioral characteristics of fires, which helps staff to command in a successful manner. This behavior is predicted from rate of spread, fire spread directions and behavioral characteristics. The staff has to keep in mind these factors while extinguishing forest fire.

Controlling System:
The controlling system for forest fire fighting domain comprises of staff and their subordinates. The organization structure of the fire fighting operation depends upon the geographic location, technical knowledge, situation and some other parameters. The typical organization structure that is followed majority is hierarchical with at least three layers; comprising of commander and staff layer, chief layer and the fire fighting unit layer as shown in figure 3.11.

The first layer contains the staff which is responsible for decision making based on the situation in the forest they also get information from some outside world like police, hospital etc. which are not the part of fire fighting organizations. Chiefs work as mediator between the staff and the subordinates, they are responsible for taking work form subordinates based on the decision they get from the staff. Staff and chiefs are normally located at some distance from forest fire. The subordinates represents the actual fire fighting units that operate in the ground based on the instructions they receive from chiefs, they are located near the forest fire.
3.6.4 Training Management

The C3Fire simulation system also provides the feature of automatically storing all important events, communications, activities, etc. This stored information is detailed enough that it can be used later for analyzing training and for replaying whole sessions.

![Diagram of a three-level fire-fighting organization]

Figure 3-11 A three-level fire-fighting organization [9]

It works by using the replay feature in C3Fire simulation system, by the help of this feature the training managers and students are able to perform a playback of the whole session in an 'after-action review',
which provides them a good opportunity to discuss and compare the simulated event from different prospective. Figure 3.12 represents training management graphically.

3.7 Research

The second major objective of C3Fire simulation system is to conduct research on Command, Control and Communication. The idea behind this research is to bridge the gap between valid field studies and laboratory research in a cost effective manner. In order to generate a task environment which reflects a good and collaborative team work then the C3Fire system must be input with a dynamic context like distributed decision making. In such a task environment decision making process is in hand of multiple people and these people work along different time scales. So it creates an effective distributed decision making scenario.

Since C3Fire is highly configurative system, it works by retaining some important characteristics of the real world, and then generates the task environment based on these characteristics. It allows researchers to configure the system in such a way that it will meet all of their research goals. Researcher is able to configure session organization and can also control the organization size (max 20 players) depending upon the goals of the cognitive task and the capacity of the equipment. Similarly, the researcher can also configure user interfaces and communication tools for all individual players. In addition to this it is also possible for a researcher to control some aspect of collaboration by designing a session in such a way that it impacts on the collaborative process.

Apart from this the domain i.e. forest fire fighting also plays a major role in research, it helps researcher by providing a dynamic environment for the players. Moreover this environment allows working on different time scales. The players are presented with different kind of task; they are engaged in goal analysis to identify priorities and sub goals and to resolve conflicts. Similarly, they are involved in the decision making process by working in the dynamic environment. Above all the player also has to learn the task environment in order to operate the environment. During a session a subject can make some common mistakes like they following ad hoc approach, misinterpreting the things etc. The learning task and typical errors that a player makes help researchers to create an environment with such research goals that supports all these factors.

Conclusively, these all feature create a pure research environment for a researcher, which enables them to conduct a research in an easy manner. In the following we will look at the two major features of C3fire system that is of subsidiary interest of researcher.

3.7.1 Monitoring

This feature is used to record or to store the ongoing session in to C3Fire central server. It retrieve information from four major sources; simulation environment, GIS, mail and diary tool. It then sends this information to the log process which stores this information in structured log files and central database after processing it. This stored information is then used for quantitative analysis, replaying session and for situation detection. The qualitative analysis and the replay feature is supported by the system, whereas the advanced quantitative analysis and the situation detection requires some addition effort from researcher to analyze the structure log files in advanced manner. (See section 3.4, for detail)
3.7.2 Analysis
One of the major information that a researcher requires to perform a research is the data on which s/he performs some statistical analysis. The analysis module of C3Fire helps researchers to perform quantitative analysis and even replay the whole session. The data that is used to perform quantitative analysis is gathered by the monitoring module while a certain session is running. More specifically this module acquaints the researchers with frequency and statistics information. This module also performs SQL database queries on the collected session data. The analysis goals are categorized into four types;

3.7.2.1 Team Effectiveness
This analysis technique is used to judge team effectiveness, that how team has performed during a session. The common way for measuring team effectiveness is introducing some scoring system, which calculates the score based on the goal and player task.

3.7.2.2 Information Distribution
Another way to analyze the player performance is to observe that how well they collaborate with each other. It can be achieved by analyzing the communication between the players using the communication tools i.e. mail and diary.

3.7.2.3 Situation Awareness
The third type is used to analyze student’s situation awareness. It can be done by using the GIS feature, where subject shares his view and about the state during the session. Later the manager compares the actual state with the subject’s opinions. The GIS tool also keeps track of time when views are inserted to the system and then calculate accuracy in terms of information type and time difference between time when views are inserted and the time when simulated activity occurs.

3.7.2.4 Work & Collaboration Method
It is also possible to detects the players collaboration method and the way players work, but it can only be achieved by using the advanced classification method. A common example to demonstrate this concept is to categorize the communication between the staff members and the chiefs and then count mission orders and commando orders. This indicates type of command. Figure 3.13 presents the goal of analysis.

![Figure 3-13 Goals of Analysis Module](image-url)
4 Developing Prioritization Skills in Decision Making

4.1 Training Goals

Our first task is to train the team in such a way that it will be able to develop strategies, prioritize tasks & perform planning while making decisions in emergency situations. Figure 4.1 depicts these three properties. Our major area of concern is prioritizing tasks because strategy development and planning is always involved in almost every successful project. However these three areas are discussed below in more detail:

**Develop Strategies:**
The first training goal is to train the team in such a way that it should be able to develop effective strategies (to extinguish forest fire) in both of the following scenarios;

1) When they are aware with the task environment i.e. they have situational awareness (Section 2.3)
2) When they suddenly face the environment i.e. they don’t have situational awareness (Section 2.3).

**Task Prioritization:**
The second training goal is to prioritize the task in emergency management. This can be achieved by following OODA loop. This model helps how to manage the emergency situation by following a four step process i.e. Observe, Orient, Design and Act (Section 2.4)

**Planning:**
The third training goal is to strengthen the planning and decision making skills of the team. So that team can effectively coordinate to develop strategies and prioritize the tasks.

![Figure 4-1 Properties of Fire Fighting Team](image)
4.2 Organization Description

In order to develop the above three characteristics in a team, we develop an organization of six players, in which two players are assigned the role of staff (S1 and S2) and rest four players are assigned the different roles among grounded units. The duty of two staff members is to only get aware with the situation and on the basis of the situation they guide the players (W, X, Y and Z), controlling the grounded units. Means they don’t directly operate the system they only command and control the players managing the grounded units.

There are ten grounded units which are operated by four players (W, X, Y and Z). The player W can operate three fire fighter units (F1, F2, and F3). Similarly the player X can also control three fire fighter units (F4, F5, and F6). The player Y is provided the responsibility of water refilling by operating two water units (W7 and W8). The player Z is assigned the responsibility of refilling the fuel, which can be done by the help of two fuel units (G9 and G10). This command and control structure is graphically presented in the table 4-1:

<table>
<thead>
<tr>
<th>Fire Fighting Unit Chiefs</th>
<th>S1</th>
<th>S2</th>
<th>W</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire Fighting Units &amp; Reconnaissance Persons</td>
<td>F1</td>
<td>F2</td>
<td>F3</td>
<td>F4</td>
<td>F5</td>
<td>F6</td>
</tr>
<tr>
<td></td>
<td>W7</td>
<td>W8</td>
<td>G9</td>
<td>G10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The communication structure of these six players is designed in such a way that the player S1 can only allowed to communicate with the player S2 on the basis of current ground situations. Whereas the player S2 is allowed to communicate with the rest four players, it is also able to coordinate back with player S1. The responsibility of S2 is to coordinate with the relevant player/players on the basis of the instructions received from player S1. The four players who are controlling the grounded units are allowed to communicate with each other and with player S2. This communication hierarchy can be better understood by the table 4-2;
### 4.3 Scenarios Types

Two different scenarios are developed to develop the prioritization skills of a team. The two scenarios are based on the same organization and same communication structure, the only difference is that in the first scenario the players have given no time to plan and to organize their units because in this scenario the fire is set up right after the game starts means they have no situation awareness and they just know playing the game. But in order to provide some ease to the players all the units are placed near different fire locations according to their intended purpose.

In the second scenario the fire was set up after two minutes from the start of the game and along with this the participants were also informed with the fire locations on the map before playing the game means that they have high situation awareness. Moreover in this scenario initially all the unit are placed in the center of the map, so that player can chose by themselves that which unit goes where and perform what.

The subsequent section describes the scenarios from static and dynamic point of view. The time information given in the static section is according to the second scenario (the scenario in which team has high situation awareness). So in order to compute the time information for the first scenario, simply subtract 2min from the time values given in that section.

### 4.4 Scenario Description

We design scenario in such a way that it fulfills all of our three goals, in order to enable team to learn about developing strategies, we set fire at three different locations in the map so that the team start working in a planned manner to successfully extinguish forest fire. In addition to this we also introduce custom objects to the task environment, so that the team should learn to prioritize tasks in dynamic situations.

#### 4.4.1 Static Information

The static information presented here is the static view of task environment. Fire locations its spreading speed and other similar information based on the session configuration is discussed here. In addition to this, the static information about the custom objects and information about fire fighting team is discussed by describing the optimal stats in which the fire should be extinguished.
4.4.1.1 Fire Information
As discussed earlier the fire was set at three different areas on the map. Figure 4-2 shows the whole task area pointing to the three fire areas, namely fire in middle left area, top left area and bottom right area.

Fire in the Middle Left:
This fire is less critical among the three fire locations, because it don’t have any critical objects near it. Although there are some pine trees in the bottom of this fire location but these are far away from the fire and it requires 1min & 43 sec to reach to the pine trees, and once it ignite a pine tree then situation become more critical because some house are located at some distance from pine trees and it took
6min & 58 sec to ignite the house if fire not extinguished. So the fire fighting team has less than 1min & 43 sec to successfully control this fire and 6min & 58sec to control this fire after a little loss (pine trees). If the fire is still not control then it starts spreading other objects. Figure 4-3 presents the graphical view of this fire area and its surroundings.

