

A MOBILE RADIATION DETECTION SYSTEM RESISTANT TO EXPORT CONTROL

A Thesis

by

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MASTER OF SCIENCE

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ABSTRACT

Radiation detection software is a critical component of detection systems used to identify and ultimately prevent the spread of harmful radiation. Monitoring is critical for a variety of settings which include security, health and safety and early response. Some specialized radiation detection software is difficult to obtain, either because it is expensive or because its export may be subject to the export controls or regulatory and licensing requirements of the United States or other countries. The goal of this project was to create a radiation detection system that can evaluate an environment for potentially high levels of radiation and, if it exists, communicate the geo-spatial position and amount of radiation in the relevant area to the program user. This system, which includes software, a global navigation satellite system (GNSS), and a multichannel analyzer (MCA) with scintillation detector was also created with export control in mind, so that others around the world can also utilize and change the software to their specifications. The software system was field tested on the Texas A&M University campus July 28, 2022. This project successfully assembled a mobile radiation detection software system which will register, map and record geo-synchronized radiation count rate data.

DEDICATION

To my family and Toby who would sit by my window while I worked.

ACKNOWLEDGEMENTS

I would like to thank my mother and father.

CONTRIBUTORS AND FUNDING SOURCES

Contributors

This work was supervised by a thesis committee consisting of Professors Craig Marianno [advisor] and Sunil Chirayath of the Department of Nuclear Engineering and Professor Khanh Nguyen of the Department of Computer Science and Engineering.

All work conducted for the thesis was completed by the student independently in the nuclear engineering laboratories located on the Texas A&M University campus.

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INTRODUCTION

Radiation detection software is a critical component of detection systems used to identify and ultimately prevent the spread of harmful radiation. Monitoring is critical in a variety of potential settings such as security, health and safety or emergency response. Most radiation software is difficult to obtain, due primarily to high cost or governmental regulations that restrict the ability to export the software internationally. The reasons for these regulations could be related to matters of national security, protecting the exporting nation's economy, or other reasons. These reasons are especially difficult to overcome for people not within the country where the software was developed. The purpose of this project was to produce a radiation detection system with a graphical user interface (GUI) that can be distributed internationally and is not subject to export control issues and restrictions.

OBJECTIVES

The goal of this project was to create a mobile radiation detection system that registers elevated levels of radiation and communicates and displays these readings on a map. This system, which includes software, a global navigation satellite system (GNSS), and a multichannel analyzer (MCA) with scintillation detector was also created with export control in mind, so that others around the world can also utilize and change the software to their specifications. A completed system could be mounted in vehicles or worn as a backpack and allow users the ability to scan for elevated levels of radiation. The software, created for this project, would allow real-time display of the data on a map and allow further analysis in post-processing.

LITERATURE REVIEW

Radiation safety, security, and crisis response have been topics studied by many researchers and agencies such as the International Atomic Energy Agency (IAEA). The IAEA (2018), which is comprised of over 150 member states and other participants, develops standards and exchanges information on how nuclear energy can be safely developed, including through effective monitoring and radiation measurement systems. However, a thorough body of peer-reviewed literature specifically devoted to mobile radiation detection software systems is lacking, which demonstrates the need for further development and testing of these systems. This review of the literature will examine existing software, software systems and software shortfalls.

Tran-Quang and Dao-Viet (2022) discussed environmental concerns posed by radiation management and the need for developing a radiation detection device to identify radiation threats. In line with this stated goal, they “developed the Internet of Radiation Sensor System (IoRSS) to detect radioactive sources out of regulatory control in scrap iron and steel recycling and collection facilities”. The device is wireless with a mobile radiation detector. However, the cost of each device is \$10,000, and could prove too expensive for some academic or training programs.

Portnoy, Fisher, and Phifer (2015), in evaluating threats posed to national security through nuclear energy generation and waste, also recognize the need for developing detection systems. Specifically, in their evaluation of radiation detection software, they identified the need for common software algorithms that can be used with any fully developed mobile or static radiation detection system.

Existing mobile detection system software includes AVID, which offers a framework and associated modules used for real-time acquisition, visualization and analysis of radiation data

from aerial and mobile detection systems. It is designed to support data acquisition and analysis functionality for radiation detection systems. It was developed by the Remote Sensing Laboratory and the Pacific Northwest National Laboratory. AVID has three primary applications, those being data acquisition, remote monitoring, and data processing (AVID, 2015). While this is a powerful software, the reason AVID software cannot be used by many users is its Official Use Only (OUO) designation (AVID, 2015). According to the Office of Health, Safety and Security Office, OUO information is “unclassified information that has the potential to damage governmental, commercial, or private interests and may be exempt from public release under the Freedom of Information Act (FOIA)” (Office of Health, Safety, and Security, n.d.). This specific exemption excludes many foreign nationals from being able to use it. The research presented in this thesis would not be under OUO restrictions.

An existing commercial system is NaI-SS which is a radiation search system developed by ORTEC that has real-time gamma and neutron source location from the ground and air (Ortec, n.d.). The system is designed with portability in mind and includes GPS and mapping software (Ortec, n.d.). The system is similar to the system developed in this project with its radiation detection and mapping capabilities. However, this system’s cost was nearly \$180,000 and would be well beyond many institutions ability to purchase (personal communication, Craig Marianno, July 16, 2022).

In the of development of a radiation monitoring system for livestock, the Osprey multichannel analyzer (MCA) was utilized for its “fast count rate detection intervals and could be powered through a USB connection or Ethernet connection” (Erchinger, Marianno, & Herring, 2015). This relates to this project, as the Osprey MCA was utilized for its USB

connection and small but powerful size. However, custom software was developed for this project.

CraneWow was a program created by the nuclear engineering department at Texas A&M University that allowed arrays of NaI detectors to collect gamma spectral data over a long span of time (Hearn, 2012). However, CraneWow did not have the geo-locational capabilities that this project will include.

SETUP AND PROCEDURES

Project Setup/Description of Experimental Arrangement

The project started with trials of equipment and code that led to the use of the Osprey MCA and specific GNSS. To develop the system an MCA, which collects radiation data would be required. The project started with the ORTEC digibase-E MCA and code developed by a prior student, but connection difficulties and an inability to contact the creator made this hardware difficult to use. As a result, the decision was made to create new software utilizing the Mirion Technologies Osprey software development kit (SDK) version 1.0.1 in order to interact with the Osprey. To receive locational data a GNSS was needed. Based on outside advice the GNSS, u-blox model XPLR-M9, was decided on to be used (personal communication, Joshua Handley, October 7, 2020). Also included in the software system was GeoTools. This add-on is an open-source Java library with tools for geo-spatial data and uses shapefiles to create background maps. See APPENDIX A for more information on shapefiles. GeoTools provided the methods for the manipulation of geo-spatial data and provided instructions on setting up the library with the Java Eclipse IDE, the integrated development environment used for the project (GeoTools, n.d.).

This research created a radiation detection system comprised of several components which run in unison. The equipment, GUI and code required for system are described.

Equipment

In order for this system to be effective it must be comprised equipment that can detect radiation, store the data and then pair with geo-locational data. The equipment utilized to develop the system included the following:

- The MCA: Osprey multi-channel analyzer that includes a software development kit (SDK) version 1.0.1 (see Figure 1).

- A GNSS: u-blox model XPLR-M9. This kit includes the XPLR-M9 unit that collects geolocal data. The kit also included a USB cable, a 3-meter antenna for receiving signals from space and cable, and a quick start card (see Figure 2).
- A NaI scintillation detector: Model 802 scintillation detector (see Figure 3).
- A computer or laptop: The device requires Windows 10 and will act as the brains of the system. It runs the software and is connected to the MCA and GNSS. Figure 4 shows the system hardware connected to a laptop.



Figure 1: Osprey; universal digital MCA tube base for scintillation spectrometry (reprinted from Mirion Technologies, n.d.)



Figure 2: u-blox model XPLR-M9 GNSS (reprinted from u-blox, n.d)

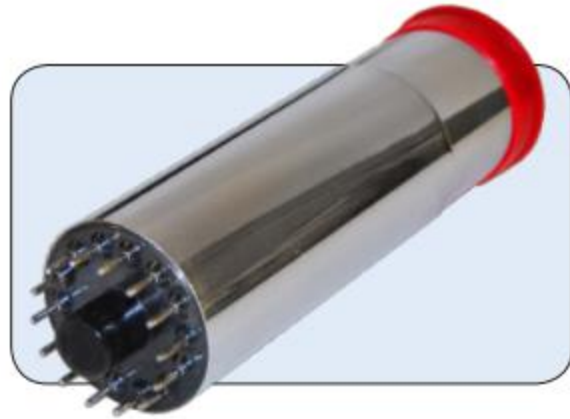


Figure 3: Model 802 scintillation detector (reprinted from Canberra, 2009)



Figure 4: Picture of the system hardware connected.

To integrate this equipment into a useful radiation detection system easy to use software needed to be developed so that users could operate the system, collect data and view results.

GUI

The GUI is derived from the 4 steps of the code. The code will be discussed in more detail below (in section titled: *The Code*). When the program is run, a window will pop up. This allows the user to input the settings they desire (talked about more in Appendix B). Once the user has set the initial parameters three other windows will open. These three windows are the only windows that can be created and give a description on the amount of radiation along a path. This in turn can help locate areas of high radiation. The first window will display a map. The next window will display the count rate, latitude, and longitude. The last window displays the last 50 recorded one-second counts. This “ticker-tape” display allows users to isolate areas where increased count rates occurred. Figure 5 shows how the GUI will appear on the screen.

