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Characterization of Radiation Detectors: Uranium Mines Monitoring on the Navajo Nation Utilizing an Aerial Drone

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Abstract: The Navajo Nation (NN) was a mining hub for the uranium ore industry in the mid-20th century. Extractions of uranium on the Navajo Nation led to one of the largest radioactive spills recorded in United States (US) history, the Northeast Church Rock Mine (NECM). NECM is located 17 miles northeast of Gallup, New Mexico, and is one of 523 Abandoned Uranium Mines (AUM) on the NN. AUMs such as the NECM exposed community wells, water systems, and humans to high ionizing radiation levels. Contracted companies have evaluated these sites for radiation levels, but the collected data rarely gets communicated to the Navajo communities and to other local researchers. This project aims to bring new emerging technologies to help with data collection in monitoring these AUMs on the NN. Bringing industry-standard equipment will help with not only data collection, but it will bring hands-on experience to local students. The project's concentrated Area of Interest (AoI) in the beginning stages is the NECM. The evaluation will be separated into three major phases to complete the monitoring of the AoI: Scouting, Monitoring, and Inspection. Each component will offer a new set of challenges and step into other disciplines as the project progresses into each phase, (e.g., Geographical information systems and Environmental sciences etc.). Upon the completion of this project, students and researchers involved will have built the capacity to post process and analyze data obtained in each phase, along with an executable workflow to help guide future projects.

Keywords: Drone. Radiation; Uranium; Navajo; Area of Interest

1. Introduction

Monitoring radiation levels in uranium mines is critical to protect the health and well-being of communities residing near these sites. In the context of the Navajo Nation, where over 500 abandoned uranium mines pose significant environmental and health hazards, the use of aerial drones provides a promising solution for efficient and comprehensive monitoring. This article focuses on the characterization of radiation detectors suitable for aerial drone-based monitoring of uranium mines on the Navajo Nation, highlighting the importance of selecting appropriate detectors for accurate and reliable radiation measurements [1].

Preparation and experimental surveys were conducted over several months for students to get acquainted with newly purchased Unmanned Aerial Vehicles (UAV) and associated software [2].

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This approach will help to facilitate a smooth transition in implementing the first phase of AUM monitoring at the AoI, NECM. Teledyne Flirs' newly introduced UAV, the SIRAS, was utilized for starting the groundwork to begin the potential workflow of this project and subsequently will introduce DJIs' Matrice 300RTK. UAVs were considered rather than humans taken surveys, due to their versatility and their feature to keep personnel away from potential work hazards from radioactive materials. Several entities will assist in the guidance to creating a successful workflow for this projects' approach and supervision of implementation of the monitoring of the AUM [3].

The NECM is a previous site for uranium extraction in the NN during the 1960s through late 1970s. It is located 17 miles northeast of Gallup, New Mexico, in the Pinedale Navajo Community, at approximately (approx.) 35°39'67"N, 108°30'55.98"W and elevation approx.. 7000 feet. As mentioned in [1] NECM is the second highest producing mine on the Navajo Nation behind the Kermac Mine No. 22 in the Ambrosia Lake Area north of Grants, New Mexico. Navajo residents still occupy the area around site, which makes the location accessible through state and tribal highways but is within a secure area. The mine is separated into two sites covering approx. 0.7 square miles with three different mine identification numbers: 303,304, and 305. The site being in a rural area makes an ideal location to utilize a UAV. Since, avoiding radioactive material and maximizing the area covered per mission is key to success, remote sensing was chosen. Also, rather than having personal assess the contaminated areas with handheld detectors, drones can easily access rough terrain with little to no risk to workforce. With this technology multiple missions can be implemented and multiple payloads for the UAV can be utilized, (e.g., Photogrammetry cameras, Light Detection and Ranging (LIDAR), and Radiation Detectors etc.) during the duration of this project [4].

Fig. 1. shows general location of NECM.

2. Literature Review

. Uranium mines on the Navajo Nation have been identified as potential sources of radiation exposure, posing risks to both the environment and the local community. Traditional ground-based monitoring methods may be challenging due to the vast and often inaccessible terrain. Aerial drones, equipped with radiation detectors, offer a unique advantage by providing a bird's-eye view and the ability to cover large areas efficiently. This technology enables timely detection and mapping of radiation hotspots, supporting informed decision-making for mitigation and remediation efforts [5].

