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Natural Disaster Relief
Concept of Operations

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Content

1. Scope
2. Referenced Documents
3. Background Information
4. Existing System and Operations
5. Operational Overview
6. System Overview
7. Operational Processes
8. Other Operational Needs
9. Analysis of the Proposed System

1. Scope

When disasters strike, first responders put their lives on the line in order to save those affected. Unfortunately, not everyone is able to be rescued due to the limited abilities of these responders. This includes the inability to locate all survivors, the inability to arrive at the location of survivors in time, and the inability of the first responders to effectively get to some survivors trapped in rubble. Many of these brave men and women also lose their lives in the line of duty trying to save the people affected. Recognizing this, it would be advantageous to develop a new system that would aid the first responders in locating survivors, as well as minimizing the risks for the first responders entering dangerous areas. This system is intended to possess features that are not currently available to the first responders, therefore maximizing its potential benefits. This system may incorporate more travel options, different imaging techniques, new communication systems, and risk assessment tools that can aid in the relief efforts. In turn, more survivors will be rescued, and more first responders will stay safe.

The purpose of this document is to summarize the mission of the proposed system in its entirety. A background and a discussion of currently employed models will be discussed, as well as what is wrong with the current systems. Then an overview of the operational environment and the proposed system will be explored. This will be followed by an analysis of the system needs and capabilities, as well as an analysis of alternatives. In essence, this document introduces the reasons behind the proposal of this system and why each key feature is suggested.

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3. Background Information

A natural disaster is an environmental event such as a flood, earthquake, tornado, hurricane or fire that causes great damage or loss of life. Many natural disasters occur without notice or time for preparation. Natural disasters cause chaos for emergency planning and first responders. Challenges that government face in response to a natural disaster include the effective distribution of aid to the community and the personal safety of the first responders. The “number of people suffering food crises as a result of natural disasters has tripled in the last thirty years.” (Oxford)

Community members may not be aware of the danger that first responders can endure when called to the scene. First responders such as firefighter’s, police officers and EMT must withstand “heat stress; injuries from working around debris and on unstable surfaces; dust; confined spaces; chemicals and contaminated flood and standing waters; electrical hazards; infectious diseases; food-borne, water-borne, insect-borne and animal-borne diseases of concern; animal and insect hazards; and traumatic stress injuries.”(Contiguglia) There has been a call to improve safety for the first responders.

Public Safety and Homeland Security Bureau has developed emergency plan for first responders. The emergency plan consists of three main concepts; preparation, response, and recovery. These concepts provide goals to develop and implement strategies that can save lives. If these concepts were adopted in autonomous robotic systems, it could enhance the efforts of searching and recovering survivors and analyzing infrastructure to improve safety first responders.

Preparation is necessary for assisting in natural disasters. Training is very important for emergency. If individuals are taught the evacuation protocols, lives can be saved. Emergency notification is essential. Making the population aware of a pending natural disaster before it strikes can assist in the evacuation efforts. Many people from California say "prepare for the Big One." If there was an autonomous robotic system that was developed to detect the "Big One" it could react quickly to examine damage and direct resources to those in dangers or in need. Response includes "impact assessments, repairs and implementation of alternate solution."(FEMA) If Response time is decreased damage can be mitigated and lives can be saved. An autonomous robotic system can work with the first responders to increase response time. During Hurricane Katrina the government ineffectively responded to its citizens resulting to increase pain and suffer.

Recovery is essential in natural disaster relief. Recovery efforts can be very difficult after any natural disaster. There are many cities still trying to recover after natural disaster including New Orleans and Fukushima. Many citizens are still left homeless due to these terrible disasters. Recovery focuses "on how best to restore, redevelop and revitalize the health, social, economic, natural and environmental fabric of the community and build a more resilient Nation."(FEMA). Recovery efforts need to be increased so that citizens can try to get back to normal life as soon as possible.

4. Existing System and Operations

In the event of a natural disaster such as a hurricane, tsunami, or earthquake, emergency response personnel need real-time information concerning the whereabouts of survivors, the condition of infrastructure, and recommended ingress and evacuation routes. Current practice for gathering this information relies heavily on humans (e.g., first responders, law enforcement, and drone operators). An autonomous robotic system with sensors can facilitate such information gathering tasks, freeing humans to perform more critical tasks in natural disaster relief operations. As each disaster is distinct, a single domain model that incorporates all the necessary steps for a mission will be required such that rescue personnel would be able to tailor possible autonomous robotic system missions to the current situation.

