MODELING & SIMULATION OF GEOLOGIC REPOSITORY SPENT FUEL CANISTERS

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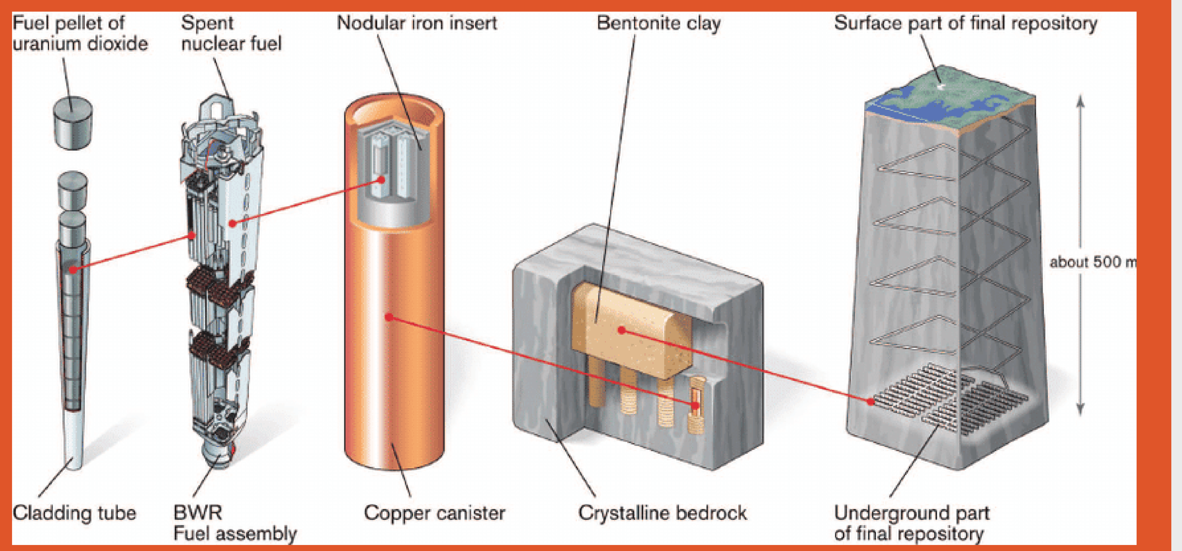
BACKGROUND