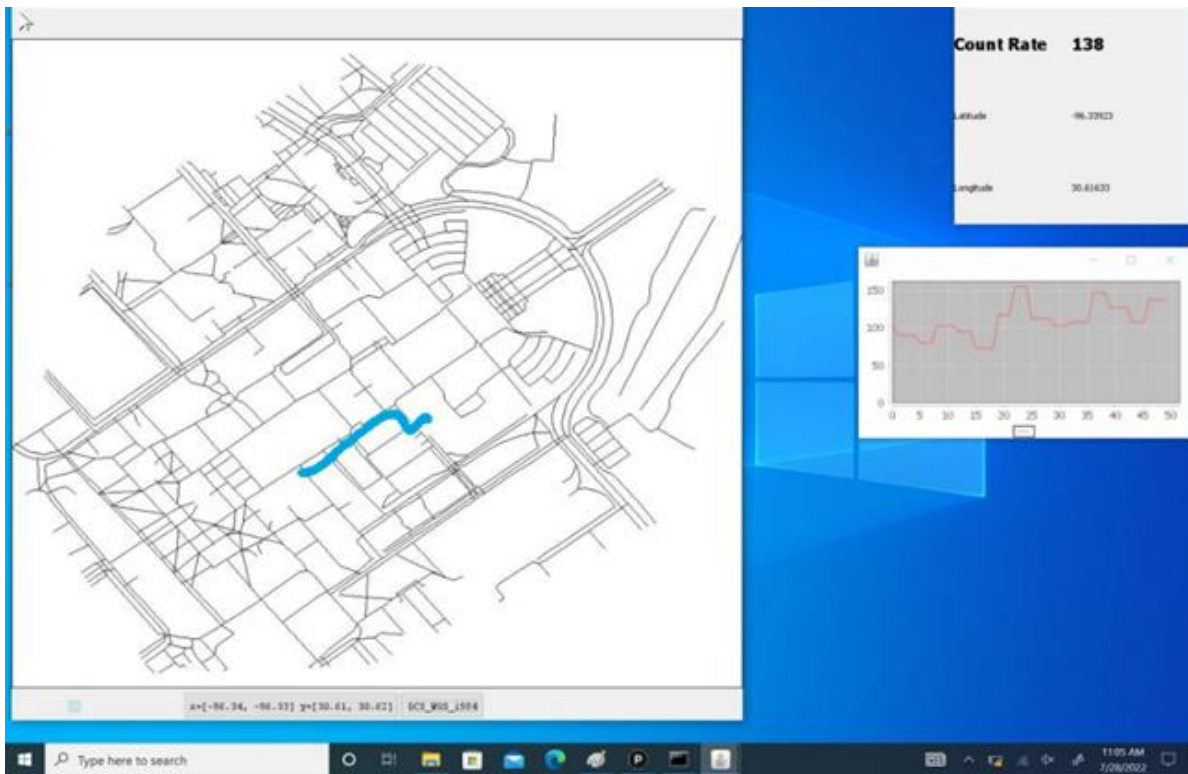


Figure 5: How the GUI will appear on screen

The code

There were four major steps involved in developing this Java based software package. The first step of the developed program is its interaction with the MCA from which it receives data. The examples in the SDK provided code that does this easily. The program starts by opening a connection to the MCA. Then it sets the acquisition mode. The acquisition modes are what type of data the MCA will return when pinged. For this project, the multispectral scaling (MSS) acquisition mode was used. MSS mode collects pulse height analysis data in two separate memory groups (Canberra, 2011). Then it sets the presets - options for the acquisition mode. For the project, the presets allowed the collection of detector data in live and/or real time, the specification of the number of energy channels (2048 used in the program), and the specification of the auxiliary acquisition interval, which is the time between switching memory groups (10,000 ms used in the project). The memory groups are used to reduce dead time in the detector and switch automatically. In the software, after HV is applied the acquisition starts and the MCA is sent electrical signals by the detector; the MCA interprets those electrical signals. Every second, the program pings the MCA for the information it has stored and sends the data which the program has requested. The second step is to receive data from u-center in the form of geo-locational data. This step is done by using the built-in recording ability of u-center to save the geo-spatial data that it receives from the GNSS. U-center continuously records that data in a text file, while the program continuously reads from that same text file. The third step is to log geo-locational data together with MCA data. The data is first stored together in a data structure called an ArrayList. The data is then taken from the ArrayList and written to a specified .csv file. This data includes the time of the recording, the latitude and longitude of where the recording was taken, whether the GPS was receiving valid data, the count rate, which count rate bin (low, mid,

high) the count rate falls into, and 2048 energy channels which give the amount of counts at the energy half that of the bin number. The final step is to plot geo-located MCA data. This is done by taking the data from step 3 and passing it to a class which utilizes the GeoTools library. The end result is the 3 windows shown in the GUI section above.

METHODS

Once the equipment, GUI and code were developed testing was performed to determine the mobile radiation detection system's ability, to evaluate radiation levels and display results to a user (See Appendix B for complete installation and setup steps). To perform the tests the assembled system was placed in the backseat of the golf cart (Figure 6; Figure 7 shows the entire golf cart). It was positioned in the backseat so the driver would not attenuate incoming radiation. As seen in the Figure 6 a laptop is connected via USB to the GNSS and to the MCA. The MCA is connected to the NaI detector through a 2-in 14-pin photomultiplier tube (PMT). Both the GNSS and MCA will be placed inside the backpack (see Figure 8). The backpack is not necessary for running of the program. However, the backpack provides convenience and stability for mobilizing. The GNSS has a 3-meter cord attached to an antenna for receiving signals from space and is seen coming out of the backpack and placed over the window of the golf cart.



Figure 6: System ready for use in backseat of golf cart.



Figure 7: The system in the golf cart



Figure 8: Use of backpack for system transport

The system was tested on the Texas of Texas A&M University College Station campus to determine if the system would project to map accurately while moving; to see if system would record detector data correctly while moving; and to see if system could locate where the radiation source was placed. Figure 9 shows the map of the path utilized for testing. The route is presented on the map as a series of blue dots. These indicate where count rate and spectral measurements were taken at a rate of once per second. The first test was to determine if the system would display data accurately while moving. The route included driving from the around the Texas A&M campus.

Part of the testing evaluated how the system would respond to increased levels of radiation. Over the route mentioned above, a 400 μCi source was placed on the walkway near the AI Engineering Building (AIEN) (see Figure 10). During the test the cart was allowed to pass the source going approximately 10 miles per hour. The source was on the ground approximately 2 meters from the moving cart. The route to assess if the system could identify the source on the walkway started on the northwest side of the AIEN building and ended on the southwest side. Next the source was placed in the middle of the trunk of a car parked by the AIEN building (see Figures 11 and 12). The route to assess if the system could identify the source in a parked car was similar to the route to assess the source on the walkway. During this test the driver passed the parked car at approximately 10 miles per hour. The car with source was approximately 2 meters on the left side of the moving cart.

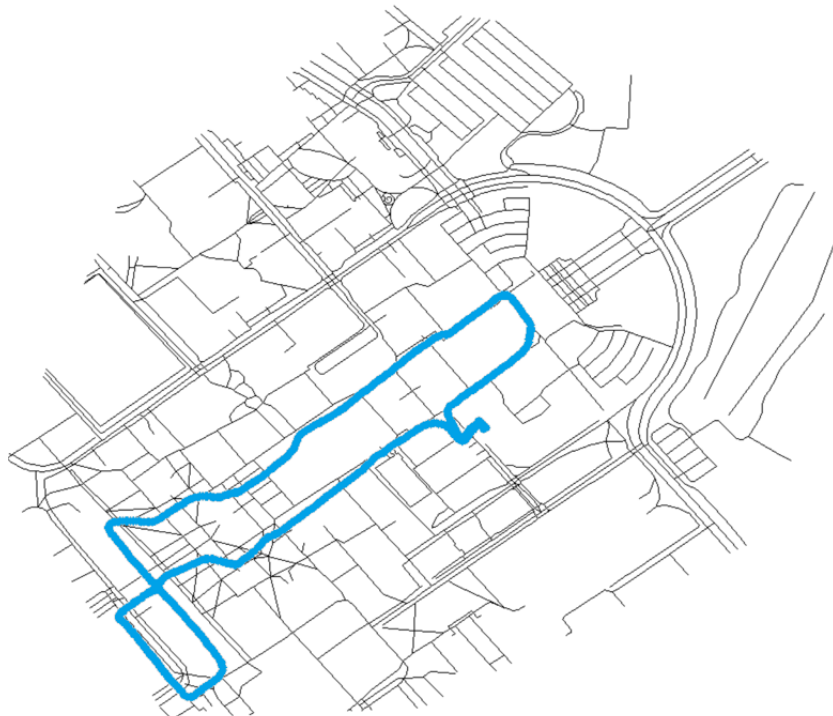


Figure 9: Map of the Texas A&M Campus where testing occurred. The complete path for testing the system is displayed in blue.



Figure 10: The 400 μCi Cs-137 source placed on a concrete walkway used for testing the mobile system under working conditions.