There are several existing autonomous robotic systems tasked to assist in disaster relief. For example, the Gemini-Scout is less than two feet tall and has the capability to move through 18 inches of water while sampling the air for toxic fumes. It also rolls over stairs, sand and gravel and is able to climb 45-degree inclines. Sakura was created to inspect the Fukushima nuclear reactor building and has an infrared thermal camera and a directional microphone to detect the sound of water. DARPA's disaster relief robot, Pet-Proto, is able to jump, climb and avoid obstacles. Designed primarily to help Navy Sailors fight fires, the Charli and Charli II is able to stay upright, pick itself up if it falls down, talk, walk and hold a light bulb without breaking it. Charli was the first untethered, autonomous, full-sized, walking, humanoid robot with four moving limbs and a head, built in the United States. DARPA recently held its Robotics Challenge which tasked teams to develop a semi-autonomous ground robot that can perform eight different tasks (e.g, open and enter a building and climb an industrial ladder).

The existing robotic systems have distinct characteristics useful in providing support in certain key areas of concern. In the aftermath of Hurricane Katrina in 2005, robots searched for stranded victims using cameras, microphones and sensors to provide images from heavily damaged areas inaccessible by rescuers.

5. Operational Overview

I. Mission Statement

It is the mission of the Talk Nerdy To Me (TNM) team, to provide improvement in search and rescue for survivors and analyze infrastructure for potential safety concerns for first responders. These improvements will elevate the ability to locate victims trapped in various natural disasters such as:

- Avalanches & Snow Storms
- Earthquakes
- Floods
- Hurricanes
- Lightning
- Tornadoes
- Tsunamis
- Volcanoes
- Wildfires

To accomplish this mission, TNM members will determine strategies to deploy efficient and effective rescue technologies that can be implemented to elevate the response time of the first responders based on infrastructure analysis. TNM will concentrate on the usage of autonomous robotics system, infrared and thermal vision cameras, satellite communication and system interfaces (DARPA supplied wired, communication, touch, GPS/navigation, power and tools).

II. Operational Policies and Constraints

In accordance to our mission to improve the natural disaster survival rate and first responder response times, it is the policy of TNM to promote and support the various disaster and management systems through a spectrum of activities, objectives, and management cycles. Our policy is mandated to implement plans and

strategies in all emergency levels to aid safe recovery of individuals laying helpless in the adverse effects of the given disaster.
TNM is determined to produce change and work effective and efficiently under the guiding principles defining our mission. These principles are initiatives that will be implemented to observe and improve disaster casualty rates. A few of these initiatives are:

- Community advancement in training and procedure for disaster preparedness
- Code of conduct during a natural disaster event (e.g. effective communication, coordination, and collaboration)
- Implementation of international advisory and support
- Mitigation and operating procedure implementation
- Hazard identification and risk assessment
- Resource management implementation

In order to enhance life safety or recovery, disaster preparedness must encompass proper training for personnel that are risking their lives to save a life. It also allows the ability to produce emergency actions in a systematic effort to keep all parties safe and enhance the establishment of a cohesive unit within the relief community.

III. Operational Environment

The environment is often characterized as the root cause or carrier of a disaster. For example, we can relate this to the earthquakes in California, tornadoes in Kansas, hurricanes in Louisiana, or even floods in Texas. The environment can behave in such a way that can affect any community it associates with. On the other hand, our environment can be affected by our own agenda. It is evident that global warming was the primary cause of man-made production that emitted harmful chemicals in the air that drastically changed our atmospheric conditions. (E.g. oil / chemical spills, use and procurement of fuels, water degradation, farming or material selection practices for industrial production)

In our efforts to find solutions to refine support systems in natural disaster related incidences, we also must acknowledge the potential causes of these threats. We must develop or refine our environment management strategies. This strategy will oppose all hazards and support the systematic effort of stakeholders to mitigate the problem before the effects become drastic.

IV. Personnel

Preventative and preparedness efforts are often difficult to tolerate over time. Due to our human nature to satisfy self-need, if no disaster is prevalent for an extended period of time, we often become wrapped up in our own agenda. Over time we lose focus of the preventative or preparedness principles and become less vigilant of what we are advocating for. This becomes more difficult when educated personnel follow this motion. In reality, the best solution is to develop a stronger group of advocacy personnel. These advocates will accommodate a full spectrum of classes such as: scientist, engineers, individual activists or groups who specifically focus on hazards and disasters, and public officials, etc. These advocates must all agree to make these disaster relief principles a priority, thus producing the ability to refine strategy, produce new mechanical/ technical developments and interfaces for disaster preparedness, and aid in the training of our extended personnel.

