

# Detecting and Creating a 2D Heatmap of Radiation Hot Spots via Unmanned Ground Vehicle

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**Author Note:** Cadets Hales and Lee are fourth-year students at the United States Military Academy working on the first year of the RADBOT capstone team. Cadet Hales is an Operations Research major and Cadet Lee is a Systems Engineering major. Mr. Edward Londner, Visiting Professor in the Department of Systems Engineering, is the group's Systems Engineering advisor. Mr. Londner has provided a significant amount of guidance and assistance to the cadet team for this project. Thank you to all the team's advisors from Electrical Engineering and Computer Science, Physics and Nuclear Engineering, and Civil and Mechanical Engineering for their assistance and support.

**Abstract:** The Army's chemical, biological, radiological, nuclear, and explosives (CBRNE) units respond to the any threat involving CBRNE elements. Their missions often involve the search and identification of radiation sources in a compromised facility. A major concern with this mission is the survivability of the Initial Entry Team, who is tasked with surveying the volatile indoor environment for data. The creation of a system to assist in, and expediate, the process of initial entry will greatly increase the health and welfare of the team. In order to localize and detect radiation in a potentially contaminated indoor environment, our team will develop the RADBOT, an unmanned, tethered robot that can detect and map radiation. This paper will summarize the research, design, testing, and results for the development of the RADBOT system.

**Keywords:** Radiation, Detection, Robot, Unmanned, Tethered

## 1. Introduction

CBRNE responders are trained to assess threats and act upon them so that other missions across the Army can succeed. More specifically, the Initial Entry Teams (IET) handle initial evaluations of radiologically contaminated operating environments. Several factors in current operations inhibit the maneuverability and efficiency of the IETs. When the levels of radiological contamination are unknown, IETS, conduct their missions by assuming high levels of radiation exist. They don their most protective gear and go into the facilities that they are tasked to clear with handheld radiation detectors. The gear that they wear to keep them safe inhibits their maneuverability and increases mission time. Their operating environment is complex. The buildings may be cluttered because of a quick departure from those utilizing the facility. The building may be damaged by indirect fire if it was an occupied enemy location or suspected radiological warehouse. It may be a former nuclear facility or an informal site of radiological threats. The team goes into each mission with little definitive intelligence—it is their job to collect information about the compromised site.

RADBOT is the proposed solution to CBRNE responders' IET problems of soldier health, safety, and data collection. In order to increase the IET's survivability and efficiency in providing initial survey data, the IET will utilize a radiation detecting robot. The research team's goal is to develop an unmanned, tethered ground vehicle capable of detecting and mapping levels of radiation in real time to identify and localize the radiation in an unknown environment. The soldiers of CBRNE units will operate and control the vehicle from a ground control station located outside of the facility or room being cleared. Once the room is cleared and the team has all pertinent information at their disposal, the team can continue the mission and move RADBOT into the next room or facility needing to be cleared. RADBOT is in its first few months of development and the team does not have a tested prototype thus far. This report addresses RADBOT requirements in Section 2, details of the system's current design in Section 3, and results and analysis of critical tests in Section 4.

## 2. RADBOT Design and Requirements

### 2.1 Stakeholder Requirements

RADBOT's primary requirements were derived from stakeholder analysis, which was conducted early in the design process in keeping with systems engineering best practices (Chen & Saboonchi, 2016). These requirements can be divided into three different categories. The robot itself shall be able to navigate obstacles, cover an area of 2500 to 3000 square feet (the size of the facilities indicated by stakeholders), and operate for at least 12 hours at 30-minute intervals. Stakeholders desire a tether that avoids tangling or snagging on obstacles inside of the facility. The tether of the system shall provide power to the robot and its sensors, transfer information to and from the user and robot, avoid tangling, be 30 to 100 meters long, and be protected from environmental hazards. The sensors on the RADBOT shall focus on dosage and hotspots of gamma radiation, immediately provide data to the user, and localize and map point sources of radiation. These requirements came directly from CBRNE personnel, the future users of RADBOT and important stakeholders.