Figure 11: Source in car



Figure 12: Picture of the car (source inside)

RESULTS/ANALYSIS

Data from the testing phase was analyzed to determine the effectiveness of the system. The first system test resulted in points correctly projected to the map while the golf cart was moving (see Figure 13). In Figure 13 the three GUI windows of the program are displayed. The large window to the left is the map. The blue points on the map show where the user had been, and the color identified a low radiation field. During each testing phase background count counts were approximately 80 counts per second. Points will be displayed by the program regardless of the amount of radiation. When counts were 0-100 the map would show blue. When counts were between 101-150 the map would show yellow and when the counts were greater than 150 the map would show red. These break points were arbitrarily picked (see Table 1 for values). In this first test Figure 14 shows a closer view of the points evidenced in blue. The test also demonstrated that the system recorded detector data and displayed the data while moving evidenced by the 2 windows on the right in Figure 15 and the .csv file logging. The top right window shows the current count rate, latitude, and longitude. The bottom right window is a display showing the count rate for the previous 50 one-second intervals.

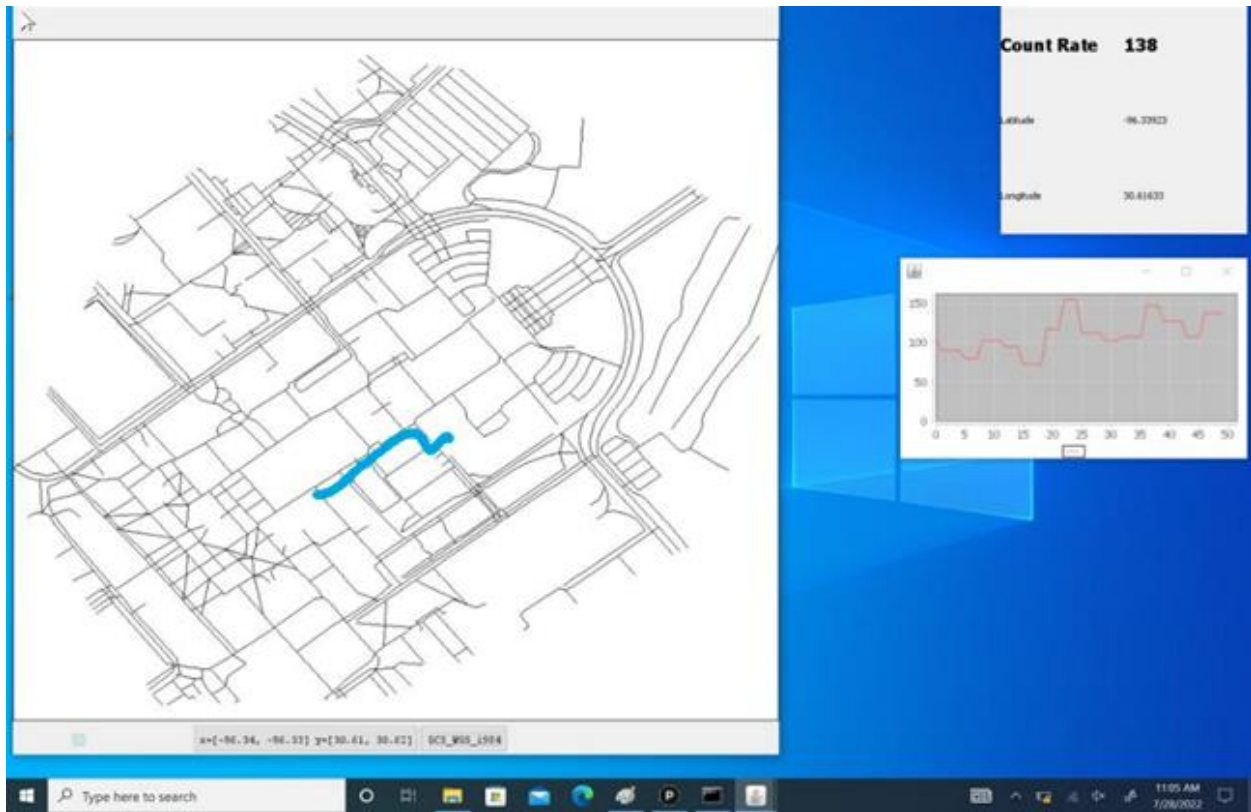


Figure 13: The system points projected to map

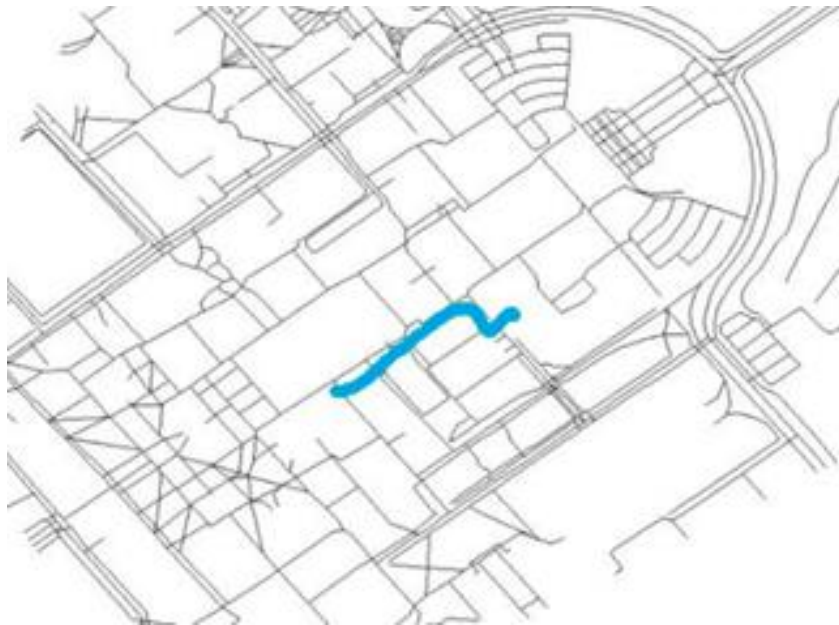


Figure 14: Close-up view of Figure 13

Table:1
Count Rate, Color, and Threshold Presets

	0	100	150	
Threshold		0-100	100-150	>150
Count Rate		Low	Mid	High
Colors		Blue	Yellow	Red

In the second test the system was able to identify areas of higher background by displaying the blue to yellow colors. The yellow color signifies points that are higher, and the blue color signifies points that are lower (see Figure 15). Figure 16 shows a close up of the color changes.

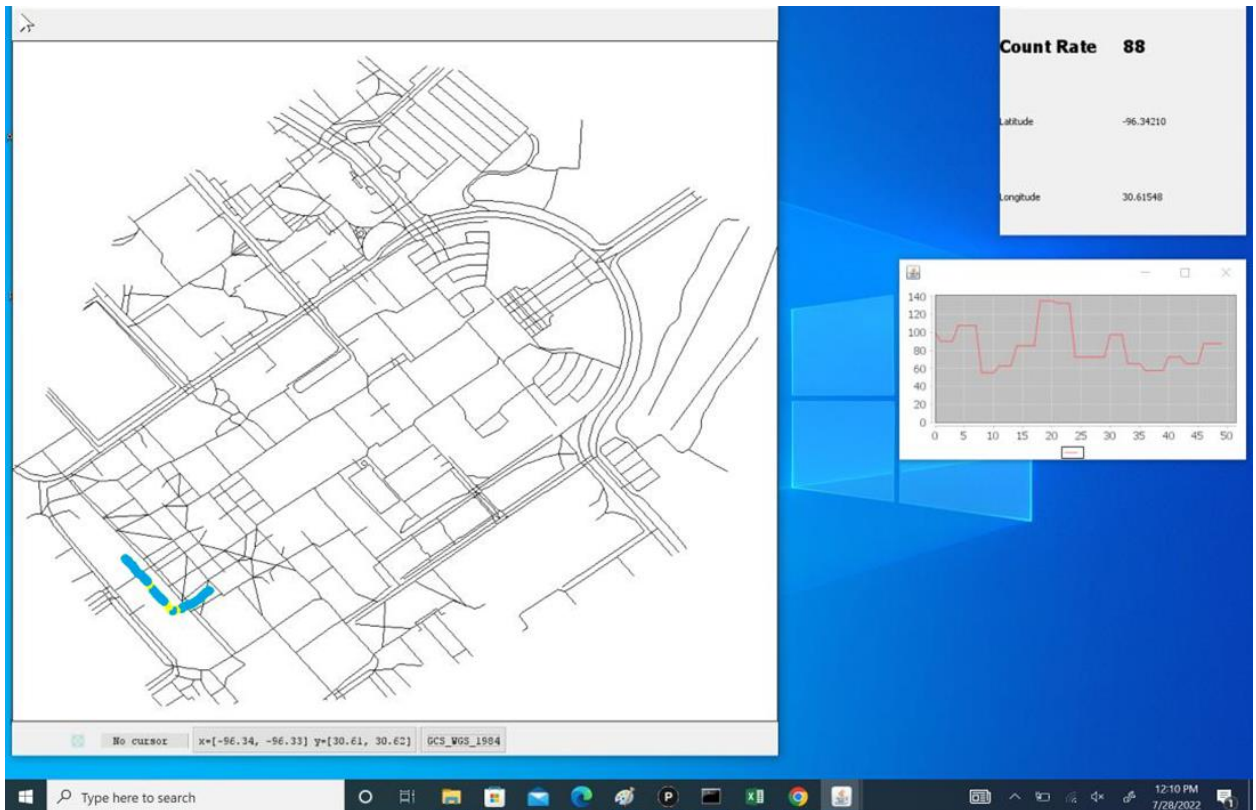


Figure 15: Color changes signified by higher background

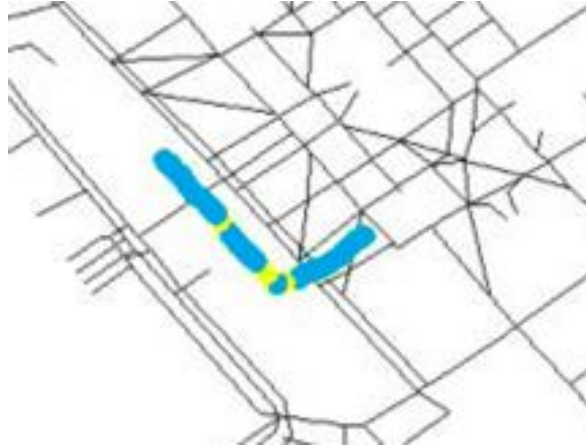


Figure 16: Close up of the color changes in Figure 15

The tests to locate the source were also successful. First, the test was able to locate the source placed on the walkway. Figure 17 shows an area where the color is red which means it has the highest count rate (great than 150) based on the color, count rate, and threshold presets (see Table 1 for presets). Figure 18 shows a closer view. If this was not a test, we would need to identify what the source is as it could be out of regulatory control. A .csv file was used to create Figure 19, which shows the spectrum from the test. This was done by summing the counts of each of the 2048 energy bins during the time which the detector was close to the source (about 1 meter), and then plotting them. While a known source was used (a 400 μCi Cs-137 source), the prominent 662 keV photopeak, showed that the source would easily be identified as cesium-137.