Satellite remote sensing has revolutionized the field of aerial photography, replacing film cameras and balloons as platforms for data acquisition. Multispectral and hyperspectral remote sensors, along with Geographic Information System (GIS) technology, are now widely employed in mineral exploration to evaluate mineral potential [6]. Data from sensors such as Landsat, Advanced Spaceborne Thermal Reflection and Emission Radiometer (ASTER), System Pour l'Observation de la Terre (SPOT), Indian Remote Sensing (IRS), Sentinel-2, and Airborne Visible Infrared Imaging Spectrometer (AVIRIS) are utilized in the analysis. Various image processing techniques, such as Minimum Noise Fraction (MNF), Principal Component Analysis (PCA), Band Rationing (BR), and Independent Component Analysis (ICA), are applied to enhance data for effective mineral recognition. Software tools like Earth Resources Data Analysis System (ERDAS) Imagine and ArcGIS facilitate numerical image processing and integration of geological, geophysical, and geochemical survey data with image data, enabling the delineation of mineral potential zones [7].

CdZnTe-based room temperature radiation detection has witnessed notable advancements, positioning it as a viable solution for nuclear power plant applications. This comprehensive review provides insights into the physical and electronic properties of CZT detectors, compares various growth methods and geometries, and presents an overview of performance evaluations. The progress in CdZnTe detector technology demonstrates its potential for improving nuclear radiation detection and spectroscopy. By leveraging the advantages offered by CZT over traditional semiconductor materials, researchers can contribute to enhanced safety and efficiency in nuclear power plant operations [8].

The implementation of an IoT-based system for real-time radiation monitoring at uranium mining sites demonstrates the potential of technology in enhancing safety and efficiency. The ESP 32 microcontroller board, in combination with cloud storage and a mobile application, enables seamless data transmission, remote visualization, and real-time monitoring of radiation levels [9-10]. The system's IoT capabilities provide end-users with flexibility, convenience, and timely alerts in case of excessive radiation levels. As technology continues to advance, IoT-based solutions like this can play a vital role in ensuring the well-being of workers and the environment in uranium mining operations [11-12].

The investigation into the use of infrared thermography as a tool for thermal monitoring of intelligent grassland in uranium mines highlights its potential applications. Real experiments using a low-resolution sensor on a drone provide valuable thermal data, enabling the evaluation of temperature variations within the grassland. The statistical processing of the results enhances our understanding of the grassland's thermal behavior and contributes to effective environmental monitoring [13].

The utilization of aerial drones in monitoring uranium mines presents significant advantages in terms of real-time data collection, enhanced accessibility, improved safety measures, and comprehensive data analysis [14]. By leveraging this technology, mine operators can enhance safety protocols, identify potential risks, and take proactive measures to protect workers and the environment. The integration of drone data with GIS further enhances the visualization and understanding of radiation distribution in the mining site. As technology continues to advance, the use of aerial drones in uranium mine monitoring is expected to become an indispensable tool for ensuring safe and efficient operations [15].

3. Methodology

In this project, a proposed approach was considered to help structure a successful workflow. Although details are still being developed as the project matures, the following main phases will carry ideas through the development. As mentioned in [2] the phases will be: Scouting, Monitoring, and Inspection as shown in Fig.1. Each section of the proposed workflow will carry out new data sets and visuals to complement the next. There will also be a set flight path for the drone to implement flyovers while taking aerial photos to capture the most optimal images.

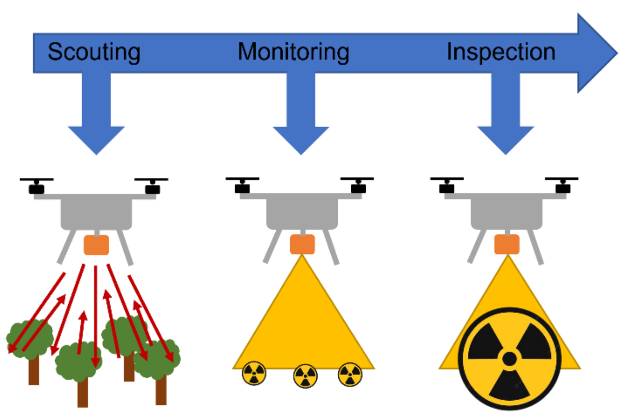

Fig 1. Displays proposed three phases.

Fig.2 shows the flow chart of Creating Keynote Markup Language (KML) files in Google earth. Creation of KML files will allow practice to creating flight paths for proposed drone missions. This practie can be used on some drones that allow KML files to be downloaded onto a Secure Digital (SD) card for flight paths.