**Fire in Top Left:**
This fire is more critical than the first one because it contains important objects in its surroundings. There are some pine trees, people and vehicles on the top of fire and in the bottom there is a school and a bank. Fire requires 5min & 36sec to ignite a school, 3min & 50 sec to ignite a bank, 4min and 30sec to ignite pine, and 7min & 10 sec to ignite people and 4min & 55sec for vehicles and 2min &22 sec for birch trees. So fire fighting team has less than 2min & 22sec to successfully extinguish this portion of fire. Figure 4-4 presents the graphical view of this fire area and its surroundings.
Fire in Bottom Right:
This fire area is of most critical importance because it contains the important objects near its surroundings like houses, bank people and pine. It took 3min & 8sec to ignite bank, 3min & 30 sec to ignite people, 3min & 53sec to ignite upper pine, 3min & 53sec to ignite lower pine, 5min & 50sec to ignite birch and 4min & 40 sec to ignite houses. So fire fighting team has less than 3min & 8 sec to successfully extinguish this portion of fire. The following figure presents the graphical view of this fire area and its surroundings.

Following graph (Figure 4-6) shows the static information about the objects and their burning time, based on the information which we described above.

Figure 4-5 Critical Object that may be effected by fire in bottom right position

Figure 4-6 Graphical representation of Static Data
4.4.1.2 Objects

Three new objects (people, vehicle & bank) introduced into the system to develop the prioritization skills in team. Following are the different types of objects along with their burning time.

- Normal Vegetation
- Pine trees burn three times faster than normal vegetation.
- Birch trees burn at half the rate of normal vegetation.
- Swamp never burns.
- People burn three times faster than normal vegetation.
- Bank burns four times faster than normal vegetation.
- Vehicle burns four times faster than normal vegetation.
- School burns as fast as normal vegetation.
- House burns as fast as normal vegetation.
- Fuel Station having unlimited fuel and never burns. In order to refill the fuel, units (Firefighter, fuel and water) must be on the NEWS (North, East, West or South) location. If the unit will be on the fuel station cell there will be no refill of fuel.
- Water Station having unlimited water and never burns. In order to refill the water, units (Firefighter and water) must be on the NEWS (North, East, West or South) location. If the unit will be on the water station cell there will be no refill of water.

Out of these three new objects two are materialistic and the rest one represents human beings. This means that bank and vehicles are less important than humans. But on the other hand a loss of bank results in great financial loss. So it requires a fire fighter to think thoroughly before making any decision and in order to put some ease into the system we add vehicle as third object, which is of least importance among all the three objects. But it also has a fuel tank embedded in it so the burn out time for the vehicle is higher than the remaining two objects, which again puts decision maker in confusion. So conclusively all these objects are used in conjunction to develop the prioritization skills of the fire fighting team.

4.4.1.3 Unit Information

Unit Movement Calculation:

- Initially all the units except fuel units have 60 units of fuel and the fuel level countdown speed is 1 unit of fuel per second. It means that each unit is able to move for at least 1 min without requiring any further fuel.
• And the moving speed of each unit is 3sec, (means it requires 3 seconds to move around a single square)
• So initially a unit is able to cover 20 squares, without requiring any further fuel

**Fire Fighting Calculation:**
• Initially all the fire fighters have 90 units of water with them and the water level countdown speed is 1 unit of water per second during firefighting. The Fire Fighter Fighting Speed is 5 sec, means it takes 5 sec to close out fire from single square
• So a single fire fighter unit is able extinguish fire from 18 squares without requiring any further water, hence initially fire from 18 squares can be extinguished without requiring any further water

### 4.4.2 Dynamic Information
In this section we will discuss the decision making from dynamic perspective by stating the information which we gathered by practically running the configuration. As described above that the organization is defined in such a way that it requires 6 players to accomplish given task by coordinating and communicating with each other. Hence we invite 6 persons to play in the simulated environment all of them belong to Asia. First, we gave them a brief presentation about C3Fire simulation environment and then gave them player instructions manual, so that they read and learn how to operate the simulation environment.

Afterwards we present two task environments to these players, both are similar in behavior and in geographic view, the only difference is that in first environment the team has high situation awareness because they are informed about the situation and the fire sets off after 2 min, it gives some time to the team to plan and then assemble their units accordingly. Whereas in the second scenario the team has low situation awareness because they faced the same environment all at sudden and fire sets up directly they don’t have any time for planning. We then observe and analyze the both situations and the behavior of the players. In the following we discussed the findings of both the scenarios.

#### 4.4.2.1 Performance of team having low Situational Awareness
We analyzed the configuration environment from the OODA loop perspective, when we run the configuration using first scenario the team was having no time for observing the environment also they were having low situational awareness. So they can’t make planning (i.e. can’t orient themselves according to the situation) in advance to extinguish the fire. So they have to decide at runtime of how to extinguish the fire. If we classify the fire in the order of criticality then the fire at middle left was less critical, fire in the top left was more critical than last one and fire at the bottom right was most critical. When the game started the initial position of units are near the fire areas, So that they don’t take much time & resources to move along the map. We observed the team management for extinguishing the fire at three different locations. We explained the fire at three different locations in the ascending order of criticality.
**Fire in the middle left:**
In this area team successfully extinguished the fire without any loss of objects (people, pine, birch etc). Two firefighters managed the situation without spreading the fire in other cells. Figure 4-7 represents the screen shot of this specific fire area which is taken during the replay of original session.

![Figure 4-7 Fire Conditions in Middle Left Area](image)

**Fire in top Left:**
In this area the team also successfully extinguished the forest fire without any loss of objects (people, pine, birch etc). This fire was controlled by two firefighters. There was some spread of fire but it didn’t destroy any object because the objects were far away from the fire. The screen shot of this specific area is also shown in the Figure 4-8.

![Figure 4-8 Fire Conditions in Top Left](image)

**Fire in Bottom Right:**
This was the most critical area for extinguishing the fire because there were a lot of critical objects in the surroundings. Initially two firefighters rushed to the fire place as there were more critical objects; the speed of spreading the fire was more than other two locations. There was some loss of pines and vehicles but they managed to save the humans, houses and bank. Other firefighters were also there from other fire locations to help extinguishing the fire after completing their own tasks. Figure 4-9 shows the screen shot of this specific area.
4.4.2.2 Performance of team having high Situational Awareness

In this scenario we give some time (2min) to team before the fire set up. So the players should be able to assemble their units in the appropriate places and make planning by coordinating with each other. So in this scenario team was having better planning based on their observation of the configuration environment and they orient themselves for the situation. They already decided the places that which unit should be sent to which location to take further action. Now we will see the team management for extinguishing the fire at three different locations. During the test the water was enough so that there was no need to demand water from any water unit. In the case of fuel, the team planned that the fuel refill unit provides fuel to only those units who are fighting fire or who are far away from refilling units, because there are only two fuel units who needs to cater the fuel requirements of rest eight units and the rest units tried to best manage the fuel by refilling it from nearest refill station so that there should be low dependency on the fuel units. We are explaining the fire at three different locations in the ascending order of criticality.

Fire in Middle Left:
This was the least critical area on the map for extinguishing the forest fire with respect to the criticality of the fire. Team adjusted itself by sending two firefighters at this location. These firefighters were successful in extinguishing the fire without allowing spreading it. The figure 4-10 shows the screen shot of that specific fire area.
Fire in Top Left:
This was the second most critical area on the map for extinguishing the forest fire. Team decided to send two firefighters at this location. Finally two firefighters were successful in extinguishing the fire without any spread of fire. The diagrammatic representation of that specific fire area is shown in the figure 4-11.

![Figure 4-11 Fire Conditions in the Top Left Area](image)

Fire in Bottom Right:
This was the most crucial area on the map. So the team decided to send three players at this location. Hence, on the basis of high situational awareness and planning they managed the most critical area without burning any object and without any spread of it. The figure 4-12 showing the screen shot of fire situations in the bottom right position.

![Figure 4-12 Fire Conditions in the Bottom Right Area](image)

4.5 Analysis Instructions
The information presented in this section is helpful to managers, observers and analysts. It provides them instructions that enable them to analyze the task environment. These analysis instructions are classified into two major categories; qualitative analysis and quantitative analysis. In C3Fire simulation system the quantitative analysis is performed by the help of log files and by retrieving the information...
stored in database, describing the activities performed during the session simulation. The qualitative analysis was performed during the session play. Figure 4-13 presenting the graphical view of the analysis categories along with their possible means.

4.5.1 Quantitative Analysis
This type of analysis is performed on the base of the log files, automatically created after playing a session. This analysis is also referred to as the post session analysis because it is performed after running the task environment. The log file contains all the information about the activities occurred during the whole session. The information present in log file is in XML format. Its bit trickier to read and extract information from log files. In the following we discuss how to read & understand the information given in log file by describing the major tags.

<SessionInfo>
This tag provides the information about the session, like experiment name, type etc.

<LogEventInfo>
This tag contains the static information in it, means that the information is same for all the log files. Basically contains the information about events, activities performed by the units, types of session control and mark events.

<Events>
This tag provides information about the roles, units, fire types and object types. In fact these all types are associated with unique ids which are further used in <log> tag. The log tag contains the most critical information of the whole session, because its store all the activities performed during the task environment.

Figure 4-13 Analysis in C3Fire Simulation System
4.5.2 Qualitative Analysis
This analysis can be performed by manager or observer. It can be performed at the time when session is running. The result of this analysis is totally based on analyst perception and experience. It helps analyst (manager or observer) to analyze the situation:

- By observing the activities performed by different players during the ongoing training session
- By reading the mails sent during the session and then analyzing the information contained in those mails.
- To achieve a certain goal by giving specific commands to units during the ongoing sessions.
- By looking at the unit positions in the map and then analyzing whether they are operating in organized manner or not.

This section discusses some important points to consider while observing the session. The user interface available to manager or observer provides several types of information in the form of different palettes. The important palettes are discussed below

**Wind Palette:**
Wind palette provides information about the wind direction and speed. While measuring the performance of team the wind factor should also be kept in mind. In other words the wind factor should also be added into the decision parameters list. The information about wind can be obtained from wind palette (figure 4-14) at specific interval of time.

![Figure 4-14 Wind Palette Example](image)

**Role Panel:**
Use this palette to realize which units are active and which are not, if all are not active then observe the inactive unit and realize its behavior from time to time, if its state is inactive for short time then its fine otherwise try to find the root cause and take preventive measures accordingly.