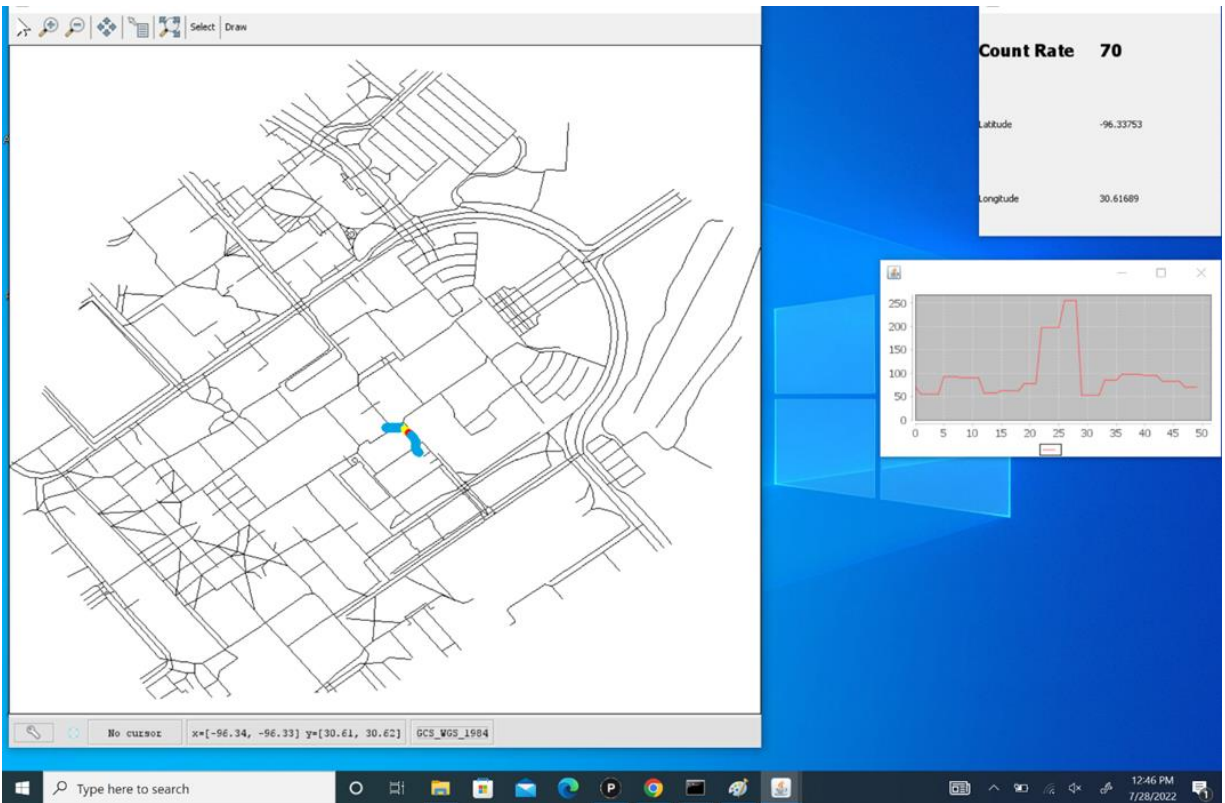


Figure 17: Color changes, count rate, and latitude/longitude that is displayed on the laptop of the source located on the walkway.

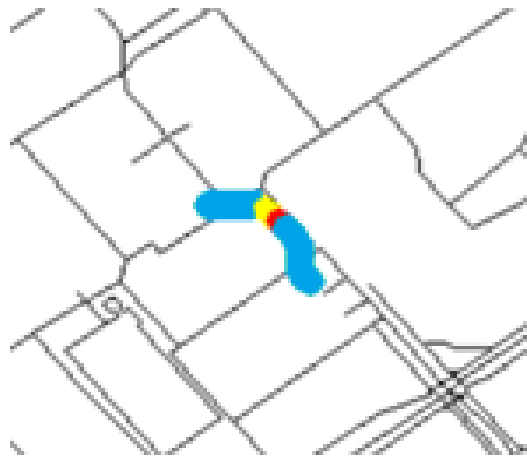


Figure 18: Closeup of Figure 17

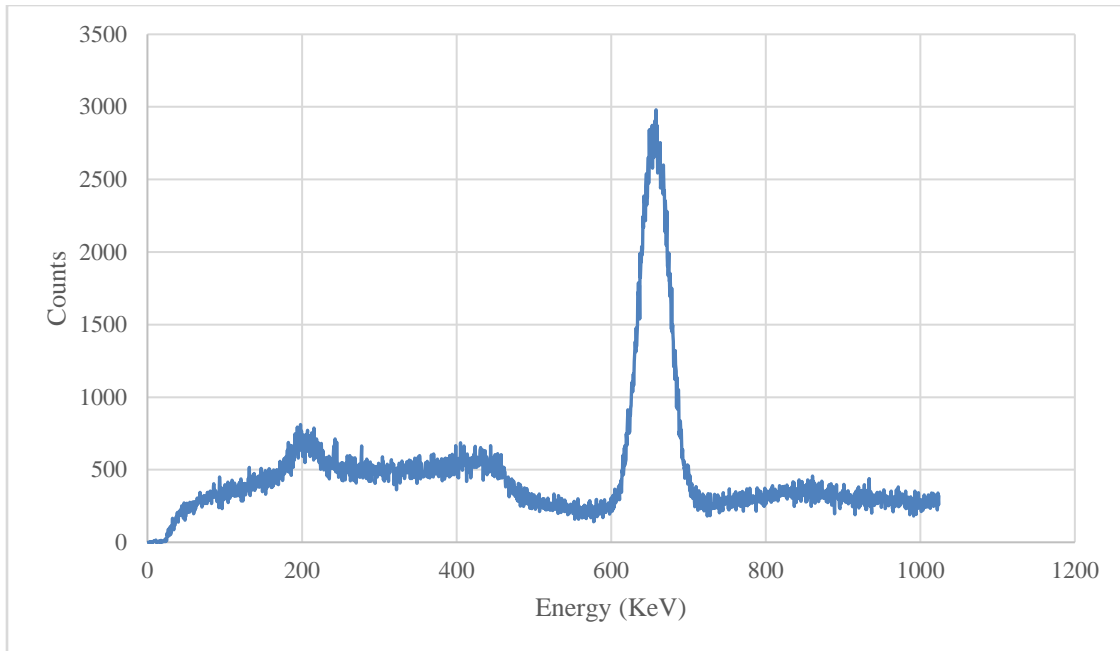


Figure 19: Radiation spectrum of the 400 μCi Cs-137 source from the bare-source test

The system was also able to locate the source placed in the parked car. Figure 20 shows an area in red signifying the highest count rate (greater than 150). The count rates were lower for the source in the parked car as compared to the source on the pathway because the car attenuated the radiation from the source. The max count rate from the bare-source test was approximately 250 counts per second. The max count rate from the car test was approximately 330 counts per second. Figure 21 shows a closer view of the colors. The source is clearly identified by the red color. The .csv file was used to create Figure 22, which shows the spectrum from the test. This was done by summing the counts of each of the 2048 energy buckets during the time which the detector was close to the source (about 2 meters), and then plotting them. While a known source was used (a 400 μCi Cs-137 source), the prominent 662 keV photopeak, showed that the source would easily be identified as Cs-137.