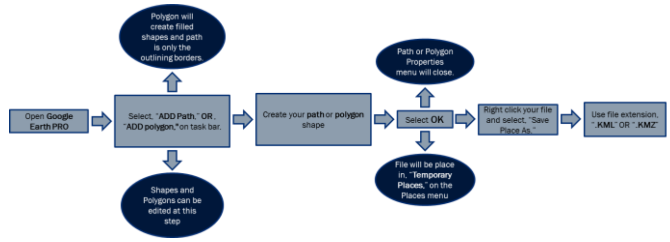

Fig 1. flow chart of Creating Keynote Markup Language (KML) files in Google earth.

2.1 Scouting:

In the scouting stage, the main objective is to become familiarized with the terrain and the obstacles that are within the AoI. To implement this, the UAV will survey the area taking aerial visuals to create an orthro mosaic or a photogrammetry stitching to create a Digital Surface Model (DSM) of the site. All DSMs created will have location georeferencing, which will help in future map overlays of radiation heat maps that will be developed in later stages. LIDAR technology could be a possibility for this to stage to enhance the DSMs with 3-d point clouds, but aerial visualization will be sufficient at this point.

2.2 Monitoring

The monitoring stage will consist of radioactivity measurements executed by integrating a radiation detector onto the UAV. The proposed mission for this phase is to have the UAV fly autonomously throughout the site at a low altitude. As proposed in [2] sensors need to be at a maximum range of 1m from the ground and an approx. speed of 0.2 meter per second (m/s). The detector will be georeferenced, so an overlay of the radiation detected on the site can be linked with the DSM created in the scouting stage. The status of selecting a radiation detector is still being considered but has been condensed to three possible detectors: Cadmium zinc telluride (CZT), Cadmium Zinc Telluride Selenide (CZTS) and the Sodium Iodide Scintillator.

2.3 Inspection

The final phase to be completed is the inspection phase. At this point in the workflow the main concern would be to visit locations with the highest radiation detected in the previous stage. The drone would visit these locations at an even lower altitude and measure the radiation at that precise location. The locations measured will determine the heat map that will be created. The process for computing the data sets is still in development and will possibly be introduced when phase one is completed.

2.4 Flight path

The proposed flight method of the site being inspection is a meandering approach shown in Fig.3. This method decreases the amount of flight time for the drone and multiple sweeps. Since a Kriging Python script is being developed, this approach is ideal for the algorithm. Since it will use spatial interpolation fewer known points of the Area of Interest (AoI) is required. A flight path has been decided for the aerial visualization. The drone will take a meandering flight path of the site also known as the lawn mower method. The proposed overlap of each image will be 75 percent on the front, back and sides. This will be done with the camera faced directly perpendicular with the ground or nadir. This was decided to keep flight missions at a minimum and avoid the increase of data processing time due to constraints of processing capabilities at the time of this paper.

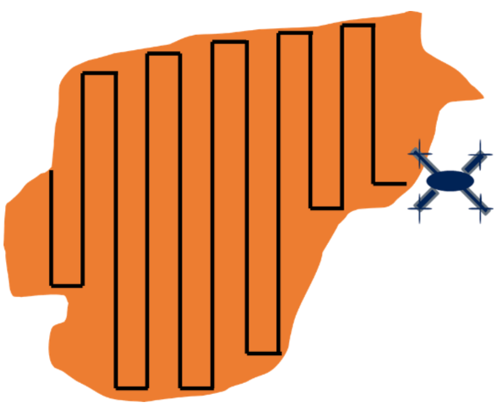

Fig. 3 shows a meandering flight path.

During the flight missions three major phases will occur, which are the scouting phase, the monitoring phase, and the inspection phase. In the scouting phase a LIDAR will be utilized to perform data acquisition to produce 3-D point clouds. Secondly, in the monitoring phase missions will collect measurements of radioactivity of the AoI and the data will be geoferenced and overlayed onto the 3d point could created during the scouting phase. Lastly, during the inspection phase; the drone will revisit the geo referenced locations to analyze the radiation concentration and identify the type of radionuclides at that location.

4. Experimental Results

There have been some flight missions conducted to prepare for missions of the AUM sites. These missions were completed off site at an arbitrary location along the Rio Puerco arroyo, approx. Latitude - 35°15’13.46 “N, Longitude - 109°16 ‘25.39” W. The SIRAS was utilize for this process to create an ortho mosaic stitching. As a result, 157 photos were taken from the most successful flight, which covered approx. 24.9 acres. The images were processed through a drone mapping software, Drone Deploy, where a 3-d model and elevation map with contours was created of the area that was surveyed.