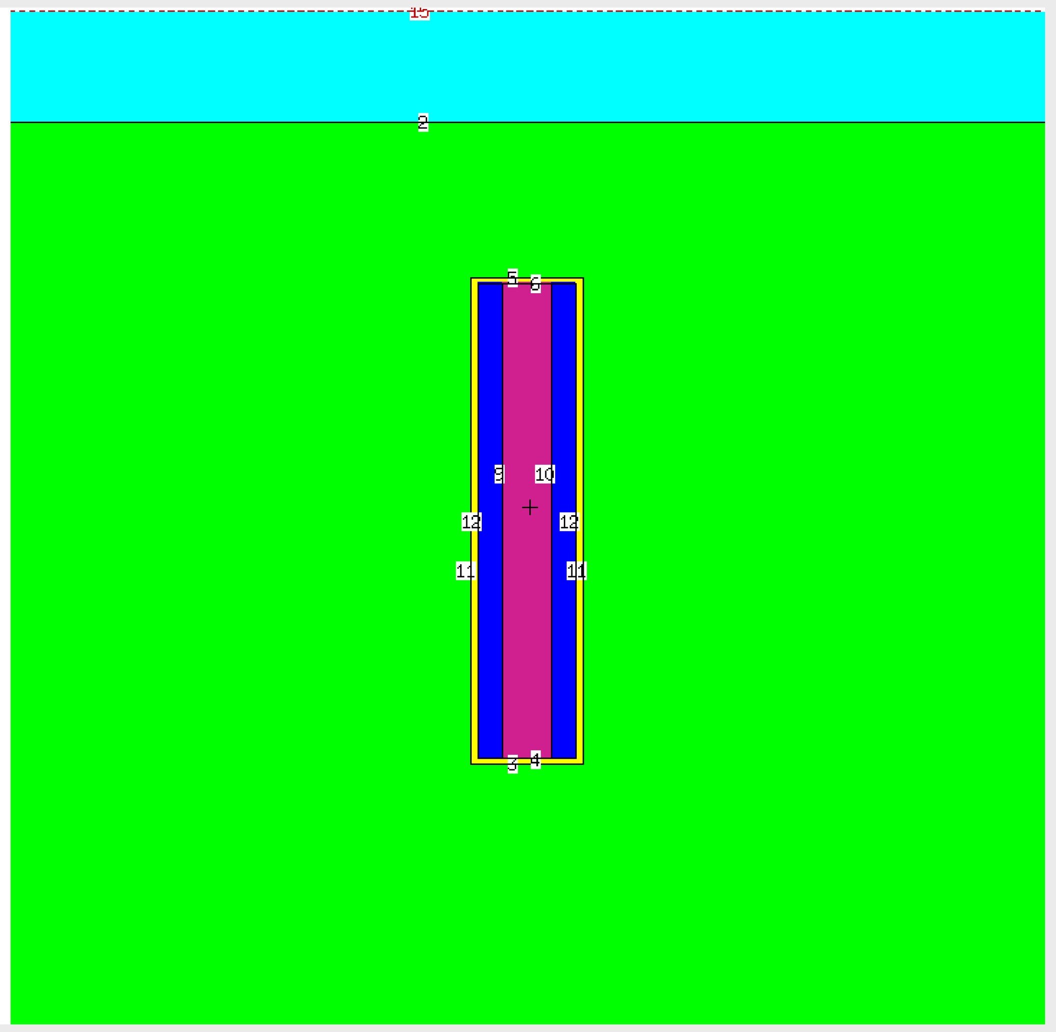
- Geological repositories are facilities operated by tunnels deep within the ground designed to store spent nuclear fuel. Currently, most countries do not have a developed repository system. As such, the International Atomic Energy Agency (IAEA) does not have a developed set of regulatory guidelines for their operation.
- For the purposes of this design all geometric considerations and assumptions are based upon the KBS-3 design. The KBS-3 design is the only functioning repository design, seen in Onkalo, Finland. A general overview of the KBS-3 repository entails spent nuclear fuel that is encapsulated in a copper deterioration resistant canister that is covered in a bentonite clay buffer and placed 400-700 meters into rock.



DESIGN OBJECTIVES

I) Design a multi-component system capable of safeguarding spent fuel held within geologic repositories that will operate at a somewhat autonomous level.

II) Address the deep penetration shielding issue by running MCNP to test the ability of the proposed system to detect radiation through some degree of backfill media.