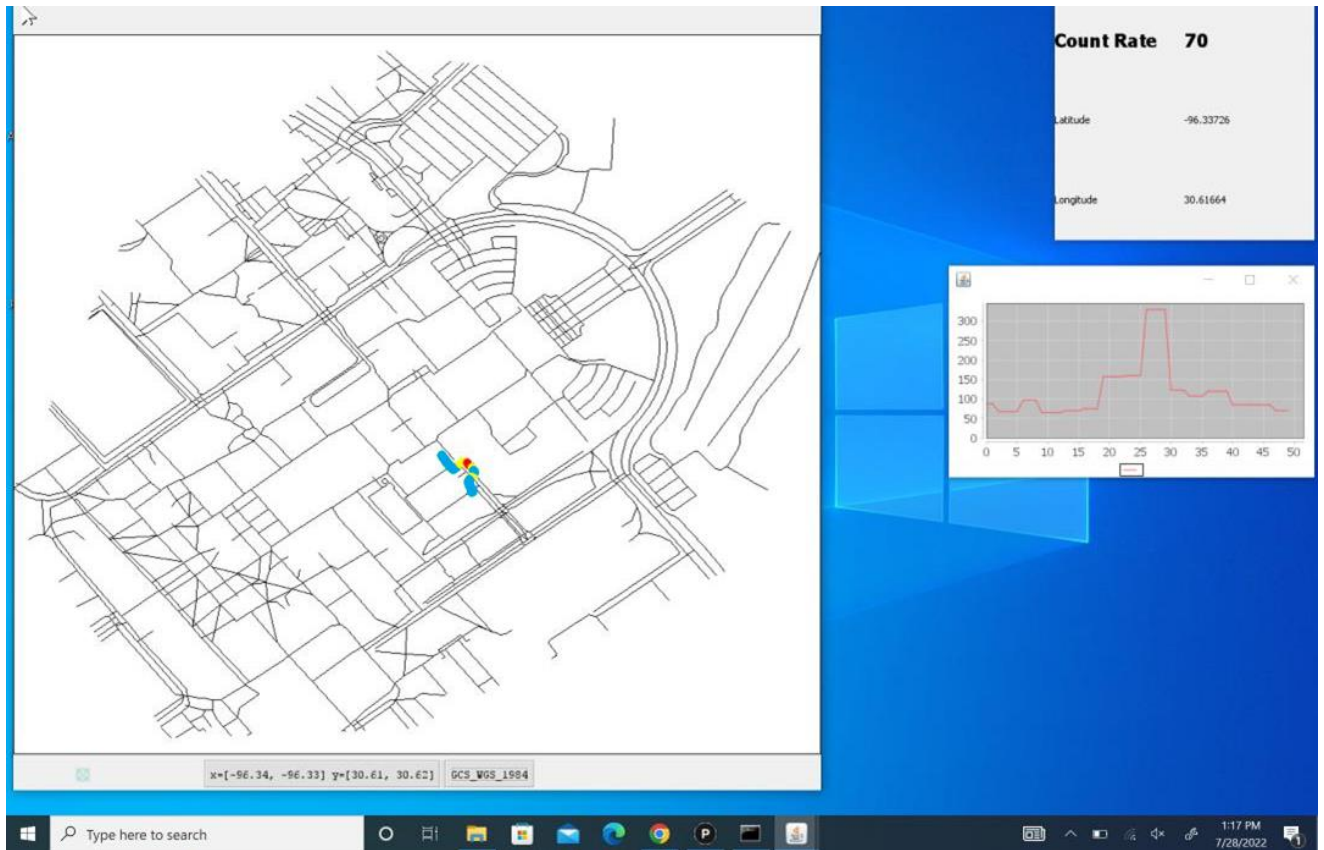


Figure 20: Color changes displayed from the source located in parked car.



Figure 21: Closeup of Figure 20

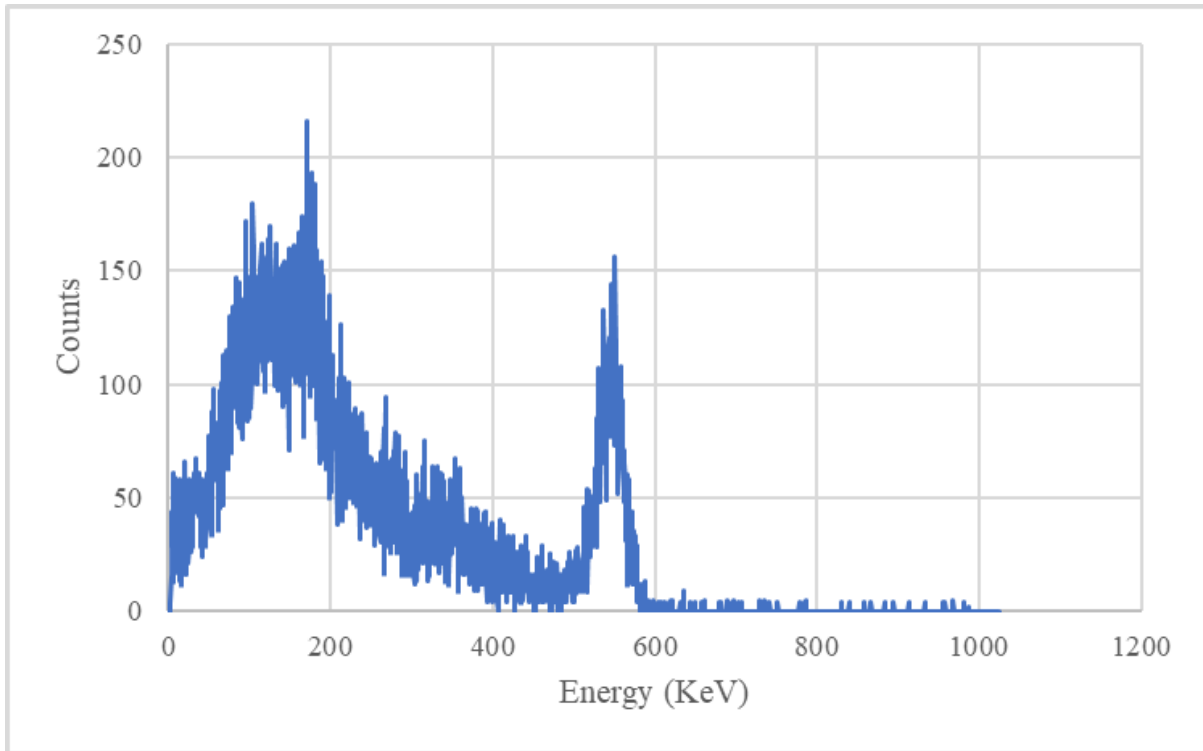


Figure 22: Radiation spectrum of the 400 μ Ci Cs-137 source from the car test

The .csv file was used to create Figure 22, which shows the spectrum from the test. As described earlier, this was done by summing the counts of each of the 2048 energy bins during the time which the detector was close to the source (about 2 meters including the width of the back of the car), and then plotting them. The same source was used as the bare-source test. Interestingly, the spectrum does not show an accurate Cs-137 spectrum. Instead, it appears as if the spectrum has been shifted to the left and compressed. It was determined that this could be the result of two problems. One, gain shift occurs when the electronics that govern gain are heated or cooled. In the case of this test, the temperature was above 100°F. This increased temperature can decrease the gain which in turn shifts the spectrum to the left and compresses it as well. Two, the lower energy-channel calibration was incorrectly done. However, an incorrect calibration of lower energies does not explain the shift of the Cs-137 photopeak.

SHORTFALLS

Some weaknesses were discovered during the testing. First, USB plugs could easily be dislodged during testing. This issue could be resolved by using better connection options, such as screw on connection ports. Another weakness was the need to restart the program if there were any system interruptions such as a cable dislodging. For example, the MSS becoming unplugged or jostled too much would cause the program to throw an error before stopping. Finally, if the map window was moved too much it could cause the drawn points to become inaccurately displayed. Future recommendations would be collaborating with a programmer who is able to address the presented coding issues.

CONCLUSION

Radiation detection software and systems are critical in identifying and preventing the spread of radiation. The goal of the project was to create a mobile radiation detection system that registers elevated levels of radiation and communicates and displays these readings on a map. This project successfully assembled a mobile radiation detection software system which registers, maps, and records geo-synchronized radiation count rate data. The system was able to successfully identify radiation sources in the open and inside of cars. The system's size makes it easy to transport and utilize. The complete system can be mounted in a vehicle or worn as a backpack. Also, the software created for the system can be shared with others around the world who can use and change without concern for export control.

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APPENDIX A – SHAPEFILE

The geo-spatial data format which GeoTools uses is the shapefile format. According to Environmental Systems Research Institute (ESRI) “a shapefile stores nontopological geometry and attribute information for spatial features in a data set. The geometry for a feature is stored as a shape comprising of a set of vector coordinates” (Environmental Systems Research Institute, 1998). The shapefile creates background maps for geographic information system software. Shapefiles are useful since they are fast and editable. They are easy to read and write as well. Shapefiles consist of a main file (.shp), that houses the geometrical features; an index file (.shx), which is partner to the main file and houses position data in the .shp file; and a dBASE format file (.dbf) where attributes of features are held (needs source). “Each attribute record has a one-to-one relationship with the associated shape record” (Environmental Systems Research Institute, 1998).

APPENDIX B – USER MANUAL

Introduction

Mirion Technologies developed the Osprey software development kit (SDK) version 1.0.1. The Osprey is a multi-channel analyzer (MCA) that includes a software development kit which includes everything required to carry scintillation spectrometry. The Osprey is small, yet powerful and can be controlled with either a USB or Ethernet cable.

The Osprey is supported by the Genie 2000, a spectroscopy software suite, which can support multiple detectors providing ample networking and data analysis capabilities.

To develop the mobile radiation detection system u-blox model XPLR-M9 GNSS was utilized with the Osprey.

Installation

Install the latest version of Java, the Canberra Osprey firmware, and the latest version of u-center. The required hardware required for installation include a computer, the XPLR-M9 kit, a compatible 14-pin scintillation detector, and an Osprey MCA.