![Figure 4-15 Role Panel Example](image)
Unit Info & Unit property palette:
These two palettes gives detailed information about the units, including their current position, intended position, activity, and amount of fuel and water which it currently has. The difference between both the palettes is that the unit info provides a brief info about all the units in tabular form whereas the unit property palette displays the detailed information about each individual unit.

<table>
<thead>
<tr>
<th>ID</th>
<th>Pos</th>
<th>GoTo</th>
<th>Activity</th>
<th>Water</th>
<th>Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>F, 30</td>
<td>O, 29</td>
<td>Moving</td>
<td>90</td>
<td>57.00</td>
</tr>
<tr>
<td>F2</td>
<td>G, 11</td>
<td>J, 11</td>
<td>Moving</td>
<td>90</td>
<td>54.00</td>
</tr>
<tr>
<td>F3</td>
<td>Z, 39</td>
<td>A, 30</td>
<td>Moving</td>
<td>90</td>
<td>60</td>
</tr>
<tr>
<td>F4</td>
<td>AM, 25</td>
<td></td>
<td>Unactive</td>
<td>90</td>
<td>60</td>
</tr>
<tr>
<td>F5</td>
<td>H, 23</td>
<td></td>
<td>Firefighting</td>
<td>90</td>
<td>54.00</td>
</tr>
<tr>
<td>F6</td>
<td>F, 27</td>
<td></td>
<td>Unactive</td>
<td>90</td>
<td>60</td>
</tr>
<tr>
<td>W7</td>
<td>C, 9</td>
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<tr>
<td>W8</td>
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<td></td>
<td>Unactive</td>
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<td>0.00</td>
</tr>
<tr>
<td>Q6</td>
<td>Y, 19</td>
<td></td>
<td>Unactive</td>
<td>200</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Figure 4-16 User Info Palette Example

4.6 Common Episodes
This section presents the different scenarios with respect to the operations performed by the different units, and on the basis of fire spreading and its surrounding objects.

4.6.1 Fuel Perspective:
It was observed that during firefighting, fuel was required to move from one location to another. As there were limited fuel units which have to fulfill the requirements of all firefighting units, water units and their own requirements of fuel. In order to refill the fuel it was better to communicate the nearest fuel unit or fuel station rather than calling the fuel units every time.

4.6.2 Water Perspective:
Water is also necessary for firefighters to fight against fire. It was also important here to communicate the nearest water unit or water station rather than calling the water units every time.

4.6.3 Middle Left Fire Area
Firefighting perspective:
Middle left area was considered least critical because, although there were some critical objects around it but there were swamp which saved them from burning. Another important point which must be noted here was that it was not good idea to totally ignore this area when fire ignites. There were some pines around the fire whose burning speed was rather faster. If it will be ignored then fire will move very quickly covering all pines and it will continue moving towards houses by burning all surrounding objects like vehicles, people and school. Figure 4-17 show the fire conditions in the middle left fire area.
4.6.4 Top Left Fire Area

Firefighting perspective:
Top left area was considered to be of more critical than middle left area because there were a lot of critical objects like people, bank, school, vehicles, pines and houses around the fire. If this area was not given importance then it can start destroying these objects. One important decision to be taken in this region is that how much firefighters needed there to extinguish the fire and their coordination because if fire spreads it can burn pines, school and bank. Although school is nearer to fire but there is birch in the path of school whose burning speed is quite slow so in this case fire will first reach the bank and pines so some form of prioritization is very important there. If fire will reach the pines it will spread very quickly burning all vehicles, people and houses. As the fire will start spreading it will become difficult to control it.
4.6.5 Bottom right Area

Firefighting Perspective:
This was the most critical area in the map as fire was much closed to the objects. This area requires a serious attention of the firefighters. In this region all the objects were almost equal distance from the fire. In the case of negligence on any side may destroy the critical objects. One important decision in this case was prioritization because on south of the fire there were pines, on east there were houses and birch, on the north there were vehicles, bank, pines and people. This area required a considerably more firefighter’s attention. If there is a spread of fire it becomes more difficult to control the fire because most of the objects were igniting quickly. Figure 4-19 shows the fire conditions in the bottom right fire area.

Figure 4-19 Fire situations in bottom right area
5 Information Searching Using UAV & Non-UAV

The information presented in this chapter is related to our second task i.e. “Information searching using UAV and non-UAV”. This chapter presents goals of this task along with the description of organization that is used to achieve this task. Moreover a detailed description of scenarios is also given in this chapter covering both the static and dynamic aspects as well. The readers of this chapter are expected to have a prior knowledge of UAV & Non-UAV.

5.1 Training Goals

The major goal of this training session is to search information in an effective manner by using two different means; namely:

- UAV (Unmanned Ariel Vehicle)
- Non UAV (Unmanned Ariel Vehicle)

This information helps fire fighting team to extinguish fire in a better manner on the basis of the ground realities. More specifically this information that is obtained by using above means, is relevant to fire conditions, fire type, intensity of fire, fire spread speed and direction etc. This information allows fire fighting teams to extinguish fire in a planned and efficient manner, which helps them to control fire in timely manner by keeping the loss as low as possible.

In order to develop this skill we develop two different scenarios; one scenario is related to the information searching using UAV and the other one is related to the information searching using Non-UAV. In addition to that the map is also crowded with a lot of objects, so that training goals of this task should be achieved efficiently. The fire area is also reduced as well, normally the fire spans on four cells after setting up, but in these scenarios the fire span on only one cell after it sets up and then it starts spreading.

5.2 Organization Description

We developed an organization of nine players, in which three players are assigned the role of staff (S1, S2 and S3) and rest six players are assigned the different roles among grounded units. The duty of three staff members is to only get aware with the situation and on the basis of the situation they guide the players (A, B, C, D, E and F)controlling the grounded units. Means they don’t directly operate the system they only command and control the players that manages the grounded units.

There are eighteen grounded units which are operated by six players (A, B, C, D, E and F). The player A can operate three gasoline units (G1, G2, and G3). Similarly the players B, C, and D each control three fire fighter units (F4, F5, and F6 (controlled by B), F7, F8, and F9 (controlled by C) and F10, F11, and F12 (controlled by D)). The player E is provided with two fire breaks (B13 and B14) and one helicopter (H15) for searching the fire. The player F is provided the responsibility of water refilling by operating three water units (W16, W17 and W18). This command and control structure is graphically presented in table 5.1 by using the modeling notation that is described in Chapter3:
Team Organization (Command & Control)

<table>
<thead>
<tr>
<th>Fire Fighting Unit Chiefs</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire Fighting Units &amp; Reconnaissance Persons</td>
<td>G</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>B</td>
<td>W</td>
<td>W</td>
<td>W</td>
</tr>
<tr>
<td>G</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>B</td>
<td>W</td>
<td>W</td>
<td>W</td>
<td>W</td>
</tr>
<tr>
<td>G</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>B</td>
<td>W</td>
<td>W</td>
<td>W</td>
<td>W</td>
</tr>
</tbody>
</table>

Table 5-1 Task 2 – Information Searching Command & Control Structure

The communication structure of these nine players is designed in such a way that the player S1 can only allow communication with the players S2 and S3 on the basis of current ground situations. Whereas the players S2 and S3 are allowed to communicate with the rest six players, they (S2 and S3) are also able to coordinate back with player S1. The responsibility of S2 and S3 is to coordinate with the relevant player on the basis of the instructions received from player S1. The six players who are controlling the grounded units are allowed to communicate with each other and with player S2 and S3. This communication hierarchy can be better understood by table 5.2;
**Note:** The organizations (command control & communication structure) for both scenarios are same. The only difference in two scenarios is that a UAV unit is used for information searching in one scenario and in the other scenario a Non-UAV unit is used for information searching.

### 5.3 Scenario Description

The scenario is designed in such a way that is crowded with the multiple objects, which enables teams to search information in an efficient manner by keeping the objects in focus and as well as searching for fire and once fire is found then gathering information about the fire in a timely manner. Some custom objects are also included in the scenario to make scenario more interactive.

Two different scenarios are defined based on the same organization. The purpose of the first scenario is to search information using non-UAV and in the second scenario the information is searched using UAV. In the first scenario the functionality of UAV is achieved by customizing the behavior of an ordinary unit (i.e. Non-UAV) but in the second scenario a new version of C3fire is used which retains the characteristics of real world UAV and on the basis of those characteristics a unit is introduced which simulates the behavior of UAV. The subsequent section discusses the objects used in the both scenario and then fire positions are discussed on the map.

#### 5.3.1 Objects

Following are the different types of objects along with their burning time.

- **Normal Vegetation**
  - Pine trees burns **three times faster** than normal vegetation.
  - Birch trees burn **at half the rate** of normal vegetation.
- **Swamp** never burns.
- People burns **three times faster** than normal vegetation
- Bank burns **four times faster** than normal vegetation.
- School burns as fast as normal vegetation.
- House burns as fast as normal vegetation.
- Fuel Station having unlimited fuel and **never burns**. In order to refill the fuel, units (Firefighter, fuel and water) must be on the NEWS (North, East, West or South) location. If the unit will be on the fuel station cell there will be no refill of fuel.
- Water Station having unlimited water and **never burns**. In order to refill the water, units (Firefighter and water) must be on the NEWS (North, East, West or South) location. If the unit will be on the water station cell there will be no refill of water.
5.3.2 Fire Information

In order to make the information searching more active the fire is set up at two different locations on the map. Both locations are far away from each other, located almost near two different corners and on the third corner is the information searching unit (UAV & Non-UAV). Moreover the fire area is set to the least possible value, means that initially the fire setup in only one cell. The following figure illustrates the whole map along with the two fire areas, namely; top left fire area and bottom right fire area.

Figure 5-1 Map pointing three fire areas
5.3.3 Static Information for UAV and Non-UAV

The static information presents the static view of task environment. It discusses each fire location, its spreading speed and other similar information based on the session configuration. The static information presented in this sub section is same for both the scenarios (UAV & Non-UAV).

5.3.3.1 Fire in the Top Left

This area is the most critical area to save because there are a lot of critical objects around it like people, houses, school and vehicles. When the fire explodes the first possibility of burning is of houses. If fire is not extinguished within 3min & 57sec then houses start burning and fire continue spreading and burning all houses. The next chance is of saving people so the firefighting team has less than 4min & 30sec to control the fire in order to successfully save the people. There is also a school near the fire area and the total time for saving the school is less than 4min & 54sec. The time required for successfully saving the vehicle is less than 5min & 6sec. There are also some birch trees near the fire area. The time required for burning the birch is less than 5min & 12sec. The image of middle left area is shown in figure 5.2.