V. Support Concept and Environment

The process that will have an ultimate effect to improve disaster recovery are set on the bases of acquiring adequate support. These efforts must stem from the premise of gaining support from the social, economic, and cultural dimensions of society in order to improve the human life quality. This also resonates proper development to influence change of multifaceted, unified natural / man-made properties and procedures causing damage to our environment. Supporting concepts to aid in strategizing for environment efficiency will be defined through the operational process of technology based functions and system interfaces.

VI. Justification for and Nature of Changes

It is perceived in some cases that 9 out of ten natural disasters are climate related. The blame of natural disaster due to global warming can be justified, it is also justifiable that many natural disasters or essentially just natural disasters. If it is proven that the nature of change in the environment is in some sense global or even universal. With the way environmental change is perceived, especially with the public policy, it is seen justifiable for human stability. It is that same policy that allows global or market related solutions to implement or solve environmental disasters. Now with the support of government officials and disaster preparedness managements (e.g. FEMA, Red Cross, NEMA, NFPA), this environmental control policy has been refined.

VII. Impact

All TNM efforts, activities, and development must be based on the knowledge of hazards, the possibility of any given disaster, and the acknowledgement of potential impacts that originate from them. The information presented from these acknowledgements exemplify the impacts on:

- Health and safety hazards

- Infrastructure
- Procurement of first responders
- Economic or financial circumstances
- Implementation of interfaces

TNM was developed to mitigate these impacts through the development of technology and systematic strategies. This will consist of the development of several technical interfaces (e.g. communication, imaging, controller, navigation, threat assessment, power, and maintenance) and technology development (e.g. DARPA, robotics, sensory systems, control systems, and monitoring systems) by the support of primary personnel advocates.

6. System Overview

In order to improve upon the current models of disaster relief, a new system – such as a robot or drone – should be designed that has many capabilities that are not currently employed. The purpose of having such a system is to help the first responders locate survivors more quickly and to assess that area for damage to ensure the safety of the first responders. Some of the more specific goals of this system include traveling the area of the disaster more quickly than first responders currently do. This could be done via flying, driving, or traveling through the water. Then this system should be able to locate survivors more quickly than current methods by employing things such as cameras, radar, lidar, thermal imagery, and more. If the system can also communicate with the survivors that it finds via a speaker and microphone with a direct line to the operator, survivors may be able to share the location of other survivors as well. In addition to these, this system may be able to assess the risk for the first responders before the go in, which can improve the safety and wellbeing of these brave men and women. This can be done by a live video feed being analyzed by experts to assess the structural damage and risk. The system should also be able to constantly search for pollutants/contaminants in the air that may be harmful to either the first responders or the survivors.

This system can be employed by any organization involved in the aftermath relief of these disasters, such as the police department, fire department, medical services, and large relief organizations such as FEMA. Each of these departments/organizations will require a team that specializes in the use of this system. These teams will require training on the handling and operation of this system. These teams would be set up at the command centers of the disasters and would work in conjunction with each department. These departments will also require a maintenance team to fix any issues with these devices on site. The first responders should also have basic knowledge on operation and maintenance in the event of an emergency in the field.

The potential system interfaces/capabilities and their purposes include:

- *Communication Interface*: Speaker and microphone
    - In the event that a survivor is found, it is important to communicate with them to determine whether or not they are injured and if there are other survivors. With this interface, they can communicate with the operator and the operator can alert the proper authorities to determine the next step.
- *Imaging Interface*: Thermal, infrared, radar, lidar, cameras, night vision, flashlights, etc.