When the XPLR-M9 unit is initially plugged into a computer via a USB cable, a file Explorer window will open with its initial directory being in the XPLR-M9 unit. A single file will be there. This is the installer for the software u-start. u-start is a basic software that is mostly useful to test that the GNSS is working. It displays geo-locational data; however, it does not have the ability to record this data. In order to record the geo-locational data, a software called u-center, also from u-start, is used. Figure 1 below shows the u-center program once installed with no GNSS connected. Figure 2 shows the u-center program once GNSS is connected.

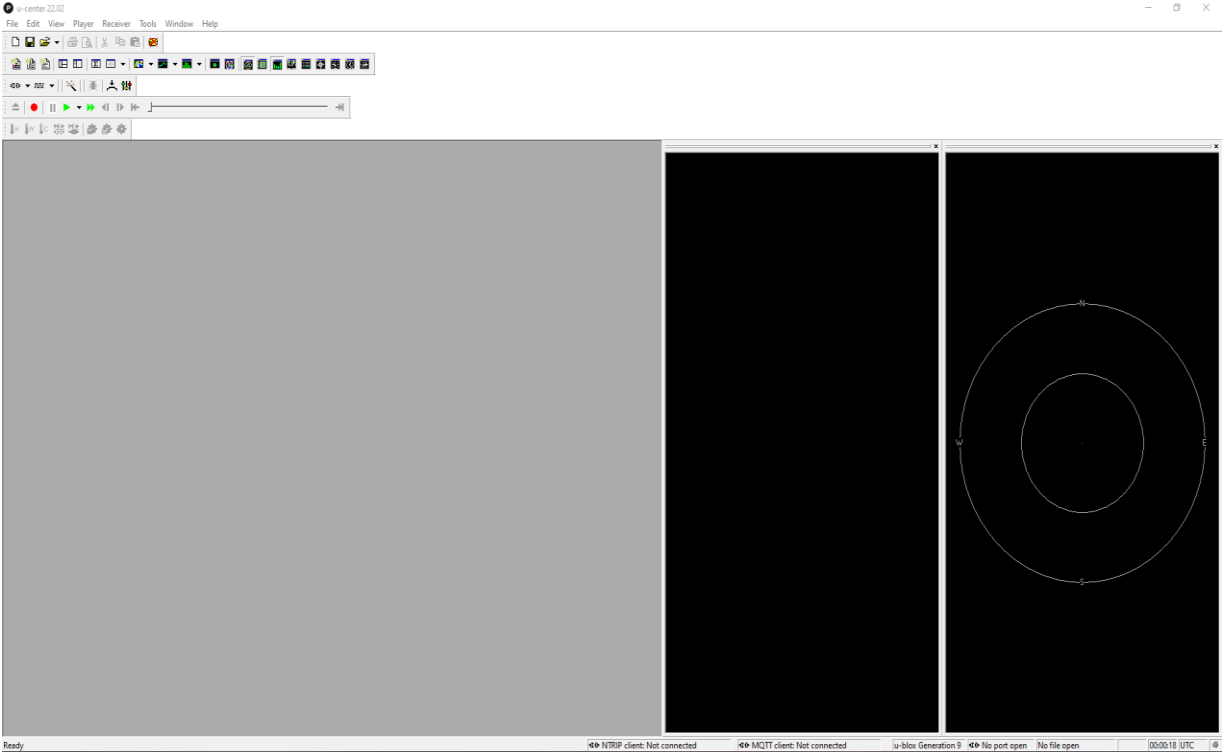


Figure 1: Example of what u-center looks like. In this image, no GNSS is connected.

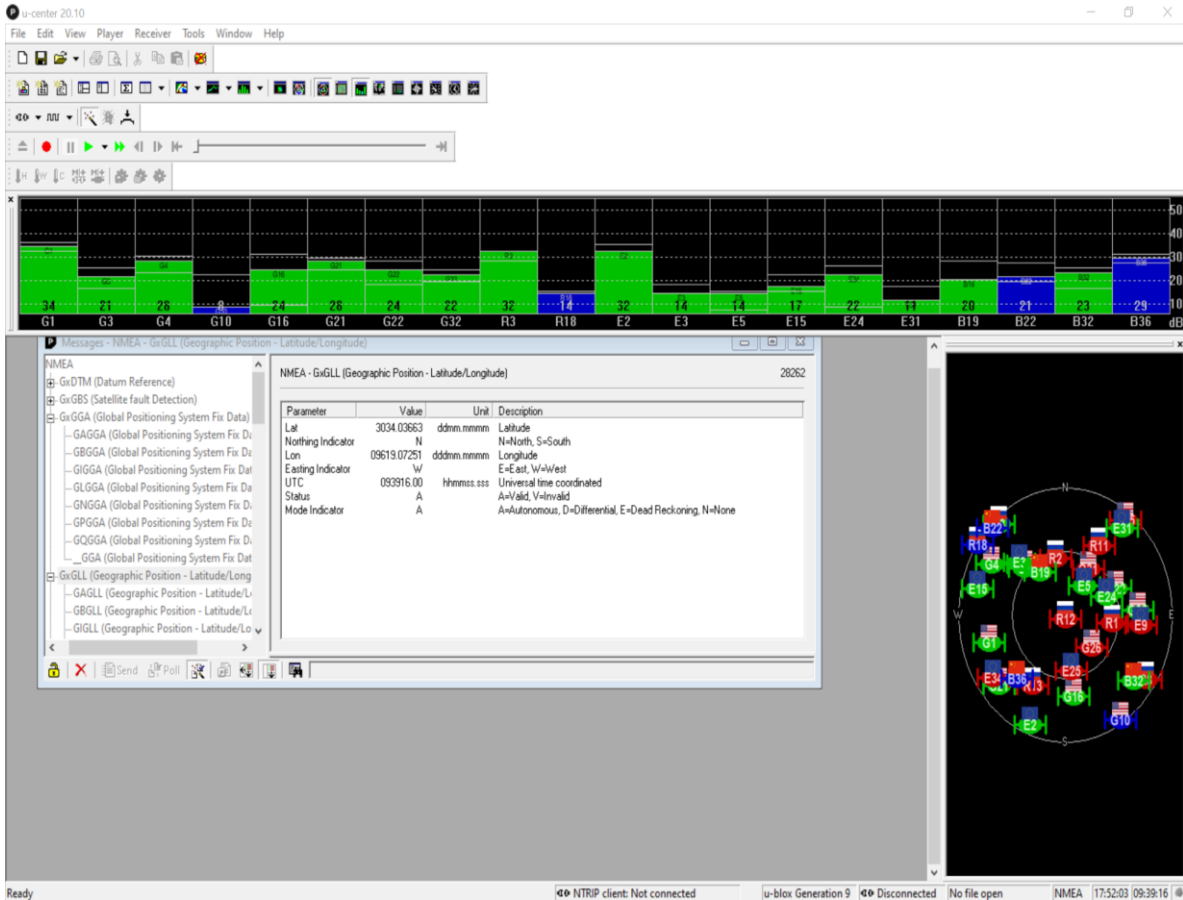


Figure 2: Example of what u-center looks like with a GNSS connected.

For the program to run, the latest version of Java, the Canberra Osprey firmware, and the latest version of u-center are used. The required hardware should include a computer, the XPLR-M9 kit, a compatible 14-pin PMT scintillation detector, and an Osprey MCA.

System Use

Once installation is complete; calibration of the detector with GENIE, a spectroscopy software, should be performed. Next u-center is opened and connected to the GNSS. Connection can be verified by checking the button (Figure 3) and drop-down menu to make sure that the device is connected, and the button is green. The device will be in the form “COMX” (Figure 4).

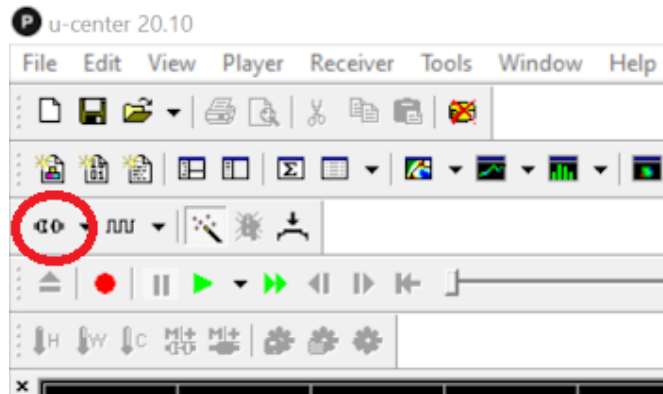


Figure 3: Button to verify GNSS connection

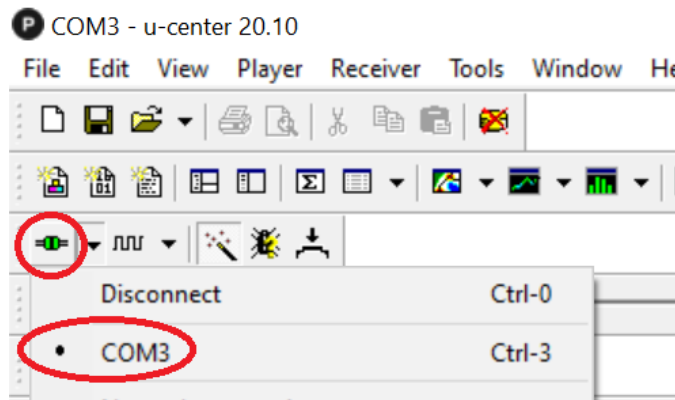


Figure 4: Example of selecting a GNSS

Next the baud rate (Figure 5) should be set to 38'400 (Figure 6). The baud rate of 38'400 is dependent on the GNSS device. The importance of calibration is to get accurate data. If the baud rate is not 38''400 the data may not have been recognized accurately and the system would not run.