5.3.3.2 Fire in the Bottom Right

This area is of least importance than the other two areas because the first two objects that are expected caught fire are bank and the pine trees. The objects in this fire area are vehicles, school, birch, pine and bank. In this area, if fire is not extinguished the first possibility of burning is of bank. The fire fighting organization has only 1min & 58 sec to save bank. The next object is the pine which allows the time factor of 3min & 54 sec to save it from fire. The third object is the vehicles; in order to save these vehicles the team has only 4min and 3sec. The last but the critical object is school, the fire fighting team has only 6 min & 5 sec to save the school. The image of bottom right area is shown in figure 5.3.
5.3.4 Dynamic Information

In this section we discussed the scenarios from dynamic perspective by stating the information which we gathered by practically running the configuration. The organization is defined in such a way that it requires 9 players to accomplish given task by coordinating and communicating with each other. Hence we invite 9 persons to play in the simulated environment all of them belong to Asia. First, we gave them a brief presentation about C3Fire simulation environment and then gave them player instructions manual, so that they read and learn how to operate the simulation environment.

Afterwards we present two task environments to these players; both are similar in behavior and in geographic view. The only difference in both of the environment is of information searching units. In the first scenario and ordinary object is customized to behave as UAV unit (i.e. Non-UAV), whereas in the
second environment the team is given a simulated UAV for information searching based on the characteristics of the real world. We then observed and analyzed the both situations and the behavior of the players. In the following we discuss the findings of both the scenarios.

5.3.4.1 Information Searching using Non-UAV

The results of the session and the analysis on those are presented below by categorizing the results and information on the basis of different fire areas.

Fire in the Top Left:
As discussed earlier, this is the most critical area in the map with respect to extinguishing the fire because there are a lot of critical objects like people, vehicle, houses and school. Fortunately the fire in this area was searched within a short time without being a loss of lot of objects. Just a few houses burnt during searching the fire. Depending on the fire, helicopter unit informed the fire fighters to reach the location. Five firefighters, two water units and two fuel units rushed to the fire location to extinguish the fire and the fire was successfully controlled. This situation is shown in figure 5.5.

![Figure 5-5 Fire conditions in Top left Fire Area](image)

Fire in the Bottom Right:
This is the second area which is to be searched by the helicopter to inform firefighter units to extinguish the fire. The criticality of this area is less than previous one but this area may cause a big loss if not controlled within time. When the helicopter searched this location some of the pines, birches and bank were burning. Also, when helicopter informed firefighter units to extinguish the fire some of the objects were totally burned out and fire was continuously spreading and burning the surroundings. So in order to extinguish the fire: four fighter units, one water unit, two fire break units and one fuel unit rushed to the location to extinguish the fire. Although fire break units tried to stop spreading the fire and they succeed in some ways but not totally because bank, some pines and some birches were burned out. This situation is shown in figure 5-6.
5.3.4.2 Information Searching using UAV

There are not enough resources available to conduct experiment for this scenario. Hence there is no dynamic information regarding the information searching using UAV. However the information provided elsewhere in this report about this area (information searching using UAV) is based on the educational background and experience of the authors.

5.3.4.3 Good & Bad Behavior

This section discusses the both good and bad behaviors regarding this specific scenario of information searching by using UAV & Non-UAV. After analyzing the ongoing activities during the session playing, following activities are observed and are given in conjunction with some recommendations.

Searching Fire:

When the game starts the helicopter unit only search for the fire and the rest of the units are waiting for the information that would be received from the helicopter unit. It would be more effective if all the units or at least few units can also initially search for the fire along with the helicopter and once the fire found, then the units start their original work.

Continuously Search for Fire:

It is observed that after finding a fire at top left location the helicopter units stops instead of searching other areas for fire. Since there were two fire locations in the map, so in this way the bottom right fire area was ignored due to this fact. Hence it would be more feasible that helicopter will be throughout searching for fire.

Efficient Decision Making:

Once the fire is found then a proper decision making is required at that time that what unit should do what, how and when. In short the efficient & effective decision making is required for fighting fire.

Unit Position:

When the game starts all the units are almost in the center of the map. It would be more feasible if the unit initial position is selected randomly instead of placing all the units in the center. This enables the unit to search fire more efficiently by covering the larger area in less time.
Fuel Perspective:
It was observed that during firefighting fuel was required to move from one location to another. As there were limited fuel units which have to fulfill the requirements of all firefighting units, water units and their own requirements of fuel. In order to refill the fuel it was better to communicate the nearest fuel unit or fuel station rather than calling the fuel units every time.

Water Perspective:
Water is also necessary for firefighters to fight against fire. It was also important here to communicate the nearest water unit or water station rather than calling the water units every time.
6 Analysis

6.1 OODA Loop analysis
Observe Orient Decide & Act (OODA) loop as explained in section 2.4 helps in understanding the emergency situation to take appropriate decisions. In this section we explained OODA loop perspective for firefighters, logistic units (water, fuel etc.), prioritization in decision making and information searching using UAV’s and Non UAV’s.

6.2 OODA Loop Analysis for Good & Bad Behavior
OODA loop analysis helps in explaining the good and bad behavior while fire fighting in C3Fire simulation system.

6.2.1 Good Behavior
As there are four stages in OODA loop. If we consider these four stages with respect to the fire fighting domain then the most crucial step in OODA loop is decision. In order to take decisions, observation and orientation are of great importance.

![Figure 6-1 OODA loop analysis for Good behavior](image-url)
So for better decisions it must be important to have good observation and orientation with respect to the situation. The main input of observation in emergency management situations like fire fighting is information availability. As right information available at right time helps in making right decisions so it’s better to have enough information of fire so that it becomes possible to take right decisions. Information can be gathered using UAV (Unmanned armed vehicles) and Non UAV (Unmanned armed vehicles) in C3Fire simulation system. Another step in OODA loop is orienting according to the situation. While orientation it is important to consider different factors like cultural traditions, genetic heritage, previous experiences etc. Understanding of these aspects helps in better orientation. Next step in OODA loop is decision. If we have better observation and orientation then there are good chances for better decisions. While taking decisions it is important to consider the aspects like prioritization which is to be given on the basis of criticality of the fire area having different burning objects like pine, houses, bank, vehicles etc. So based on the decisions final actions are performed as shown in figure 6-1.

6.2.2 Bad Behavior
If we consider the OODA loop analysis for explaining the bad behavior in emergency management situations like fire fighting the one of the bad behavior is availability of insufficient information in observation stage. Another bad behavior may be delivering incorrect information or information that is not understandable by other players. If there will be insufficient information available then it becomes difficult to prioritize the things thus affecting the decisions. As a result action may not be fruitful as shown in figure 6-2.

![Figure 6-2 OODA loop analysis for Bad behavior](image-url)
6.2.3 OODA loop analysis for fire fighters

OODA loop perspective for fire fighters helps in taking appropriate decisions for extinguishing the fire. Each step in the loop with respect to the fire fighting units is described below also shown in figure 6-3.

- **Observe:** This includes observing the characteristics of fire, burning objects etc.
- **Orient:** Orienting firefighter units so that they can control fire in an efficient way. This doesn’t involve moving the units physically.
- **Decide:** This involves making proper decision to move units at their best suitable positions.
- **Act:** This involves start fire fighting.

![Figure 6-3 OODA loop analysis for fire fighters](image)

6.2.4 OODA loop analysis for logistics

OODA loop perspective for logistic units helps in taking appropriate decisions for providing logistics to the fire fighters in an efficient manner. Each step in the loop with respect to the logistic units (water, fuel, fire break etc.) is described below also shown in figure 6-4.

- **Observe:** This includes observing the logistics in all respective units and itself.
• **Orient**: Orienting logistic units and make plans on the basis of prioritization skills: if there are multiple units requiring logistics, supply first to those units who are in more critical areas. This doesn’t involve moving the units physically.

• **Decide**: This involves making proper decision to move units at their best suitable positions.

• **Act**: This involves start supplying logistics.

### 6.2.5 OODA loop analysis for prioritization in decision making

OODA loop perspective for prioritization helps in prioritizing decisions for extinguishing the fire. Each step in the loop with respect to the prioritization is described below also shown in figure 6-5.

- **Observe**: This includes observing the characteristics of fire, burning objects, objects burning speed etc.

- **Orient**: This includes prioritization in making decision like which objects burn quicker and what is the criticality of burning objects and then orienting according to the situation. This doesn’t involve moving the units physically.

- **Decide**: This involves making proper decision to move units at their best suitable positions.

- **Act**: This involves start fire fighting.
6.2.6 OODA Loop Analysis for Information Searching using UAV and Non-UAV

OODA loop perspective for information searching using UAV and Non-UAV helps in making decisions for searching the fire. Each step in the loop with respect to the information searching is described below also shown in figure 6-6.

- **Observe**: This includes collecting and observing the all available information from all available resources.
- **Orient**: This includes analyzing the all available data. This doesn’t involve moving the units physically.
- **Decide**: This involves making proper decision that in which direction unit (UAV, Non UAV) should move.
- **Act**: This involves start moving units and after searching fire informs firefighters to extinguish fire.

![Figure 6-5 OODA Loop Analysis for Prioritization](image)
Collecting and observing all available information from all available resources

Orient

Analyzing the all available

Decide

Decision making that in which direction unit (UAV, Non-UAV) should move

Act

Start moving units and after searching fire inform firefighters to extinguish fire

Observe

Information Searching using (UAV & Non-UAV)

Figure 6-6 OODA Loop Analysis for Information Searching using UAV & Non-UAV
7 Conclusion

C3Fire is a simulation system, which simulates the forest fire fighting domain. It is an application of emergency management system. The basic purpose of this simulation system is to train teams in the domain of Command, Control and Communication. Beside this it also enables researchers to conduct research in this domain. The systematic working of C3Fire is depending upon the set of configuration files, which includes; the session file and the scenario file.

The major purpose of this research work is to design few emergency management training sessions for the C3Fire system; while having major focus on prioritization and information searching. In order to attain this goal different command, control and communication related methodologies are studied. Then these theories are applied by conducting different experiments, based on the different configurations which were developed during the project. This methodology helps in improving the prioritization and information searching skills in the real world teams.

In addition to that these both areas of research, goes hand in hand because the results of the training sessions are only fruitful in a case when both tasks are achieved together. More specifically the team is only in a condition to perform prioritization, when it has sufficient information about the fire area and fire conditions. Hence it can be assumed that the information searching module serves a prerequisite for the prioritization task.