### 2.2 Review of Current Technology

The identified requirements and constraints provided much needed knowledge on what the RADBOT will look like at completion. An example of a system tackling a similar problem is the Robot for Investigations and Assessments of Nuclear Areas (RIANA). RIANA is a French robot dedicated to "investigating and characterizing the inside of nuclear facilities in order to collect efficiently all the required data in the shortest possible time," a mission very similar to that of RADBOT's (Kanaan et al, 2015). The RIANA is a highly modular and flexible system that can be customized towards achieving a specific mission. It can perform visual inspections, localization, 2D mapping, nuclear characterization, measurement, testing, and sample collection. In comparison, RIANA is meant to solve a much broader problem than RADBOT, exceeding it in functionality. Furthermore, the RIANA is not a substitute for RADBOT because of major differences between the two including RIANA's wireless control and environment manipulation. These things are not in the scope or criteria of RADBOT because it is a system aimed at solving the problem in which there is one mission set, a requirement for tethered control, and no need for manipulation due to hazards.

Another example of a system focused on a comparable field as it relates to mapping without a GPS, is the ASQ-6DMapSys. This is a Chinese platform aimed at autonomous navigation, location, and map generation through the employment of several different sensors in a small, lightweight, cost-effective vehicle without the ability to utilize GPS (Hu et al, 2013). These goals parallel the RADBOT regarding the characteristics of multi-sensor data collection, cost-effective, and operation in environments without GPS capabilities. When compared, the ASQ-6DMapSys and RADBOT still have several key differences. The ASQ-6DMapSys is meant to be a fully autonomous mapping system that was created from scratch, whereas the RADBOT will function tethered and with real-time video, developed in a much shorter timeline.

### 2.3 RADBOT Innovation

While RADBOT is comparable to other systems in its field, there are aspects of the system that make it unique. The tether component differs from similar systems because it provides data, control, and power to the robot itself. While other systems in the field may view wireless transmission of data and control with an onboard battery as beneficial, it is the opposite for the RADBOT. The tether ensures that the system will maintain a hard-wired connection to the user, without the possibility of this connection being disrupted by interference in signal in the same way a wireless robot might. This is important given RADBOT is required to function in an area where the nuclear facilities may have walls and structures made of materials that interrupt wireless connection. Another feature of RADBOT that contributes to its unique design and function is its heatmapping of radiation. While the mapping of radiation is not a new concept, this mapping overlays radiation density on a 2D map that is formed without the use of GPS. This unique feature is a result of the specifics required to solve the IET's problem. The radiation map is useful for the IET to understand which areas in the facility are dense with radiation and which areas are not, reducing their risk of exposure and increasing their survivability. The 2D mapping of the facility without GPS is a requirement due to the lack of signal, needed for GPS, in such facilities. This overlaying of a radiation heat map on a 2D map will happen simultaneously, increasing the IET's efficiency and decreasing the time taken for the mission.

### 3. RADBOT Overview

#### 3.1 Problem Statement

Team RADBOT will develop an unmanned, tethered ground vehicle capable of detecting and mapping levels of radiation in real time to identify and localize the radiation in an unknown environment. RADBOT's primary mission is to reduce risk for soldiers in IETs in the unknown and dangerous environments that they are tasked with assessing. RADBOT must be able to navigate the clutter and obstacles located inside of the facility to accurately assess the threat level. The robot will be controlled via a hardline tether that ensures the data collected from the robot can get back to the ground user controlling the robot, given the uncertain nature of the operating environment.