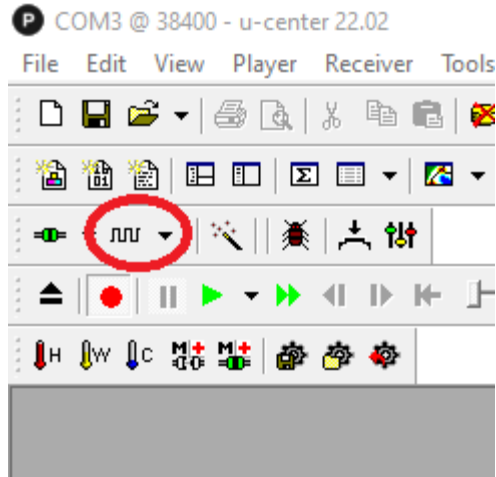


Figure 5: Baud rate drop-down menu

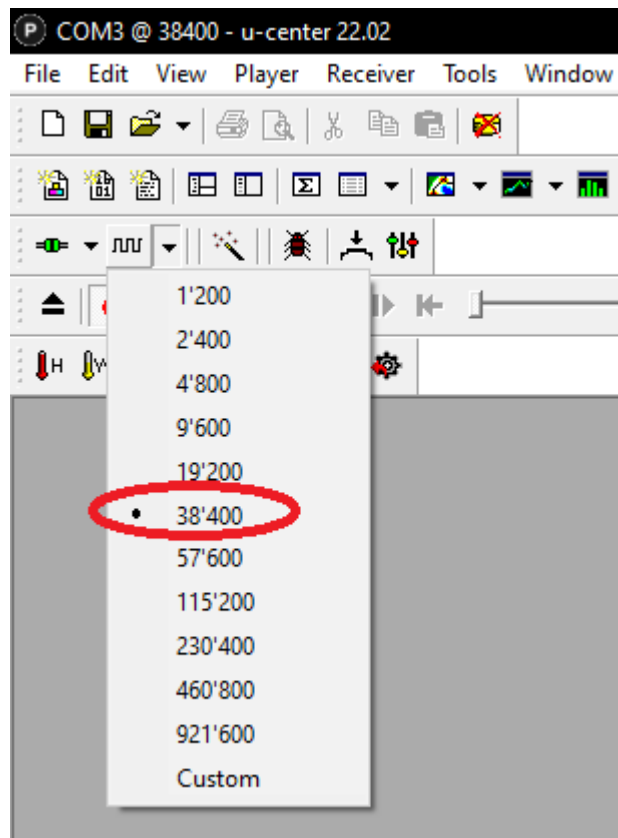


Figure 6: Selection of baud rate

On the taskbar, click view and then Messages View (Figure 7). A window will appear that shows different formats of the data received from the GNSS. To check if the data is valid under

“NMEA” select “GxGLL” (Figure 8). Once the data is valid, the user must click record (Figure 9) and save the file as logger.txt (Figure 10) on the desktop.

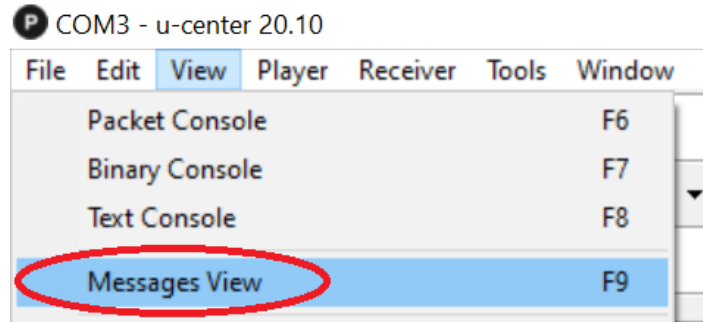


Figure 7: Opening the Messages View

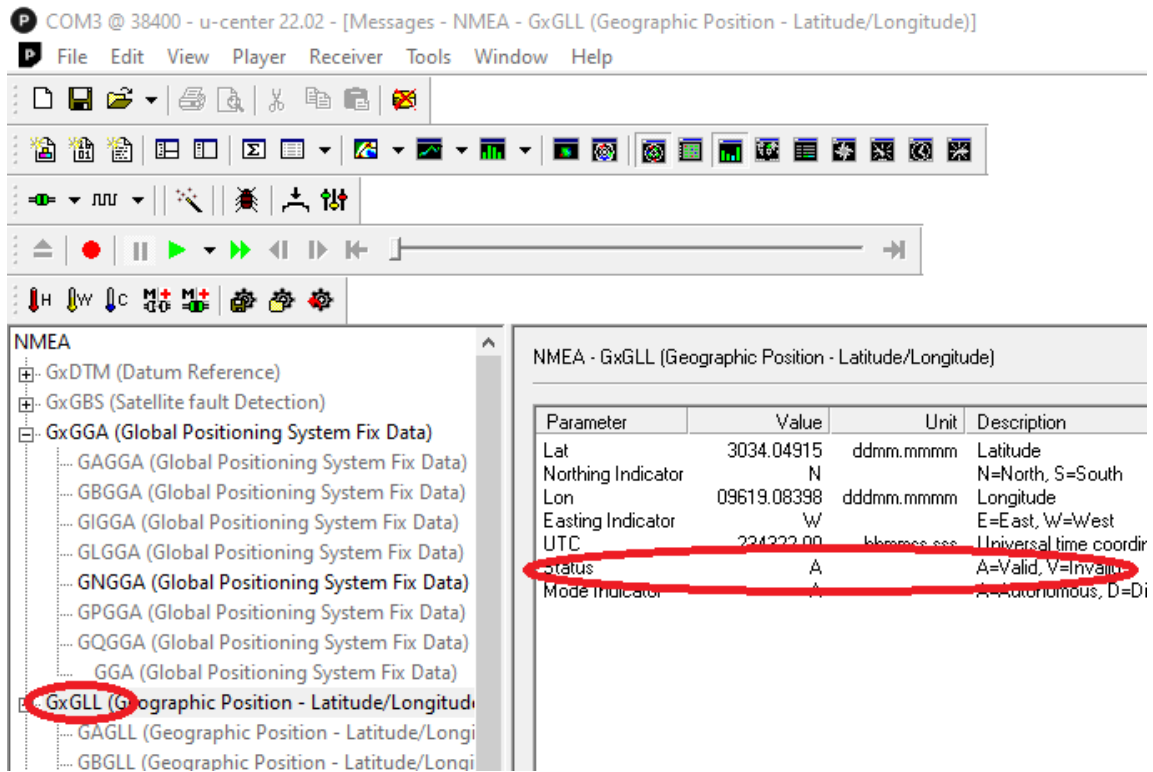


Figure 8: Verification of valid geo-locational data



Figure 9: Record button

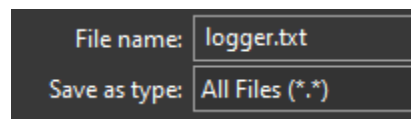


Figure 10: Save file as logger.txt

When the program is run, a window will appear. The user will need to input the necessary information before hitting confirm. The first will be the directory location for the output .csv logging file (see Figure 11).

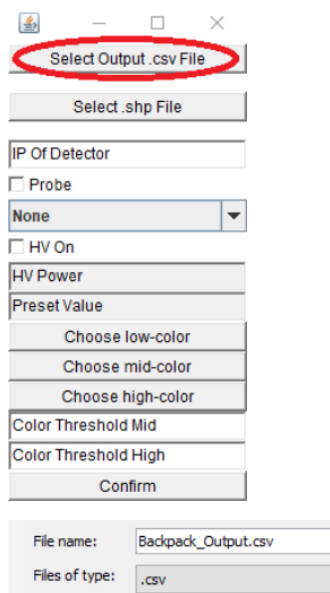


Figure 11: Show specification of output .csv file

Next, the location of the .shp file (with the .sfh and .dbf file in the same directory) is specified (Figure 12).

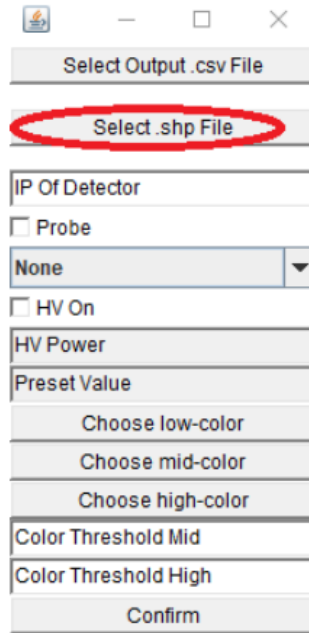


Figure 12: Shows specification of .shp file

After that, input the IP address of the MCA (Figure 13).

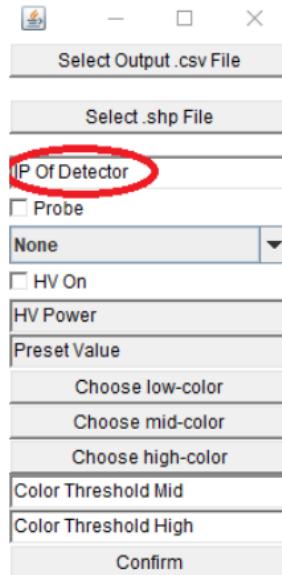


Figure 13: Shows specification of IP address

Next, select if a probe is being used or not (Figure 14).