There are two means for searching information either by using UAV or by using Non-UAV. The UAV’s are used in such conditions where it is difficult for humans to gather the information. Moreover these unmanned vehicles gather information quickly and efficiently, but the major disadvantage of using UAV is that it doesn’t responds to all the real world scenarios, so this goal can be best achieved by using Non-UAV. However the role of information searching becomes more vital and visible in the situations where team doesn’t have much information about the emergency situations and fire area and the environment. So our information searching training sessions are helpful in developing these skills, which enables the team to search information more quickly and effectively.

There are various factors that tend towards some difficulties which occurred during this project; the major difficulty which we face in this thesis was to create such a dynamic presentation of task environments that deals with different human natures and also serves the need for varying cultural differences. However later we manage to cope with these issues by applying various decision making theories and support our configurations with different cultural and social aspects. Apart from this it is also very difficult to create presentations that reflect the real world. It was due to the limitations of the system that were used in this thesis, but we also manage this problem up to some extent by first defining and then using the different custom objects in the experiments.

While designing the session scenarios our major focus was on situational awareness and OODA loop. By running different configurations in the C3Fire environment, we observed that good results in prioritization and information searching can be achieved by better situational awareness and proper implementation of OODA loop concepts. Good situational awareness can be achieved by proper
planning and keeping all the real world factors in mind. OODA loop can be more beneficial in these tasks by proper observation, orienting according to the situation and making proper decisions and then acting upon these decisions.

While doing analysis with OODA loop it is important to consider different factors in each stage as shown in figure 7-1. In observation stage we need to consider outside information and unfolding circumstances. The output from observation stage fed into the orientation stage here we need to consider factors like cultural traditions, activity coordination, new information, previous experiences, analysis and synthesis where all these aspects are inter related. The output form orientation stage is used in decision hypothesis. If decisions are seemed to be insufficient they are used again for observation. After decision hypothesis the final step is testing the decisions by performing physical actions.

Figure 7-1 Modified OODA loop [21]
References

[02] Hierarchic Organization (Figure 2), http://www.c3fire.org/doc/organisation/organisation.en.shtml (Visited: 25July, 09)
[03] Flat Organization (Figure 3), http://www.c3fire.org/doc/organisation/organisation.en.shtml (Visited: 25July, 09)
[04] Typical Organization Hierarchy (Figure 1), http://www.c3fire.org/doc/organisation/organisation.en.shtml (Visited: 25July, 09)
[05] Log Process in C3Fire (Figure 2), http://www.c3fire.org/research/overview/overview.en.shtml (Visited: 25July, 09)
[06] Human Action Control Description (Figure 2), http://www.c3fire.org/training/emergency/emergency.en.shtml (Visited: 25July, 09)
[07] Parts of Fire (Figure 1), http://www.c3fire.org/training/forestfire/forestfire.en.shtml (Visited: 25July, 09)
[08] Classification of Fire (Figure 2), http://www.c3fire.org/training/forestfire/forestfire.en.shtml (Visited: 25July, 09)
[09] Levels of Fire Fighting organization (Figure 4), http://www.c3fire.org/training/forestfire/forestfire.en.shtml (Visited: 25July, 09)
8 Appendix A - Manager Instructions - Prioritization

In this experiment, you are given the responsibility of managing a simulated task environment. The major goal of the session environment is to develop the prioritization skills of fire fighting team. The environment is designed in such a way that a total of six players (excluding you) play this game by operating 10 units. In the following we present the team command & communication structure in detail.

<table>
<thead>
<tr>
<th>Fire Fighting Unit Chiefs</th>
<th>S1</th>
<th>S2</th>
<th>W</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire Fighting Units &amp; Reconnaissance Persons</td>
<td>F1</td>
<td>F2</td>
<td>F3</td>
<td>F4</td>
<td>F5</td>
<td>F6</td>
</tr>
<tr>
<td></td>
<td>W7</td>
<td>G9</td>
<td>W8</td>
<td>G10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 8-1 Task1 – Prioritization Command & Control Structure

The above table represents the command & control structure this experiment. The titles of six players are S1, S2, W, X, Y& Z. The players S1 & S2 are the staff members so they don’t have any unit to operate. Whereas the remaining four players (W, X, Y& Z) are the part of fire fighting team. The player W is assigned the responsibility of operating three fire fighter units (F1, F2 & F3). The player X is assigned the responsibility of operating three fire fighter units (F4, F5 & F6). The player Y is assigned the responsibility of operating two water tank units (W7 & W8). The player Z is assigned the responsibility of operating two fuel tank units (G9 & G10). In the following we will present the communication structure of this game.

<table>
<thead>
<tr>
<th>Mechanisms (Coordination &amp; Communication)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
</tr>
<tr>
<td>S2</td>
</tr>
<tr>
<td>B</td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>C</td>
</tr>
<tr>
<td>D</td>
</tr>
</tbody>
</table>

Table 8-2 Task1 – Prioritization Communication Structure

The communication structure of these six players are designed in such a way that the player S1 can only allowed to communicate with the player S2 on the basis of current ground situations. Whereas the
player S2 is allowed to communicate with the rest four players, it is also able to coordinate back with player S1. Its responsibility is to coordinate with the relevant player on the basis of the instructions received from player S1. The four players who are controlling the grounded units are allowed to communicate with each other and with player S2.

There are two scenario of this game. In first scenario there will be no time for planning while in second scenario two minutes will be given for planning of how to efficiently extinguish the fire. In order to manage this game you must be aware of the user interface provided to you. The following section provides the detailed description of the interface provided to you.

8.1 Interface Description
This section describes the elements of the user interface available to you, in C3Fire simulation system. For the ease of understanding we have logically split the interface into three sections. The following figure shows a typical manager interface pointing the three partitions as well.

![Typical Manager Interface with logical Partitions](image)

In the following we will discuss these three sections in detail
8.1.1 **Left Container**
The left container mostly presents the dynamic information means the information changes with respect to time and unit actions e.g. the unit info palette. Following are the major elements of this section

8.1.1.1 **Time**
The time palette shows the time duration from which the session is going on. The format in which it shows the time is **HH: MM: SS**. Its starts showing time once you start the game before this the time displayed is 00:00:00.

![Time Panel](image)

8.1.1.2 **Role Panel**
This palette enables you to realize that whether all the units are active or not. It enables you to find out the idle units by checking the color of this palette. The color of this palette turns red when any of the unit is idle. This panel can be more fruitful if used in conjunction with session control.

![Role Panel Example](image)

8.1.1.3 **Session Control**
This is a sort of a tool box that provides the facility of starting the session, and once started then stopping or pausing it. This tool bar provides three buttons to support these three features. The buttons are titled as **Start, Pause and Stop**. In order to start the configuration, make sure that all the roles must be active, if any role is free then the start button will be disabled.

![Session Control Tool Bar](image)

8.1.1.4 **Wind Direction Palette**
This palette shows the information about wind, including its direction and speed. The direction is indicated by the direction compass, whereas the wind speed is stated below the direction compass.
8.1.1.5 Unit Info
The unit info palette gives a brief overview of all the units performing in the session environment. The information provided this palette includes Unit Id, current position of the unit, intended position of the unit (if any, else left blank) and the current activity performed by that unit.

```
<table>
<thead>
<tr>
<th>ID</th>
<th>Pos</th>
<th>GoTo</th>
<th>Activity</th>
<th>Water</th>
<th>Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>E, 31</td>
<td>Unactive</td>
<td>90</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>F2</td>
<td>E, 11</td>
<td>Unactive</td>
<td>90</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>F3</td>
<td>Z, 39</td>
<td>Unactive</td>
<td>90</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>F4</td>
<td>AM, 25</td>
<td>Unactive</td>
<td>90</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>F5</td>
<td>J, 29</td>
<td>Unactive</td>
<td>90</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>F6</td>
<td>F, 2T</td>
<td>Unactive</td>
<td>90</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>V7</td>
<td>N, 10</td>
<td>Unactive</td>
<td>200</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>V8</td>
<td>B, 23</td>
<td>Unactive</td>
<td>200</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>G9</td>
<td>V, 19</td>
<td>Unactive</td>
<td>0</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>G10</td>
<td>L, 32</td>
<td>Unactive</td>
<td>0</td>
<td>200</td>
<td></td>
</tr>
</tbody>
</table>
```

8.1.1.6 Unit Property
This palette provides detailed information about the individual unit. The main difference between this and the unit info palette is that it provides detailed information about an individual unit whereas the unit info palette provides brief information about all the units. The information obtained through this palette includes Unit Id, type of the unit, current position of the unit, intended position of the unit (if any, else left blank), the current activity performed by that unit and the moving speed of the unit. Along with this it also provides some additional information depending upon the unit type, e.g. Fire Fighting speed in case if the unit’s type is fire fighter.
8.1.2 Middle Container
The middle container displays map in it which simulates the real world environment along with all the simulated activities that goes on during the whole session. This map is a combination of 40X40 matrix. Each cell in a map is uniquely identified by specifying its coordinates. The column is identified by an alphabetic character and the row is identified numeric value ranging from 1 to 40.

8.1.3 Right Container
On contrary to the left panel the right panel displays the static information, means the information doesn’t changes neither with respect to time nor with unit’s actions. In the following we will describe each individual element of this container.

8.1.3.1 Pointer Position
This palette gives information about the current position of the pointer. It changes it values as the mouse pointer moves at any point within the map. The format in which the position is displayed is like that column, row. The column is represented by alphabetic character and the row is represented by a numeric value in range of 1 to 40.

8.1.3.2 Unit Palette
This palette gives the information about all the units present in the game. The information displayed here is in semi graphical notation means that image of the unit id and its title is given. The image color represents the type of the unit. If color is red then the unit type is fire fighter, if blue then the unit type is water refill and if yellow then the unit type is fuel refill.
8.1.3.3 Object Palette

The object palette lists the entire object used in the simulation environment. Following are the different types of objects in the game along with their burning time.

- Normal Vegetation
- Pine trees burns **three times faster** than normal vegetation.
- Birch trees burn **at half the rate** of normal vegetation.
- Swamp never burns.
- People burns **three times faster** than normal vegetation.
- Bank burns **four times faster** than normal vegetation.
- Vehicle burns **four times faster** than normal vegetation.
Manager Instructions – Prioritization

School burns as fast as normal vegetation.