#### 3.2 RADBOT OV-1

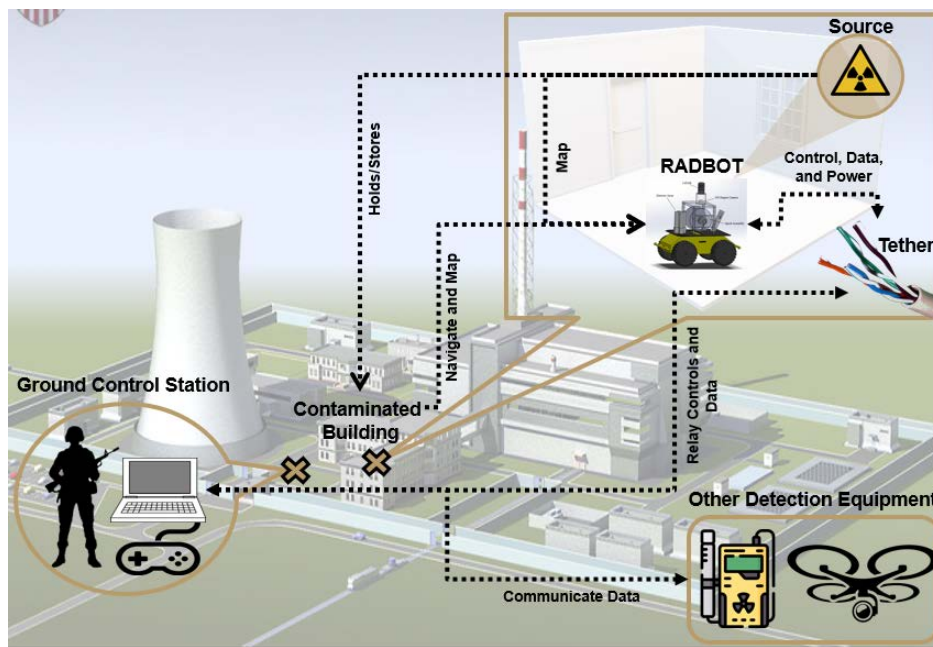


Figure 1. RADBOT OV-1 Diagram

Figure 1 outlines the different systems it interacts with and where it lies in the CBRNE unit's mission at large. The concept of RADBOT's operation begins when the soldiers deploy the robot, which is a small, 4-wheeled robot, from their ground control station to maneuver inside a contaminated facility. The exact weight of the finished robot is undetermined, but the system is designed to be easily carried by a team of soldiers. The soldier operating the robot will use their hand-held controller and the camera on RADBOT to navigate the building. LiDAR will be mounted high on the robot to assist the user in navigating and provide a floorplan to accompany the heat map being produced in real time. The robot contains a radiation detector array on its platform used to detect and transmit data about the location and dosage of radiation in the facility. The data gathered by the sensors on the robot is then sent through the tether, which is also transmitting control, data, and power to the RADBOT. It is housed on a spool assembly system located on RADBOT's platform. The tether is designed to unspool at the same rate as the robot to avoid tangling or snagging on objects. The tether will relay information back to the ground control station and populate a 2D heat map, conveying the direction and level of radiation inside the building. This IET member will also have other detection equipment at their disposal, all of which, in combination with the RADBOT, gives them a more comprehensive understanding of the environment they are surveying.

### 3.3 High-Level Design

#### 3.3.1 Functional Hierarchy

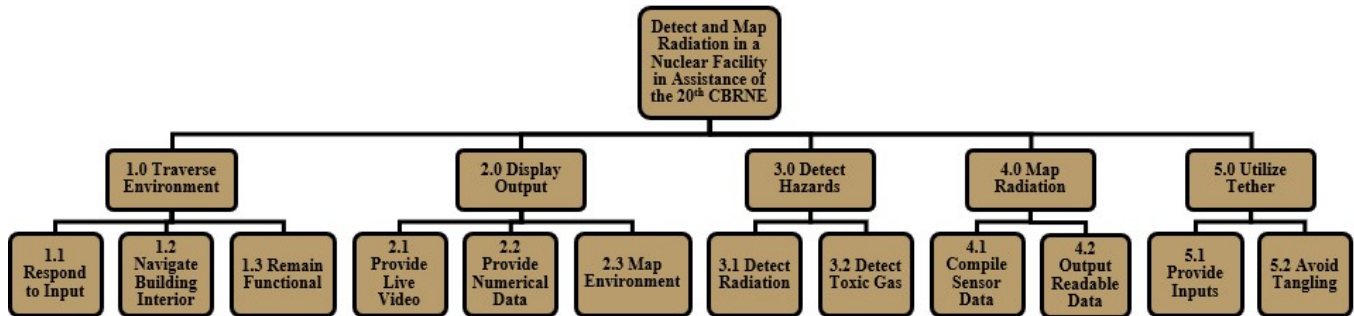


Figure 2. Functional Hierarchy

The Functional Hierarchy displayed in Figure 2 depicts RADBOT’s top-level functions. These functions address the way in which the system will solve the problem and address the requirements of this problem, which will be further discussed. The Functional Hierarchy was developed using the combined expertise of the team members and the problem definition provided by both the sponsors and users of the system.