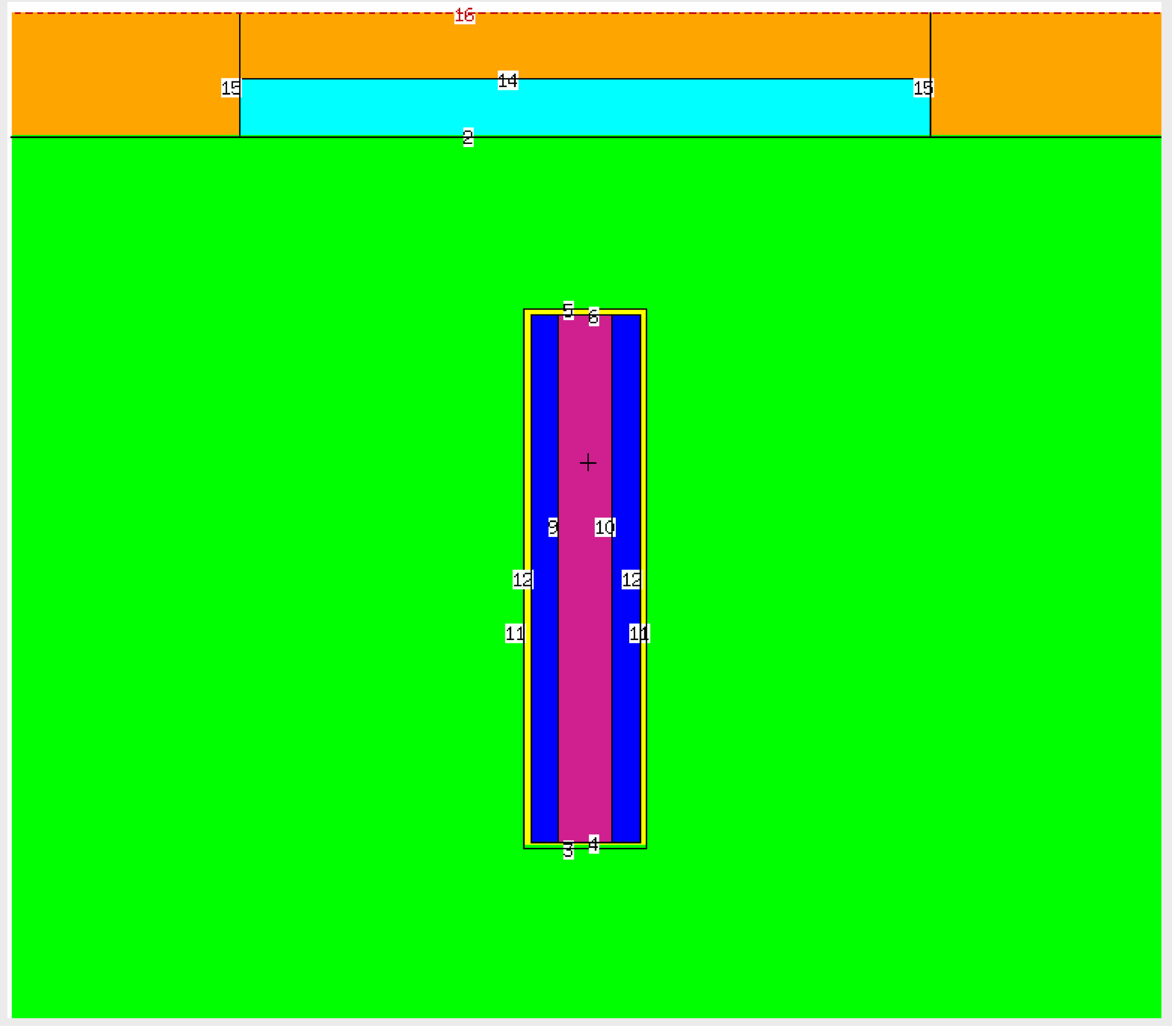


MCNP output diagram without concrete cap only air above (blue)

DESIGN CONSTRAINTS

This design must:

- Be environmentally sturdy and robust.
- Take into account the need for a power source.
- Take into account the KBS-3 base model constraints.
- Resistant to malicious tampering.
- Be considerate of implementation procedures.
- Be cost effective.



MCNP diagram with concrete cap (blue) and air above (orange)

MCNP

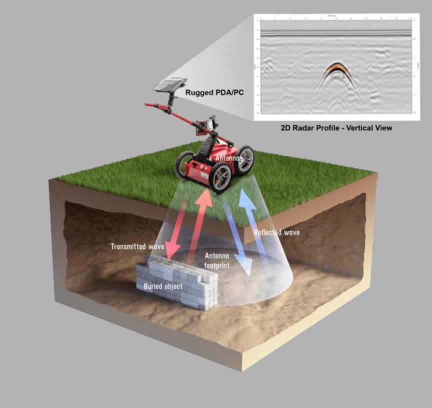
MCNP is a software package that models the radiation from its source throughout their lifetimes and displays how many much radiation makes it to areas of interest. Running the program requires the creation of an input deck, which requires both training and experience in the program. Each possible source energy and the corresponding probability of each must be put in, as well as the material properties of each material using in the simulation. The geometry of the model must be input by defining different boundaries and how those boundaries fit around the different materials defined. This is shown in the images above with the dark lines defining the cells, like the blue concrete cell surrounded by a green bentonite cell and an orange cell that defines air.