    - Each of these different imaging interfaces can be used for many different situations, for example thermal imaging to determine where humans are in a wreckage or even at night with low visibility.
- *Controller Interface*: Touch screen, joy stick, controller (similar to xbox), keyboard, etc.
    - The controller interface is what allows the operator to control the system. In different cases, it is beneficial to use different kinds of controllers, so the controllers listed above are options for potential controllers.
    - Different capabilities of the system may be accessed by different controllers (for example, movement controlled by joystick while sensors controlled by keyboard…).
    - Commands and responses are sent via radar.
    - Different types of movement may also be controlled using different controllers. For example, the ability to drive on land (similar to a tank), the ability to drive on water (like a boat), or swim underwater (like a submarine), or fly in the air (drone), can each be controlled by different controllers.
- *Navigation Interface*: GPS/Map, blueprints of buildings programmed in
    - The operator will need some way of tracking the system, so the position of the system/robot could be linked to the command center via GPS.
    - Blueprints of major city buildings could be programmed in so that the location of survivors within the building can be easily accessed as well as the operator being able to track where the system has already traveled inside the building.
- *Threat assessment interface*: Cameras for operator to assess structural damage, built in air sampler to test for harmful airborne pollutants
    - This feature is important to determine the safety and risk of different situations.
    - A constant live video feed could be viewed by safety analysts so they can visually determine if there are any obvious structural risks.
    - A constant testing of air can determine if there are any pollutants that are too harmful without proper equipment, and can determine the safety/prioritization of the survivors.
- *Power Interface*: Battery powered
    - Having the entire system be battery powered allows the system to be very portable as well as allowing the batteries to be easily replaced.
- *Maintenance Interface*: Device sensors on the system to determine the damage to the robot, if any.
    - Similar to trouble codes on a vehicle, this could allow the operator to know when something is wrong and what exactly is wrong to determine whether or not the system can still be used in an emergency or if maintenance must be performed before use.

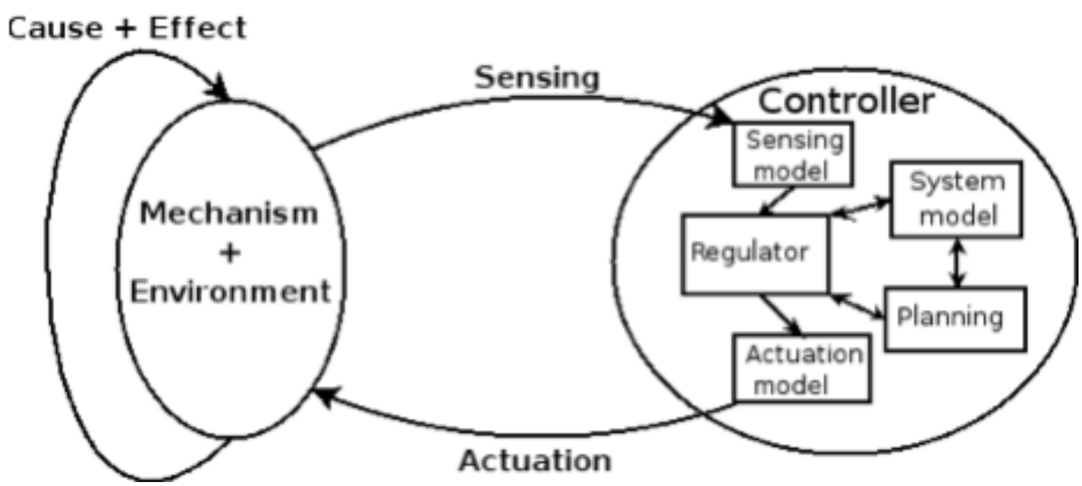
The combination of the above capabilities can make this system a very efficient and useful aid in the disaster relief efforts, and may be able to save even more lives than are saved with current methods.

7. Operational Processes

1. Missionary:

Provide improvement in searching for survivors and analyze infrastructure for potential safety concerns for first responders.

2. Operation Process Concepts:



1) User Command Interface
Through a user-friendly graphical interface or sound warning system, useful information on the current status of robot system (e.g. position, detected obstacles, path planned, task performance phase, energy/battery status, troubleshooting, etc.) can be monitored or modified by the user. User interface is the mean that enable a way to check/proof if the robot has understood human commands. User interface should be designed to be user-friendly and synoptic.
A special software interface to enable advanced communication and command understanding. Interface will enable robot to understand human commands.

2) Data Acquisition and advanced perception
The robot will enable a target and avoiding static or dynamic obstacles in its environment, which based on advanced data acquisition from surrounding using reach sensory and communication system.

3) Object Recognition& Environment Understanding
Based on visual/heat/sound signal obtained from the stereo-vision cameras attached to the robotic mechanism and based on advanced perception, robot is enable to recognize the objects in its surrounding. This kind of cognitive behavior is realized by designing an object classifier.