House burns as fast as normal vegetation.

Fuel Station having unlimited fuel and never burns. In order to refill the fuel, units (Firefighter, fuel and water) must be on the NEWS (North, East, West or South) location. If the unit will be on the fuel station cell there will be no refill of fuel.

Water Station having unlimited water and never burns. In order to refill the water, units (Firefighter and water) must be on the NEWS (North, East, West or South) location. If the unit will be on the water station cell there will be no refill of water.

8.1.3.4 Fire Palette

This palette displays information about different states of fire. Following are the different states of fire along with their graphical images.

- Clear represents no fire
- Burning represents currently burning
- No longer burning represents that the fire has been extinguished
- Burned-out represents the area has been burned out

A fire in a cell spreads in the NEWS (North, East, West and South) directions. More the cells burning at a time more quickly the fire spread and it will become difficult to control the fire. Cells that are No longer burning and those are burned out can’t start burning again.
9 Appendix B - Player Instructions - Prioritization

In this experiment, you are allowed to play a game. This game presents a simulated environment of emergency management. In this game you have to extinguish a forest fire to save objects like people, pine, banks, houses, birch and vehicles etc.

There are two scenario of the same configuration. In first scenario there will be no time for planning while in second scenario two minutes will be given for planning of how to efficiently extinguish the fire.

9.1 Organization

There are six players having names W, X, Y, Z, S1 and S2. Two players are assigned the role of staff (S1 and S2) and rest four players are assigned the different roles among grounded units. The duty of two staff members is to only get aware with the situation and on the basis of the situation they guide the players (W, X, Y and Z) controlling the grounded units. Means they don’t directly operate the system they only command and control the players managing the grounded units.

There are ten grounded units which are operated by four players (W, X, Y, Z). The player W can operate three fire fighter units (F1, F2, and F3). Similarly the player X can also control three fire fighter units (F4, F5, and F6). The player Y is provided the responsibility of water refilling by operating two water units (W7 and W8). The player Z is assigned the responsibility of refilling fuel, which can be done by the help of two fuel units (G9 and G10). This command and control structure is graphically presented in the following figure:

<table>
<thead>
<tr>
<th>Fire Fighting Unit Chiefs</th>
<th>S1</th>
<th>S2</th>
<th>W</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire Fighting Units &amp; Reconnaissance Persons</td>
<td>F1</td>
<td>F2</td>
<td>F3</td>
<td>F4</td>
<td>F5</td>
<td>F6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>W7</td>
<td></td>
<td>G9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>W8</td>
<td></td>
<td>G10</td>
</tr>
</tbody>
</table>

Table 9-1 Task 1 – Prioritization Command and control Structure

The communication structure of these six players are designed in such a way that the player S1 can only allowed to communicate with the player S2 on the basis of current ground situations. Whereas the player S2 is allowed to communicate with the rest four players, it is also able to coordinate back with player S1. Its responsibility is to coordinate with the relevant player on the basis of the instructions received from player S1. The four players who are controlling the grounded units are allowed to
communicate with each other and with player S2. This communication hierarchy can be better understood by the following figure;

<table>
<thead>
<tr>
<th>Mechanisms (Coordination &amp; Communication)</th>
</tr>
</thead>
</table>
| ![Diagram](image)

Table 9-2 Task1 – Prioritization Communication Structure

9.2 Game Interface
Look at the screens of your monitor. There is a 40 x 40 matrix showing the map. There is a map legend on the top right corner. On the left side of the screen there is an e-mail tool and different ground unit panels showing their states. All participants can see the same map. Each participant can just see the status of the units which he is controlling.

9.3 Fire states
Following are the different states of the cells in the map.

- **Clear** represents no fire
- **Burning** represents currently burning
- **No longer burning** represents that the fire has been extinguished
- **Burned-out** represents the area has been burned out

A fire in a cell spreads in the NEWS (North, East, West and South) directions. More the cells burning at a time more quickly the fire spread and it will become difficult to control the fire. Cells that are **No longer burning** and those are **burned out** can’t start burning again.

9.4 Map Description
The map is a 40 x 40 matrix. Each cell in the matrix is uniquely identified by a number (representing the row) and a letter (representing the column). The map is shown in figure below.
9.5 Objects in the game

Following are the different types of objects in the game. Some objects burn faster than others as shown below.
Normal Vegetation

Pine trees burns **three times faster** than normal vegetation.

Birch trees burn **at half the rate** of normal vegetation.

Swamp **never burns**.

People burns **three times faster** than normal vegetation

Bank burns **four times faster** than normal vegetation.

Vehicle burns **four times faster** than normal vegetation.

School burns as fast as normal vegetation.

House burns as fast as normal vegetation.

Fuel Station having unlimited fuel and **never burns**. In order to refill the fuel, units (Firefighter, fuel and water) must be on the NEWS (North, East, West or South) location. If the unit will be on the fuel station cell there will be no refill of fuel.

Water Station having unlimited water and **never burns**. In order to refill the water, units (Firefighter and water) must be on the NEWS (North, East, West or South) location. If the unit will be on the water station cell there will be no refill of water.

### 9.6 Trucks

There are three types of trucks. These trucks will be controlled by the players who are having the responsibility of that particular unit. States of trucks are shown by different colors. For example when a truck is moving towards its intended position is shown by white color having truck number as shown in figure.

![Figure 9-2 Intended position of Unit 11](image)

#### 9.6.1 Fire fighter trucks

Firefighter trucks are used to extinguish fire. These trucks are shown by red color. They require fuel to move and water to extinguish the fire. In order to extinguish fire truck must be on the unit where to extinguish fire. Following are different states of firefighting truck

1. Inactive represents truck in doing nothing
2. Moving represents truck is moving
3. Mobilizing represents truck is preparing to fight fire
4. Fire fighting represents trucks is fire fighting
5. Demobilizing represents ending the extinguish of fire
6. **Refill water** represents truck is refilling water
7. **Refill fuel** represents truck is refilling fuel

### 9.6.2 Water trucks
Water trucks are used to supply water to the fire fighter units. These trucks are shown by blue color. They also require fuel to move from one place to another. Following are different states of water trucks.

1. **Inactive** represents truck in doing nothing
2. **Moving** represents truck is moving
3. **Mobilizing** represents truck is preparing to transfer water
4. **Demobilizing** represents ending the transfer of water
5. **Refill water** represents truck is refilling water
6. **Refill fuel** represents truck is refilling fuel

### 9.6.3 Fuel trucks
Fuel trucks are used to supply fuel to the fire fighter units. These trucks are shown by yellow color. The purpose of these trucks is to supply fuel to other trucks and also manage its own fuel.

1. **Inactive** represents truck in doing nothing
2. **Moving** represents truck is moving
3. **Mobilizing** represents truck is preparing to transfer fuel
4. **Demobilizing** represents ending the transfer of fuel
5. **Refill water** represents truck is refilling fuel
6. **Refill fuel** represents truck is refilling fuel

### 9.7 Wind palette
Wind palette provides information about the wind direction and speed. While measuring the performance of team the wind factor should also be kept in mind. In other words the wind factor should also be added into the decision parameters list. The information about wind can be obtained from wind palette at specific interval of time.

![Wind Palette](image)

**Figure 9-3 Example of Wind Palette**

### 9.8 Unit Info & Unit property palette
These two palettes gives detailed information about the units, including their current position, intended position, activity, and amount of fuel and water which it currently has. The difference between both the
palettes is that the unit info provides a brief info about all the units in tabular form whereas the unit property palette displays the detailed information about each individual unit.

<table>
<thead>
<tr>
<th>Unit Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
</tr>
<tr>
<td>F1</td>
</tr>
<tr>
<td>F2</td>
</tr>
<tr>
<td>F3</td>
</tr>
<tr>
<td>F4</td>
</tr>
<tr>
<td>F5</td>
</tr>
<tr>
<td>F6</td>
</tr>
<tr>
<td>WT</td>
</tr>
<tr>
<td>WR</td>
</tr>
<tr>
<td>G2</td>
</tr>
</tbody>
</table>

Figure 9-4 Example of User Info Palette

9.9 Mail Tool

The only way to share information between all players is mail tool. With the help of this tool you can receive messages from other players and also send them messages. The players can communicate with each other on the basis of Table 2.

This tool has two parts. In the upper window you can receive and read messages from other players while in the lower window you can type and send messages to other players. The receipt of messages in the upper window is shown by the following

1. The number at the top right hand corner of the upper window changes. This number represents the number of unread messages.
2. The color of the upper window changes to pink indicating there are new messages.

There are buttons below the lower window to send messages to either specific player or all players.
10 Appendix C - Manager Instructions – Information searching using UAV & Non-UAV

In this experiment, you are given the responsibility of managing a simulated task environment. The major goal of the session environment is to search information using UAV & Non-UAV. The environment is designed in such a way that a total of nine players (excluding you) play this game by operating 18 units. In the following we present the team command & communication structure in detail.

<table>
<thead>
<tr>
<th>Team Organization (Command &amp; Control)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fire Fighting Unit Chiefs</strong></td>
</tr>
<tr>
<td>S1  S2  S3  A  B  C  D  E  F</td>
</tr>
<tr>
<td><strong>Fire Fighting Units &amp; Reconnaissance Persons</strong></td>
</tr>
<tr>
<td>G  F  F  F  F  F  B  W  W  G  F  F  F  F  B  W  W  G  F  F  F  F  H  W  W</td>
</tr>
</tbody>
</table>

Table 10-1 Task2 – Information searching command & control structure

The above table represents the command & control structure this experiment. The titles of nine players are S1, S2, S3, A, B, C, D, E & F. The players S1, S2 & S3 are the staff members so they don’t have any unit to operate, whereas the remaining six players (A, B, C, D, E & F) are the part of fire fighting team. The player A is assigned the responsibility of operating three gasoline units (G1, G2 & G3). Three players (B, C & D) are assigned the responsibility of operating nine fire fighter units (three fire fighter units each F4, F5, F6, F7, F8, F9, F10, F11 & F12 respectively). The player E is assigned the responsibility of operating two fire break units (B13 & B14) and one helicopter (H15). The player F is assigned the responsibility of operating three water tank units (W16, W17 & W18). In the following we will present the communication structure of this game.

| Mechanisms (Coordination & Communication) |

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The communication structure of these nine players are designed in such a way that the player S1 can only allowed to communicate with the players S2 and S3 on the basis of current ground situations. Whereas the players S2 and S3 are allowed to communicate with the rest six players, they (S2 and S3) are also able to coordinate back with player S1. The responsibility of S2 and S3 is to coordinate with the relevant player on the basis of the instructions received from player S1. The six players who are controlling the grounded units are allowed to communicate with each other and with player S2 and S3. This communication hierarchy can be better understood by the above table;

There are two different scenarios for this task. The purpose of the first scenario is to search information using non-UAV and in the second scenario the information is searched using UAV. In the first scenario the functionality of UAV is achieved by customizing the behavior of an ordinary unit (i.e. Non-UAV) but in the second scenario a new version of C3Fire is used which retains the characteristics of real world UAV and on the basis of those characteristics a unit is introduced which simulates the behavior of UAV.