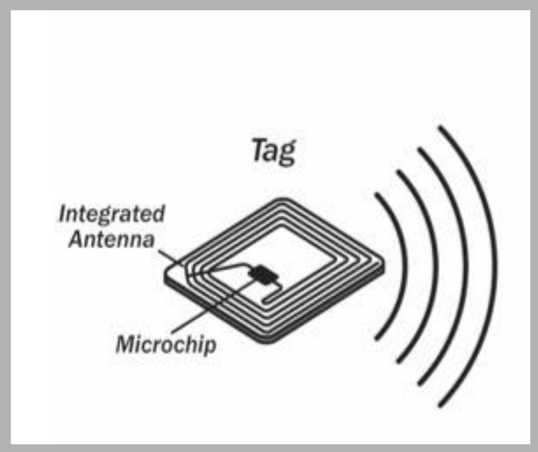
Results

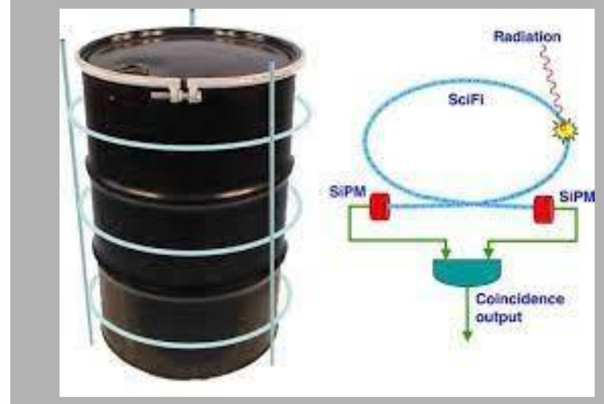
The results of the MCNP simulation resulted in very small a small photon flux making it to the detector which was situated above the canister in the air pocket. This photon flux was sufficiently small on the scale of 10^-32 for the concrete capped canister and 10^-28 for the uncapped. We did not consider time and the resulting decay schemes of the fuel nuclides, so photon energies were modeled as a spectrum with most probable photon energies being used.

DESIGN COMPONENTS

- **Detector Mesh for Nuclear Repositories (<u>DMNR</u>):** A net of radiation detection that utilizes scintillating wires and photomultiplier tubes. The proposition is to wrap this mesh around each canister to monitor the radiation emitted from the canisters. This technology would utilize radiation detection as a method of ensuring that no nuclear material has been removed from the canister.
- **Radio-frequency Identification (<u>RFID</u>) Tags:** An electronic device that utilizes RFID readers for the monitoring and tracking of the objects they are attached to. In this case, the RFID tags would be embedded in the canisters. This would limit the potential for tampering or removal of the tag entirely. With RFID tags embedded in the canisters at the top of the repository, the canisters can be tracked while they are being transported to their final deposition site thus ensuring continuity of knowledge.
- **Ground Penetrating Radar (<u>GPR</u>):** A tool that utilizes pulse reflections to develop visual representations of underground objects. This technology would be implemented in an autonomous fashion either directly above the deposition site, or directly outside the deposition site after it has been sealed off but before the entire tunnel has been backfilled.
- **<u>Weight Sensors</u>:** A device that converts a force being exerted on it into an electrical signal that can be relayed to an outside source. For the purposes of this design, the sensors would be placed below the canisters themselves. This technology addresses the potential for an individual to remove nuclear material from the canister without moving the canister entirely.







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