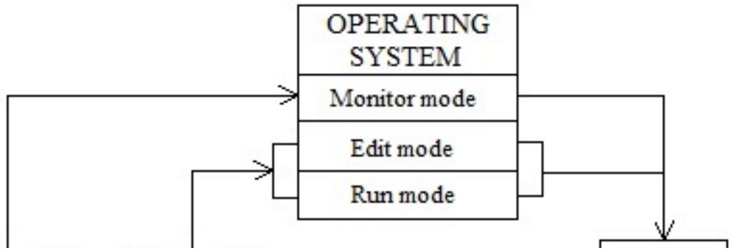
4) Decision Making& Context Reasoning
According to the data collected from sensor and the command obtained from people as well as according to the current situation in the scene, robot has to make a right decision to identify the objects. Sometimes, in the same circumstances, robot has to do interpretation and recognized human being and animals.

5) Simultaneous Localization & Mapping
According to the collected data and information, the robot be able to localization and mapping. The robot make environment maps and to find relative location of surrounding objects.

3. System Operations Overview:

1) Operators, Engineers, Manipulators
2) Sensor System: such as thermal sensor, laser sensor, vision sensor, camera
3) Control System: robot operate system, also the core of the robot, process data, Object Recognition and Environment Understanding, Localization and Mapping.
4) Monitoring System: I/O device, Screen
5) Accessory: Power, GPS/Mapping, Speakers

4. Operation flow overview:

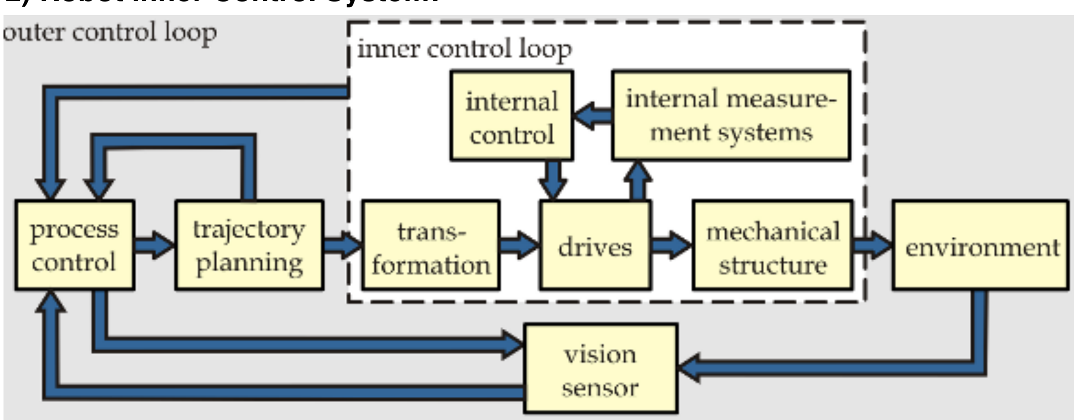


1) System Input and output:

Input: GPS/ Facility Map
Operator inputs
sensory input
Power
Tools

Output: Manipulator Movements
Sensor Readings
Video feeds
Force/Torque/ Resolver Readings
Report Data/ Status to operator
Task Completion Status

2) Robot inner Control System:



3) Operation Process:

a) Operators/ Manipulators input the command in I/O device
b) The sensors, such as Thermal Sensor, Laser Sensor, Vision Sensor, sense the color/shape/heat/sound. And transport the data to Controller.
c) Robot Collect the data and Controller Process the data, recognized the object. Localization and mapping the object.
d) I/O device read the data, output the information.

8. Other Operational Needs

Hurricanes, mudslides, earthquakes and terror attacks often leave widespread damage – and those injured can often be very hard to reach for search and rescue teams. Robots can play a vital role in getting life-saving aid to those in need. Robots help because they are small enough to enter confined spaces, or they can fly above damaged areas cut off from road transport, which allows rescuers isolated from the scene to find those in most urgent need of attention.

In the area of disaster relief robotics, which started in 2001, ground robots were the only types being used until 2005. In 2005, the first use of small unmanned aerial vehicles appeared. Such systems were being developed primarily for the military market. Since 2011, the only disaster that didn't use an unmanned aerial vehicle was the South Korea ferry where they used an underwater vehicle. Underwater vehicle usage became prevalent in 2007. Every single disaster since 2012, have used unmanned aerial systems, including the ones here in the United States.