Note: The organizations (command control & communication structure) for both scenarios are same. The only difference in two scenarios is that a Non-UAV unit is used for information searching in first scenario and in the second scenario a UAV unit is used for information searching.

10.1 Interface Description
This section describes the elements of the user interface available to you, in C3Fire simulation system. For the ease of understanding we have logically split the interface into three sections. The following figure shows a typical manager interface pointing the three partitions as well.
In the following we will discuss these three sections in detail

10.1.1 Left Container
The left containers mostly presents the dynamic information means the information changes with respect to time and unit actions e.g. the unit info palette. Following are the major elements of this section

10.1.1.1 Time
The time palette shows the time duration from which the session is going on. The format in which it shows the time is $HH: MM: SS$. Its starts showing time once you start the game before this the time displayed is 00:00:00.
10.1.1.2 Role Panel
This palette enables you to realize that whether all the units are active or not. It enables you to find out the idle units by checking the color of this palette. The color of this palette turns red when any of the unit is idle. This panel can be more fruitful if used in conjunction with session control.

![Role Panel Example](image)

10.1.1.3 Session Control
This is a sort of a tool box that provides the facility of starting the session, and once started then stopping or pausing it. This tool bar provides three buttons to support these three features. The buttons are titled as Start, Pause and Stop. In order to start the configuration, make sure that all the roles must be active, if any role is free then the start button will be disabled.

![Session Control Tool Bar](image)

10.1.1.4 Wind Direction Palette
This palette shows the information about wind, including its direction and speed. The direction is indicated by the direction compass, whereas the wind speed is stated below the direction compass.

![Wind Palette](image)

10.1.1.5 Unit Info
The unit info palette gives a brief overview of all the units performing in the session environment. The information provided this palette includes Unit Id, current position of the unit, intended position of the unit (if any, else left blank) and the current activity performed by that unit.
10.1.1.6 Unit Property
This palette provides detailed information about the individual unit. The main difference between this and the unit info palette is that it provides detailed information about an individual unit whereas the unit info palette provides brief information about all the units. The information obtained through this palette includes Unit Id, type of the unit, current position of the unit, intended position of the unit (if any, else left blank), the current activity performed by that unit and the moving speed of the unit. Along with this it also provides some additional information depending upon the unit type, e.g. Fire Fighting speed in case if the unit’s type is fire fighter.

10.1.2 Middle Container
The middle container displays map in it which simulates the real world environment along with all the simulated activities that goes on during the whole session. This map is a combination of 40X40 matrix. Each cell in a map is uniquely identified by specifying its coordinates. The column is identified by an alphabetic character and the row is identified numeric value ranging from 1 to 40.
10.1.3 Right Container
On contrary to the left panel the right panel displays the static information, means the information doesn’t changes neither with respect to time nor with unit’s actions. In the following we will describe each individual element of this container.

10.1.3.1 Pointer Position
This palette gives information about the current position of the pointer. It changes it values as the mouse pointer moves at any point within the map. The format in which the position is displayed is like that column, row. The column is represented by alphabetic character and the row is represented by a numeric value in range of 1to 40.

![Pointer Position](image)

Figure 10-8 Pointer Position

10.1.3.2 Unit Palette
This palette gives the information about all the units present in the game. The information displayed here is in semi graphical notation means that image of the unit id and its title is given. The image color represents the type of the unit. If color is red then the unit type is fire fighter, if blue then the unit type is water refill and if yellow then the unit type is fuel refill.

![Unit Palette](image)

Figure 10-9 Unit Palette

10.1.3.3 Object Palette
The object palette lists the entire object used in the simulation environment. Following are the different types of objects in the game along with their burning time.
Normal Vegetation

Pine trees burns **three times faster** than normal vegetation.

Birch trees burn at **half the rate** of normal vegetation.

Swamp **never burns**.

People burns **three times faster** than normal vegetation

Bank burns **four times faster** than normal vegetation.

Vehicle burns **four times faster** than normal vegetation

School burns as fast as normal vegetation.

House burns as fast as normal vegetation.

Fuel Station having unlimited fuel and **never burns**. In order to refill the fuel, units (Firefighter, fuel and water) must be on the NEWS (North, East, West or South) location. If the unit will be on the fuel station cell there will be no refill of fuel.

Water Station having unlimited water and **never burns**. In order to refill the water, units (Firefighter and water) must be on the NEWS (North, East, West or South) location. If the unit will be on the water station cell there will be no refill of water.

**10.1.3.4 Fire Palette**

This palette displays information about different states of fire. Following are the different states of fire along with their graphical images.

- **Clear** represents no fire
- **Burning** represents currently burning
- **No longer burning** represents that the fire has been extinguished
- **Burned-out** represents the area has been burned out

A fire in a cell spreads in the NEWS (North, East, West and South) directions. More the cells burning at a time more quickly the fire spread and it will become difficult to control the fire. Cells that are **No longer burning** and those are **burned out** can’t start burning again.
11 Appendix D - Player Instructions – Information Searching using Non-UAV

In this experiment, you are allowed to play a game. This game presents a simulated environment of emergency management. In this game you have to extinguish a forest fire to save objects like people, pine, banks, houses, birch and vehicles etc. The purpose of this training session is to improve the information searching skills using Non-UAV.

11.1 Organization

There are nine players in total, in which three players are assigned the role of staff (S1, S2 and S3) and remaining six players are assigned the different roles among grounded units. The duty of three staff members is to only get aware with the situation and on the basis of the situation they guide the players (A, B, C, D, E and F) controlling the grounded units. Means they don’t directly operate the system they only command and control the players managing the grounded units.

There are eighteen grounded units which are operated by six players (A, B, C, D, E and F). The player A can operate three gasoline units (G1, G2, and G3). Similarly the players B, C, and D each control three fire fighter units (F4, F5, and F6 (controlled by B), F7, F8, and F9 (controlled by C) and F10, F11, and F12 (controlled by D)). The player E is provided with two fire breaks (B13 and B14) and one helicopter (H15) for searching the fire. The player F is provided the responsibility of water refilling by operating three water units (W16, W17 and W18). This command and control structure is graphically presented in the following figure:

<table>
<thead>
<tr>
<th>Team Organization (Command &amp; Control)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fire Fighting Unit Chiefs</strong></td>
</tr>
<tr>
<td>S1 S2 S3 A B C D E F</td>
</tr>
<tr>
<td><strong>Fire Fighting Units &amp; Reconnaissance Persons</strong></td>
</tr>
<tr>
<td>G G F F F F B B W W G G F F F F H W W</td>
</tr>
</tbody>
</table>

Table 11-1 Task2 – Information searching command & control structure
The communication structure of these nine players are designed in such a way that the player S1 can only allow to communicate with the players S2 and S3 on the basis of current ground situations. Whereas the players S2 and S3 are allowed to communicate with the rest six players, they (S2 and S3) are also able to coordinate back with player S1. The responsibility of S2 and S3 is to coordinate with the relevant player on the basis of the instructions received from player S1. The six players who are controlling the grounded units are allowed to communicate with each other and with player S2 and S3. This communication hierarchy can be better understood by the following figure;

### Table 11-2 Task2 – Information searching communication structure

#### 11.2 Game Interface
Look at the screens of your monitor. There is 40 x 40 matrix showing the map. There is a map legend on the top right corner. On the left side of the screen there is an e-mail tool and different ground unit panels showing their states. All participants can see the same map. Each participant can just see the status of the units which he is controlling.

#### 11.3 Fire states
Following are the different states of the cells in the map.

- **Clear** represents no fire
- **Burning** represents currently burning
- **No longer burning** represents that the fire has been extinguished
- **Burned-out** represents the area has been burned out

A fire in a cell spreads in the NEWS (North, East, West and South) directions. More the cells burning at a time more quickly the fire spread and it will become difficult to control the fire. Cells that are **No longer burning** and those are **burned out** can’t start burning again.
11.4 Map Description
The map is a 40 x 40 matrix. Each cell in the matrix is uniquely identified by a number (representing the row) and a letter (representing the column). The map is shown in figure below.

![Figure 11-1 Configuration Map](image)

11.5 Objects in the game
Following are the different types of objects in the game. Some objects burn faster than others as shown below.
Normal Vegetation

Pine trees burns **three times faster** than normal vegetation.

Birch trees burn **at half the rate** of normal vegetation.

Swamp **never burns**.

People burns **three times faster** than normal vegetation.

Bank burns **four times faster** than normal vegetation.

Vehicle burns **four times faster** than normal vegetation.

School burns as fast as normal vegetation.

House burns as fast as normal vegetation.

Fuel Station having unlimited fuel and **never burns**. In order to refill the fuel, units (Firefighter, fuel and water) must be on the NEWS (North, East, West or South) location. If the unit will be on the fuel station cell there will be no refill of fuel.

Water Station having unlimited water and **never burns**. In order to refill the water, units (Firefighter and water) must be on the NEWS (North, East, West or South) location. If the unit will be on the water station cell there will be no refill of water.

**11.6 Helicopter unit (Non UAV)**

Helicopter unit is used for searching the fire. This unit can move faster than other units so that fire can be searched as soon as possible so that other objects can be saved as much as possible. After searching the fire this unit can inform other units using communication tool to extinguish the fire. This unit is shown in the figure.

![Figure 11-2 UAV unit](image)

The specified destination or intended position of the helicopter is shown in figure.