#### 3.3.2 Physical Hierarchy

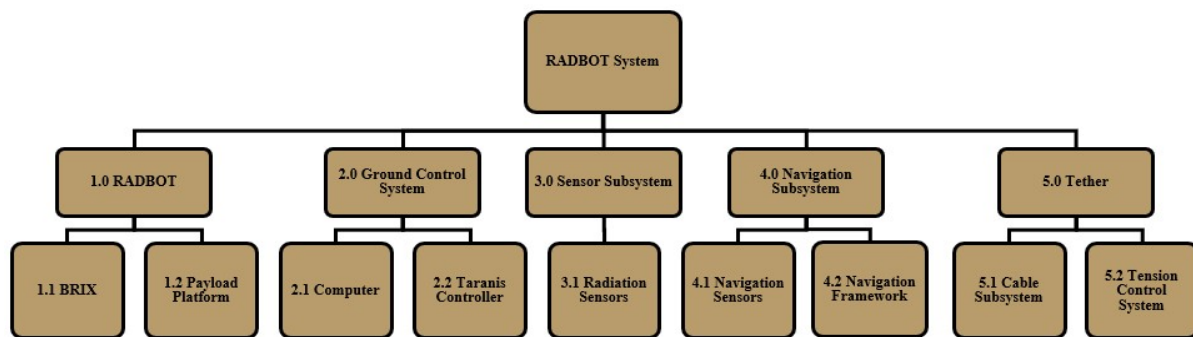


Figure 3. Physical Hierarchy

The Physical Hierarchy in Figure 3 pairs the top-level functions in the Functional Hierarchy with their physical counterparts that make up the system. The Physical Hierarchy was developed after the Functional Hierarchy was modified several times to suit the problem at hand. Additionally, the team needed to do some bench-top testing to determine the specific physical components of RADBOT and how these components would interact to accomplish the functions above. Figure 4 in Section 4.1.1 establishes a computer-aided design of RADBOT.

### 3.4 Tradeoff Analysis

There are always tradeoffs to be made when utilizing a robot where a human once operated. RADBOT exists to reduce the threat to the CBRNE soldiers, but until the system is validated, the clearance accuracy of the system compared to that of the soldiers’ standard process is unknown. The team conducted initial analysis on risks and rewards of RADBOT during the initial design phase.

### 3.4.1 Advantages

To be maximally useful to IETs, RADBOT must not only mitigate risk to soldiers, it must also match—or surpass—their performance in terms of mapping its operating environment and measuring the ambient radiation. After speaking with the users and subject matter experts, the team concluded that RADBOT will provide more accurate, more detailed results from its surveying of a space compared to that of a human, given the system performs to its full potential. This is due to its ability to perform multiple functions with sensors that soldiers would not otherwise be able to use. The system will detect and relay information on amount of radiation detected, specific direction of the radiation source, a map of the floor plan and existing obstacles, and visuals inside of the facility before the soldiers enter the building or room. RADBOT is the safer option given the mission. If the robot is employed, soldiers would not need to enter a contaminated facility without intelligence on the safety or threat of the environment. Without the use of the robot, the soldiers are exposed to the elements inside of the facility and the risk to their safety increases. RADBOT assists in the soldiers' mission of surveying a facility, while keeping the soldiers at a safe distance.