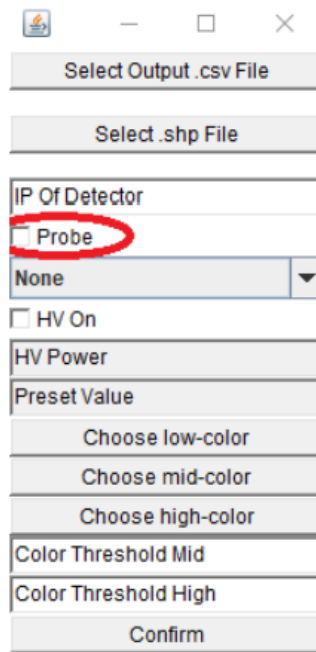


Figure 14: Shows the selection of the probe

Select whether real or live time is desired for recording (Figure 15).

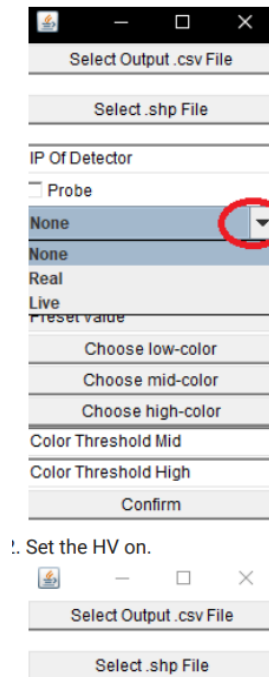
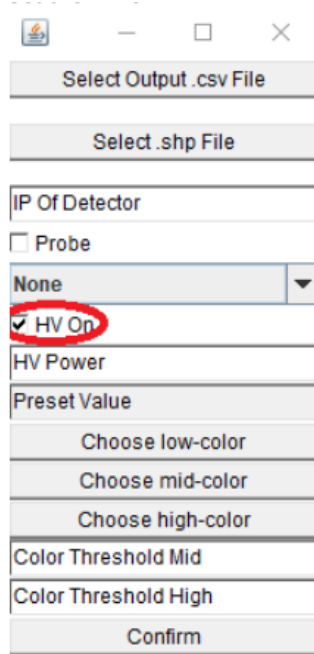


Figure 15: Shows the selection of real or live time for recording

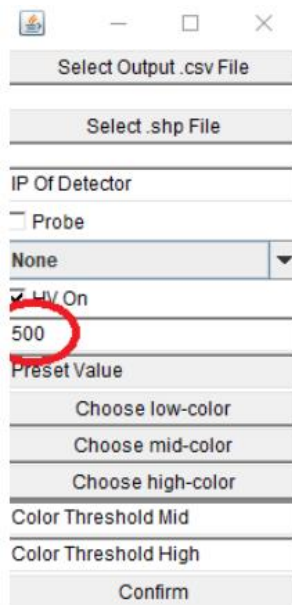
Set the HV on (Figure 16).



The screenshot shows a software dialog box with the following elements from top to bottom: a title bar with a logo and window controls; a 'Select Output .csv File' button; a 'Select .shp File' button; an 'IP Of Detector' text input field; an unchecked 'Probe' checkbox; a dropdown menu currently showing 'None' with 'HV On' selected and circled in red; an 'HV Power' text input field; a 'Preset Value' section with three buttons: 'Choose low-color', 'Choose mid-color', and 'Choose high-color'; two more text input fields labeled 'Color Threshold Mid' and 'Color Threshold High'; and a 'Confirm' button at the bottom.

Figure 16: Shows selection of HV On

Chose the desired HV power level (Figure 17).



This screenshot is identical to Figure 16, but the 'HV Power' text input field now contains the number '500', which is circled in red. The 'HV On' checkbox remains checked.

Figure 17: Shows the desired HP power level

Type the preset value for channel switching. The default value is 1, and unless the user understands the Osprey memory groups, they should not deviate (Figure 18).

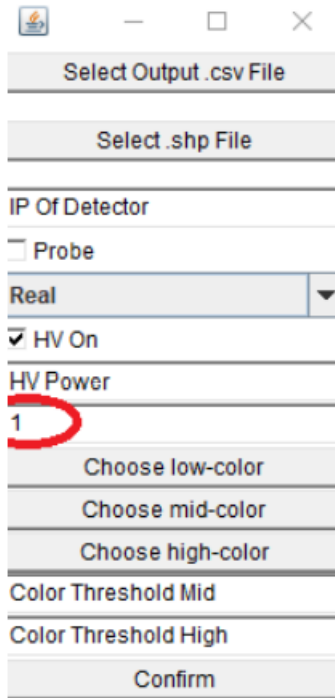


Figure 18: Preset value for channel switching set to 1

Select the three mapping colors (Figure 19). Low-color is the color below the first threshold. Mid-color is the color between the two thresholds and high-color is the color above the second thresholds.

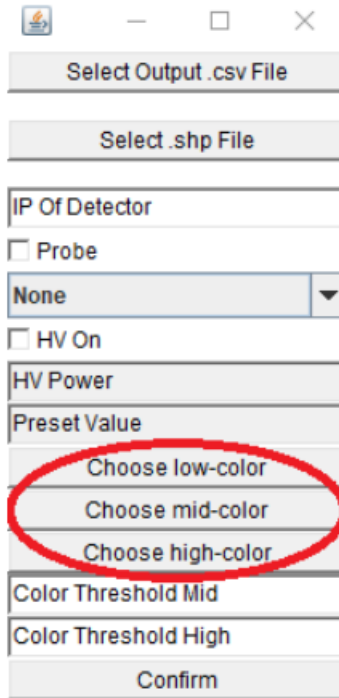


Figure 19: Selection of the three mapping colors

Next select Color Threshold Mid for the first count rate threshold for the colors and the thresholds of when to use the colors. Select Color Threshold High for the second count rate threshold for the colors (Figure 20). Example: If blue, yellow, and red are selected as the three threshold colors in order and the threshold count rates are selected as 100 and 200, a count rate of 50 would appear as green, a count rate of 150 would appear as yellow, and a count rate of 250 would appear as red.

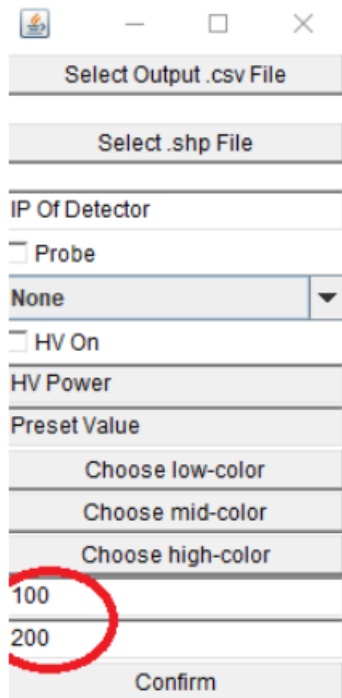


Figure 20: Selection of color thresholds and count rates

Next click confirm and 3 windows will appear that display a map (Figure 21), a tracker for the count rate (latitude/longitude) (Figure 22), and a graph which will track the count rate as a function of time (Figure 23).

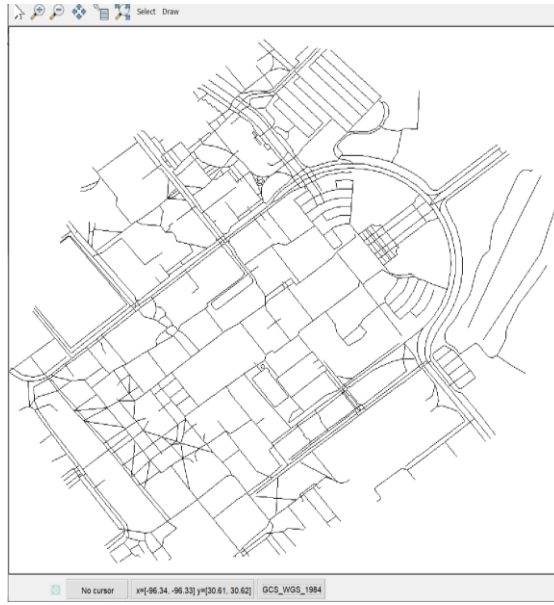


Figure 21: Map

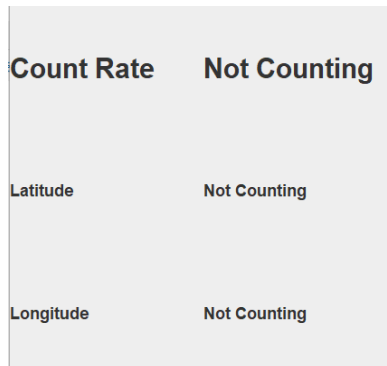


Figure 22: Tracker for the count rate (latitude/longitude)

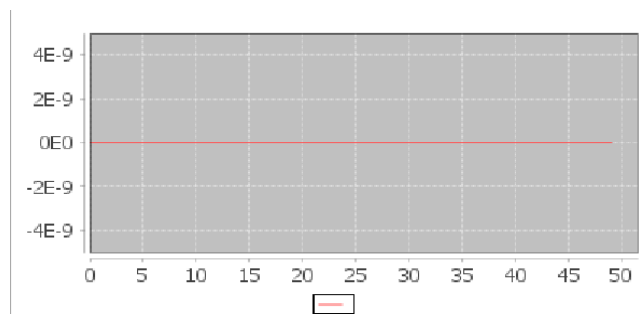


Figure 23: Graph which tracks the count rate as a function of time

Now the program is set up and ready to record.