![Figure 11-3 Intended position of the UAV unit](image)

**11.7 Trucks**

There are three types of trucks. These trucks will be controlled by the players who are having the responsibility of that particular unit. States of trucks are shown by different colors. For example when a
11.7.1 Firefighter trucks
Firefighter trucks are used to extinguish fire. These trucks are shown by red color. They require fuel to move and water to extinguish the fire. In order to extinguish fire truck must be on the unit where to extinguish fire. Following are different states of firefighting truck

8. **Inactive** represents truck in doing nothing
9. **Moving** represents truck is moving
10. **Mobilizing** represents truck is preparing to fight fire
11. **Fire fighting** represents trucks is fire fighting
12. **Demobilizing** represents ending the extinguish of fire
13. **Refill water** represents truck is refilling water
14. **Refill fuel** represents truck is refilling fuel

11.7.2 Water trucks
Water trucks are used to supply water to the fire fighter units. These trucks are shown by blue color. They also require fuel to move from one place to another. Following are different states of water trucks.

7. **Inactive** represents truck in doing nothing
8. **Moving** represents truck is moving
9. **Mobilizing** represents truck is preparing to transfer water
10. **Demobilizing** represents ending the transfer of water
11. **Refill water** represents truck is refilling water
12. **Refill fuel** represents truck is refilling fuel

11.7.3 Fuel trucks
Fuel trucks are used to supply fuel to the fire fighter units. These trucks are shown by yellow color. The purpose of these trucks is to supply fuel to other trucks and also manage its own fuel.

7. **Inactive** represents truck in doing nothing
8. **Moving** represents truck is moving
9. **Mobilizing** represents truck is preparing to transfer fuel
10. **Demobilizing** represents ending the transfer of fuel
11. **Refill water** represents truck is refilling fuel
12. **Refill fuel** represents truck is refilling fuel

11.8 Wind palette
Wind palette provides information about the wind direction and speed. While measuring the performance of team the wind factor should also be kept in mind. In other words the wind factor should
also be added into the decision parameters list. The information about wind can be obtained from wind palette at specific interval of time.

![Wind Palette Example](image1)

**Figure 11-5 Example of Wind Palette**

### 11.9 Unit Info & Unit property palette

These two palettes gives detailed information about the units, including their current position, intended position, activity, and amount of fuel and water which it currently has. The difference between both the palettes is that the unit info provides a brief info about all the units in tabular form whereas the unit property palette displays the detailed information about each individual unit.

![Unit Info Palette Example](image2)

**Figure 11-6 Example of User Info Palette**

### 11.10 Mail Tool

The only way to share information between all players is mail tool. With the help of this tool you can receive messages from other players and also send them messages. The players can communicate with each other on the basis of Table 2.

This tool has two parts. In the upper window you can receive and read messages from other players while in the lower widow you can type and send messages to other players. The receipt of messages in the upper window is shown by the following:

1. The number at the top right hand corner of the upper window changes. This number represents the number of unread messages.
2. The color of the upper window changes to pink indicating there are new messages.

There are buttons below the lower window to send messages to either specific player or all players.
Appendix E - Player Instructions- Information Searching using UAV

In this experiment, you are required to play a game. This game presents a simulated environment of emergency management system. In this game you have to extinguish a forest fire to save objects like people, pine, banks, houses, birch and vehicles etc.

The purpose of this training session is to improve the information searching skills using UAV (Unmanned Armed Vehicle)

12.1 Organization

There are nine players in total, in which three players are assigned the role of staff (S1, S2 and S3) and remaining six players are assigned the different roles among grounded units. The duty of three staff members is to only get aware with the situation and on the basis of the situation they guide the players (A, B, C, D, E and F) controlling the grounded units. Means they don’t directly operate the system they only command and control the players managing the grounded units.

There are eighteen grounded units which are operated by six players (A, B, C, D, E and F). The player A can operate three gasoline units (G1, G2, and G3). Similarly the players B, C, and D each control three fire fighter units (F4, F5, and F6 (controlled by B), F7, F8, and F9 (controlled by C) and F10, F11, and F12 (controlled by D)). The player E is provided with two fire breaks (B13 and B14) and one UAV (UAV15) for searching the fire. The player F is provided the responsibility of water refilling by operating three water units (W16, W17 and W18). This command and control structure is graphically presented in the following figure:

<table>
<thead>
<tr>
<th>Team Organization (Command &amp; Control)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fire Fighting Unit Chiefs</strong></td>
</tr>
<tr>
<td>S1  S2  S3</td>
</tr>
<tr>
<td>A  B  C  D  E  F</td>
</tr>
<tr>
<td><strong>Fire Fighting Units &amp; Reconnaissance Persons</strong></td>
</tr>
<tr>
<td>G  F  F  F  B  W</td>
</tr>
<tr>
<td>G  F  F  F  B  W</td>
</tr>
<tr>
<td>G  F  F  F  UAV  W</td>
</tr>
</tbody>
</table>

Table 12-1 Task2 – Information searching command & control structure
The communication structure of these nine players are designed in such a way that the player S1 can only allowed to communicate with the players S2 and S3 on the basis of current ground situations. Whereas the players S2 and S3 are allowed to communicate with the rest six players, they (S2 and S3) are also able to coordinate back with player S1. The responsibility of S2 and S3 is to coordinate with the relevant player on the basis of the instructions received from player S1. The six players who are controlling the grounded units are allowed to communicate with each other and with player S2 and S3. This communication hierarchy can be better understood by the following figure;

12.2 Game Interface
Look at the screens of your monitor. There is 40 x 40 matrix showing the map. There is a map legend on the top right corner. On the left side of the screen there is an e-mail tool and different ground unit panels showing their states. All participants can see the same map. Each participant can just see the status of the units which he is controlling.

12.3 Fire states
Following are the different states of the cells in the map.

- **Clear** represents no fire
- **Burning** represents currently burning
- **No longer burning** represents that the fire has been extinguished
- **Burned-out** represents the area has been burned out

A fire in a cell spreads in the NEWS (North, East, West and South) directions. More the cells burning at a time more quickly the fire spread and it will become difficult to control the fire. Cells that are **No longer burning** and those are **burned out** can’t start burning again.
12.4 Map Description
The map is a 40 x 40 matrix. Each cell in the matrix is uniquely identified by a number (representing the row) and a letter (representing the column). The map is shown in figure below.

12.5 Objects in the game
Following are the different types of objects in the game. Some objects burn faster than others as shown below.
Appendix E

Normal Vegetation

Pine trees burns **three times faster** than normal vegetation.

Birch trees burn **at half the rate** of normal vegetation.

Swamp **never burns**.

People burns **three times faster** than normal vegetation

Bank burns **four times faster** than normal vegetation.

Vehicle burns **four times faster** than normal vegetation

School burns as fast as normal vegetation.

House burns as fast as normal vegetation.

Fuel Station having unlimited fuel and **never burns**. In order to refill the fuel, units (Firefighter, fuel and water) must be on the NEWS (North, East, West or South) location. If the unit will be on the fuel station cell there will be no refill of fuel.

Water Station having unlimited water and **never burns**. In order to refill the water, units (Firefighter and water) must be on the NEWS (North, East, West or South) location. If the unit will be on the water station cell there will be no refill of water.

**12.6 UAV unit**

UAV unit is used for searching the fire. This unit is controlled by the unit control palette shown in section 1.9. After searching the fire this unit can inform other units to extinguish the fire using communication tool. This unit is shown in the figure.

![Figure 12-2 UAV unit](image)

This unit can move in multiple ways for example it may move in circle, square, or it can move directly to a specified destination. The movement for this unit is controlled by the unit control palette, which is described in the subsequent section. The movement of unit is shown in figure.

![Figure 12-3 UAV unit moving](image)

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12.7 Trucks
There are three types of trucks. These trucks will be controlled by the players who are having the responsibility of that particular unit. States of trucks are shown by different colors. For example, when a truck is moving towards its intended position is shown by white color having truck number as shown in figure.

12.7.1 Fire fighter trucks
Firefighter trucks are used to extinguish fire. These trucks are shown by red color. They require fuel to move and water to extinguish the fire. In order to extinguish fire, truck must be on the unit where to extinguish fire. Following are different states of firefighting truck.

15. Inactive represents truck in doing nothing  
16. Moving represents truck is moving  
17. Mobilizing represents truck is preparing to fight fire  
18. Fighting represents trucks is fire fighting  
19. Demobilizing represents ending the extinguish of fire  
20. Refill water represents truck is refilling water  
21. Refill fuel represents truck is refilling fuel

12.7.2 Water trucks
Water trucks are used to supply water to the fire fighter units. These trucks are shown by blue color. They also require fuel to move from one place to another. Following are different states of water trucks.

13. Inactive represents truck in doing nothing  
14. Moving represents truck is moving  
15. Mobilizing represents truck is preparing to transfer water  
16. Demobilizing represents ending the transfer of water  
17. Refill water represents truck is refilling water  
18. Refill fuel represents truck is refilling fuel

12.7.3 Fuel trucks
Fuel trucks are used to supply fuel to the fire fighter units. These trucks are shown by yellow color. The purpose of these trucks is to supply fuel to other trucks and also manage its own fuel.

13. Inactive represents truck in doing nothing  
14. Moving represents truck is moving
15. **Mobilizing** represents truck is preparing to transfer fuel
16. **Demobilizing** represents ending the transfer of fuel
17. **Refill water** represents truck is refilling fuel
18. **Refill fuel** represents truck is refilling fuel

### 12.8 Wind palette
Wind palette provides information about the wind direction and speed. While measuring the performance of team the wind factor should also be kept in mind. In other words the wind factor should also be added into the decision parameters list. The information about wind can be obtained from wind palette at specific interval of time.

![Wind Palette Example](image)

**Figure 12-6 Example of Wind Palette**

### 12.9 Unit control palette
This palette is used to control the movement of UAV unit. The figure below illustrates the graphical view of this palette. This palette contains a textbox where the UAV unit’s intended position can be specified. This can be done either by entering the values in the text box or by clicking the intended position on the map. After specifying the intended position and pressing the go button starts moving the UAV unit towards its destination. This can also be stopped by pressing the stop button. There is also a button for returning home which is used to return the unit towards its start position. This unit can move in multiple ways as shown in figure.

- **Circle**: Unit starts moving in circle of specified radius
- **Square**: Unit starts moving in square of specified radius
- **GoTo**: Unit starts moving to a specified position
- **GoTo And Home**: Unit starts moving to a specified position and returns back to home position.
- **Patrol 2 Points**: Unit patrols between two specified points
- **Patrol 3 Points**: Unit patrols between three specified points
These two palettes give detailed information about the units, including their current position, intended position, activity, and amount of fuel and water which it currently has. The difference between both the palettes is that the unit info provides a brief info about all the units in tabular form whereas the unit property palette displays the detailed information about each individual unit.

12.11 Mail Tool
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