### 3.4.2 Limitations of the System

However, there are certain constraints on the RADBOT that the team identified. The team has assessed the need for decontamination after each use. While it is not expected that subcomponents of the system will spark or cause fire, the affect that radiation will have on these subcomponents is unassessed. Additionally, if the robot's tether were to break or malfunction, then the robot would be stranded in the room with no ability to navigate back to the ground user or transmit information. The system is intentionally modular, but the parts cannot be replaced while the robot is in the middle of a mission due to the unknown threats of the environment. Finally, the robot's ability to accurately measure and detect radiation remains untested in these initial phases of development, so the team cannot definitively state the accuracy of the robot's work.

## 4. Results and Analysis

The following section summarizes the results of team RADBOT's work on the system thus far. These results cover the design decisions made on RADBOT, testing done on system components, and performance modeling. Design decisions were made as a team, stemming from our continually updated decision matrix and stakeholder requirements. Additionally, availability of equipment constrained and influenced design decisions. All the developments displayed are integral to the progress and success of the project.

### 4.1 Critical Tests

The team formed RADBOT's design from the joint expertise and guidance of the advisors along with input from stakeholders. As a result, testing of RADBOT's design concepts came slowly and on a high level to ensure basic system functionality. Below the team details three major tests that allowed the group to progress in developing RADBOT thus far. While these tests have been very useful to the development of RADBOT, more tests are required to integrate the software and the hardware on the system once all individual component tests are successful.

#### 4.1.1 Operating the Chassis

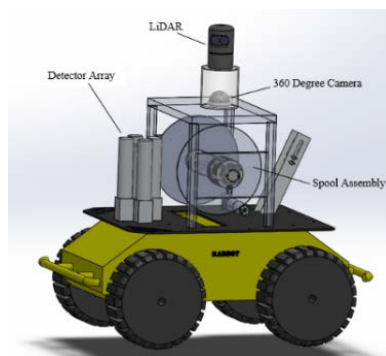


Figure 4. RADBOT CAD Model

Operation of the chassis involved the control of a bare Husky A200 platform through a prototype tether. The team selected the A200 Husky over competing chassis because of its high payload capacity. RADBOT's payload is upwards of 150 pounds due to the weight of the radiation detector array and spool assembly. The platform consisted of the Husky A200 base, its onboard computer, and an Amcrest camera. The tether itself is only a power cable and CAT-7 cable. The team connected the power cable to a wall outlet to power the platform and the camera to a CAT-7 cable to connect to a stationary laptop. The test consisted of navigating the platform through a doorway and into a hallway using the camera and a Taranis controller that was connected to the laptop. This test demonstrated the integration of the platform with sub-components of the navigation subsystem to physically traverse a simple environment.

#### 4.1.2 Selecting Sensor Array

The sensor array is the arrangement of the gamma ray radiation detectors that provide the robot's ability to detect hazards. The sensor array exists on the platform of the robot in a way that other subsystems do not interfere with their ability to detect radiation. The team analyzed a ten-detector and a five-detector array. Given space and weight constraints on the platform of the robot, the team determined that a five-detector array is optimal for RADBOT's mission given the cost and weight constraints. The team tested specific arrangements of the five sensors and developed a final layout plan. The next step for the sensor array includes the development of an algorithm that takes the counts of radiation detected by the sensors and relays it to the heat map.

#### 4.1.3 Mating Mapping Software with Visual Capabilities

The most integrative test performed thus far linked the capabilities of driving the robot through a hard-wired tether and controller duo with the LiDAR and algorithm for mapping walls and obstacles. The team uses preexisting software provided by Google that takes the data coming from the LiDAR and creates a bird's eye view of objects the robot could collide with in operation. RADBOT members tested the robot's functionality with LiDAR, the camera, the tether, the controller, and the software all working at the same time on the robot. All subsystems in this test worked in synchronization, demonstrating the user's ability to navigate the robot from a remote location.

## 5. Conclusion

RADBOT is in its first year of development and the team is diligently working to meet the needs of CBRNE soldiers. Future work includes making RADBOT semi-autonomous or fully autonomous, developing a 3D heatmap to more accurately pinpoint radiation, testing modularity of the system, and mitigating the risks associated. The team plans to prepare the incoming students for a successful transition into working on RADBOT and interfacing with the system's sponsors and users.

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