The most important element of this entire operation is information (i.e., how the data is shared and how the data is visualized). The big value in most big building collapses lies in the smaller the better, what do you do when there's not an obvious void and can you get something to literally snake and nudge and worm its way through there. There are also some great advances being made in manipulation. The first decade of robots can be characterized as having been all about allowing the responders to see at a distance, but now there appears to be a shift. While we can see at a distance, we would like to poke things, move them over, drop things off, etcetera (i.e., we need to act at a distance and not just see at a distance). Current users need an autonomous robotic system with rough terrain mobility and slippage control. More importantly, there is a need for a new way for robots to map an environment simultaneously as it rolls through an area.

9. Analysis of the Proposed System

I. Summary of Advantages

There are several advantages that can be exemplified through the TNM principles. This is made possible by the adequate support and analysis developed by our intercessors and personnel. These advantages consist of:

I.I Informational Development in Data Retrieval, Sharing, and Visualization Strategies

Informational development is the most important element of operations. Without an efficient collection of informational data, the ability to incorporate new interface systems, development in technological advancements, and disaster relief strategies and refinements of policy would all be deemed irrelevant or inconsistent. Informational development is what defines the TNM mission and sets our foundation to build upon.

II.I Autonomous Robotic Systems

For centuries man has placed themselves at the fore front of every new venture, sacrificing their lives and families for the greater good of their country or religion. Nowadays, autonomous Robotic systems has become the new age for exploration. Technology has advanced in such a way that men can charter to unknown territory without putting themselves at risk to do so. With this technology, men can control unmanned vehicles or drones to explore environments with the support of robotics to lift, peek, touch, or even listen to the environment of surrounding areas.

III.I Interface System Developments

With the support from the informational analysis, various forms of interfaces can be developed to aid in system development and implementation. Technology advancements has proven resourceful in the development of various interfaces such as:

- Communication,
- Imaging,
- Controller,
- Navigation,
- Threat Assessment,
- Power
- Maintenance

These interface developments make it possible to travel to unreachable and unseen environments by incorporating sensor driven controls. A man can remotely control each system while in a safe location. This will ultimately promote:

- Development and Retrieval of Informational Data
- Increased Feasibility and Survival Rates
- Increase Mapping Rate of Terrain
- Study of Inaccessible Areas, Regions, and Environments
- Decreases Cost in Observation

IV.I Disaster Relief Management and Organizational Support

By concentrating on the TNM principles, a collaborative effort will be initiated between different disaster relief managements or organizations. This support allows us to share viable information and implement new training procedures of each other's systems. This provides an increase in personnel knowledge, preparedness capabilities, and disaster awareness, thus establishing a better disaster relief protocol for first responders.

II. Summary of Disadvantages / Limitations

I.I Obtaining Government or Elected Official's Support

It can become a difficult and cumbersome process gaining the support of the government officials who don't contain the same beliefs as the organization. In many incidences, you would need to convince the official of the necessity or priority to implement a new system or policy. Some cases may veer away from government policy, which then political voting would need to be incorporated for this change. Although the data retrieved from analysis can prove legit, major policy holders of corporations can ultimately have a major hand in ruling against the organization due to the corporation become at risk for revenue drops or effects from policy renewal.

II.I Obtaining Community Support

Community support is another issue that can be faced. Some communities, comparable to some government or corporate officials, do not have the same beliefs as the organization. Some communities who face poverty stricken issues do not have adequate resources to support the goals and ideas of the organization. This situation can become a greater issue than the current condition if a natural disaster incident occurred. A clear example was made prevalent in the hurricane Katrina flooding where many were left in worsened conditions with minimal support due to the lack of preventative and preparedness strategies.

III.I Technology Inadequacies

Although technology advancements and implementation have grown over the years, these advancements can at any time become in operable or fail. If it extremely difficult, nearly impossible to account for human error or change of events. There are various issues of the production of these technological advancements, which are:

- Technology can become expensive, especially for a one time analysis.
- Aerial imagery can become costly
- Human method production error can occur
- Specific sensors can emit their own electromagnetic radiation (EMR), which can be intrusive of surrounding environment.
- Interfaces can produce more harm than good to a disaster related incident
- Excessive and costly training would need to be implemented

IV.I Funding

In the end, everything always boils down to costs. In order to develop these technological advancements, moreover, in order to campaign and support the TNM principle guidelines, funding would need to be developed in order to accomplish this task. As a non-profit organization, it would rely on the government and elected officials, the community supporters, and other various funding development strategies to aid and support the organizational goals.

III. Alternatives and Tradeoffs Considered

I.I Impact assessment, refinement, and implementation alternatives
II.I Increase awareness