The test flight mission conducted in the uranium mine demonstrates the significance of aerial monitoring for safety and environmental assessment purposes. Utilizing drones equipped with radiation detection sensors and environmental data capture capabilities enables comprehensive and efficient monitoring of the mining site. The collected data, along with subsequent analysis, provides valuable insights into radiation levels and environmental impacts, facilitating informed decision-making for safety enhancements and environmental preservation. Aerial monitoring techniques in uranium mining contribute to ensuring the well-being of workers and the surrounding ecosystem, promoting responsible and sustainable mining practices. Fig. 4 depicts a test flight mission.

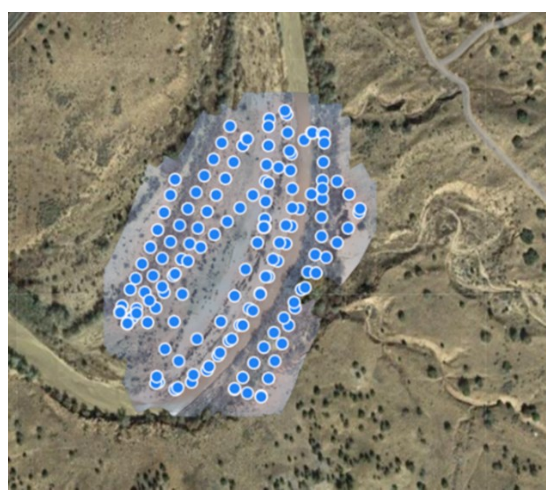

Fig. 4 Depicts a test flight mission.

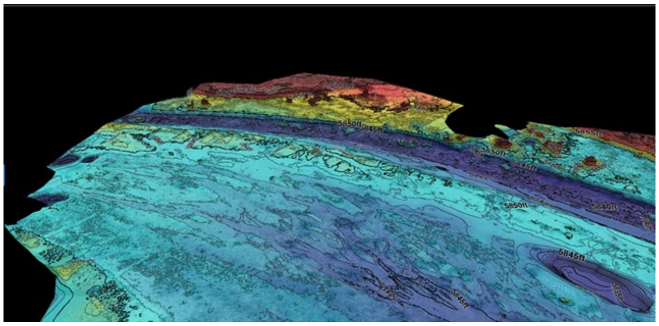

Fig. 5 shows elevation map with contours.

Also, during the early stage of this project, we have managed to collaborate with various companies to help expand the knowledge that will be going into this project. Universities Space Research Association (USRA) has helped by supplying data sets from prior research to build a Python script to recreate a spatial interpolation graph and help with project management. As a result, have managed to gather geographic information such as survey control points, radiation buffer zones and keynote markup files of all AUM claims on the NN. Also, collaborated with a company that was awarded by the NN for reclamations of the AUMs, Tetra Tech. The company has been assisting with approach and equipment selection, along with mentoring. Fig. 6 Shows the KML file of the Northeast Church rock mine (NECM) along with its mine identification number, Square mileage, alias etc. This project aims to make the NECM the concentrated mine location for data acquisition due to its location, which is in proximity of the university in Crown point, New Mexico. Although, the mine has been chosen for the Area of Interest (AoI), all the coordinates of the remaining Abandoned Uranium Mines (AUM) on the Navajo Nation have been obtained.

Fig. 7 displays the buffer zones of the AUMs across the Navajo Nation. The zones are measured from the center point outward of the mines in increments of 200 feet, ¼ mile, 1 mile, 4 miles and 15 miles. Fig. 4 also shows path of the Rio Puerco (green), which is one of the arroyos that were contaminated.

(a)

(b)

Fig. 6 (a) shows KML of NECM numbers: 303, 304, 305 (b) KML file of Northeast Church rock Mine

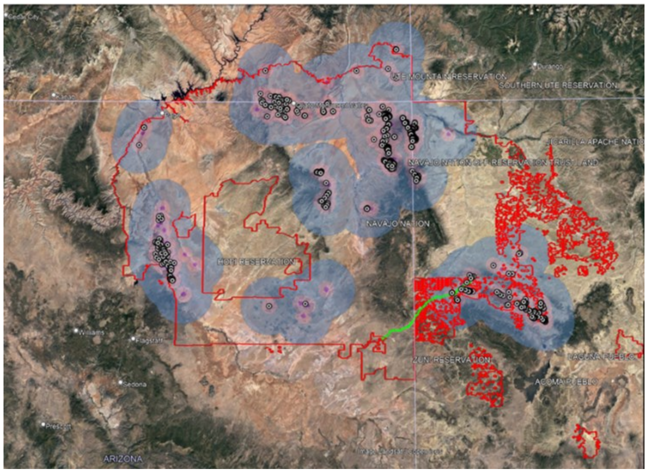

Fig. 7 (a) Buffer zones of AUMs on NN

Fig. 8 depicts control points across the Navajo Nation. Control points are used for spatial accuracy in surveying. As our project matures, drones will utilize these points with Real Time Kinematic (RTK) capabilities and base stations to implement autonomous mission plans. The usage of drones with these capabilities will introduce other equipment such as LIDARs, Thermal cameras, radiation sensors, and air control sensors to name a few. Accurate georeferencing will give the obtained data more requisition

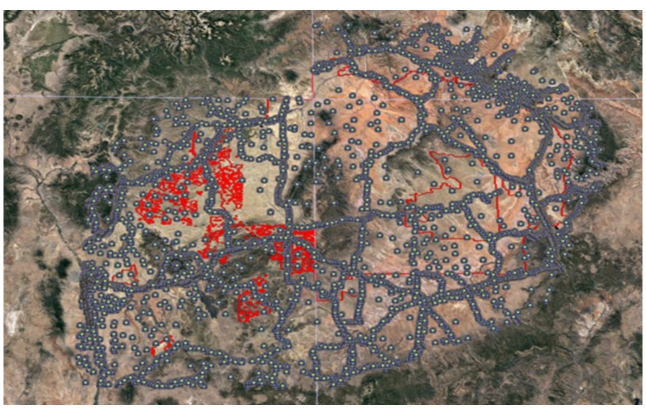

Fig. 8 survey control points on the NN.

Fig.9 shows the contaminated wells in Sanders, Arizona, approximately 58 miles west of the mine. This is the outcome from the tailing spill at the NECM in 1979. The Sanders community had 216 wells assessed and 8 were found with uranium concentration over the drinking water standards, which is 30 micrograms per liter (μg/L).

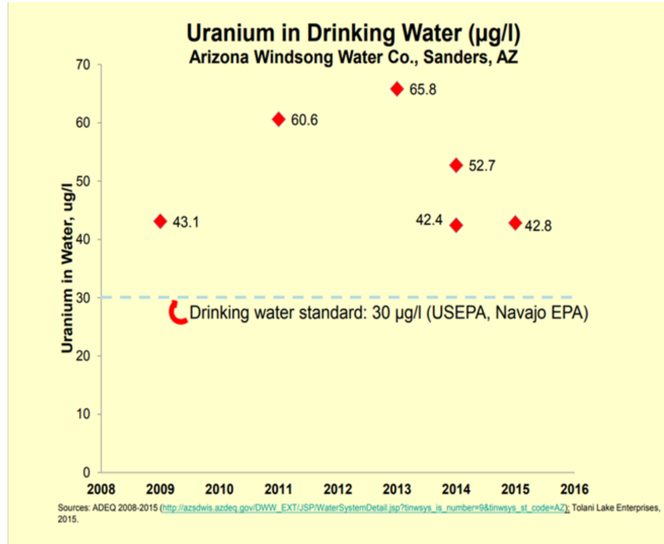

Fig.9 drinking water concentration in Sanders, Arizona

5. Conclusion

The objectives require a deep understanding of the proposed sites, which research and familiarizing ourselves with the areas of interest would set us aside from other researchers or engineers that have come and gone in the past. Most of the AUMs are surrounded by Navajo communities that lived around these sites for generations and it holds a profound feeling in their hearts. This makes it a priority to collect as much relevant data as possible, so we would not intrude in their domain without educating ourselves first. This paper is intended to help the communities of NN. As mentioned, there are 523 AUMs on the NN and only one has been successfully cleansed of radioactivity. With the completion of this project the workflow produced will be used to monitor other AUMs in the NN, producing accurate and reliable surveys of the sites. This project also plans to create problem solvers for the Navajo people. Many other disciplines will lend a helping hand and by doing so, the time spent can bring light to other engineering fields that use UAVs since the drone industry continues to grow every day. This technology has flown over the Navajo people for too long, it is time to lower the altitude and bring it to the NN.

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