COLLEGE OF ENGINEERING | Nuclear Science and Engineering | NSE.4

COMPUTATIONALLY 'TICKLING THE DRAGON'S TAIL': A TRANSIENT FALLING-SLUG 3D MODEL IN SERPENT

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INTRODUCTION

During the Manhattan project, a fast-burst type reactor called the Dragon was built to verify a fission chain reaction sustained by prompt neutrons alone.

The objective of this project is to develop a time-dependent Monte Carlo model of the Dragon assembly, examine a redesign of the assembly using modern materials, and explore the reconstruction of dose and shielding used for the system.

Figure 1: Dragon Machine Support Structure

ASSEMBLY DESIGN

The Dragon Assembly core consisted of a fuel region of highly enriched uranium hydride combined with a plastic binder. This was surrounded by a small layer of cadmium with a beryllium oxide tamper at the outer layer.

During the experiment, a fuel slug driven by gravity causes the system to briefly go prompt supercritical as it travels through the core.

Oregon State University

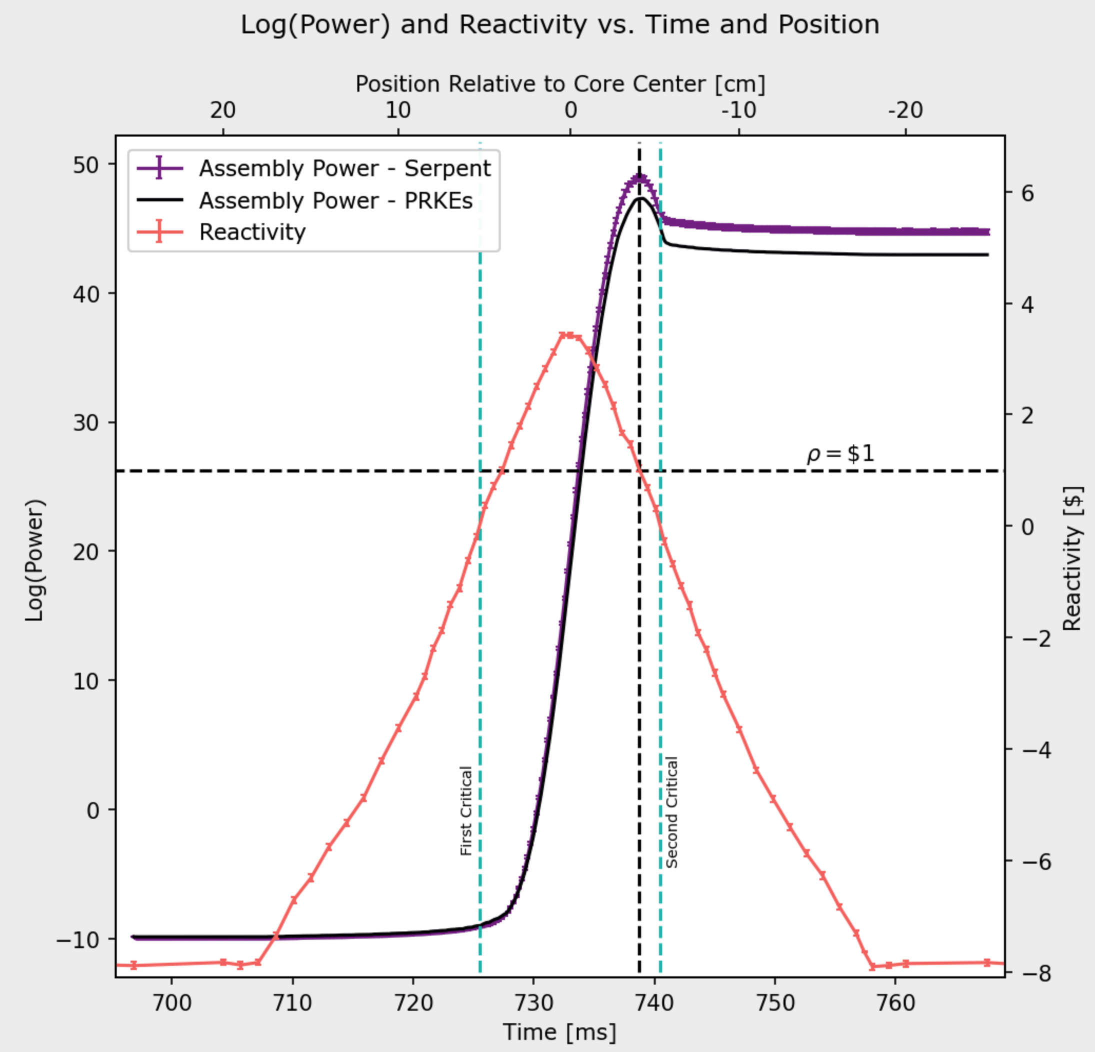

Figure 2: Assembly Power and Reactivity vs. Time and Position throughout the Transient

Table 1: Minimum and Maximum Multiplication Factors between MCNP and Serpent

Slug Position	MCNP	Serpent
Minimum k_{eff}	0.94338 ± 0.00032	0.94042 ± 0.00033
Maximum k_{eff}	1.02755 ± 0.00033	1.02939 ± 0.00034

SERPENT MODEL

The Dragon assembly was modeled using the Monte Carlo neutron and photon transport code Serpent. Serpent is ideal for this application due to dynamic simulation capabilities.

The results from a Serpent Dragon model with a larger peak reactivity than the original assembly ($3.4 vs. $1.4) were validated against a PRKE model. Good agreement is seen between the Serpent model and PRKE model using the same reactivity curve and mean generation time.

The material, geometric, and kinematic parameters of the Dragon experiment found in literature have been iterated upon to develop a model of the Dragon assembly which correctly models the reactivity curve outlined for the original experiment.

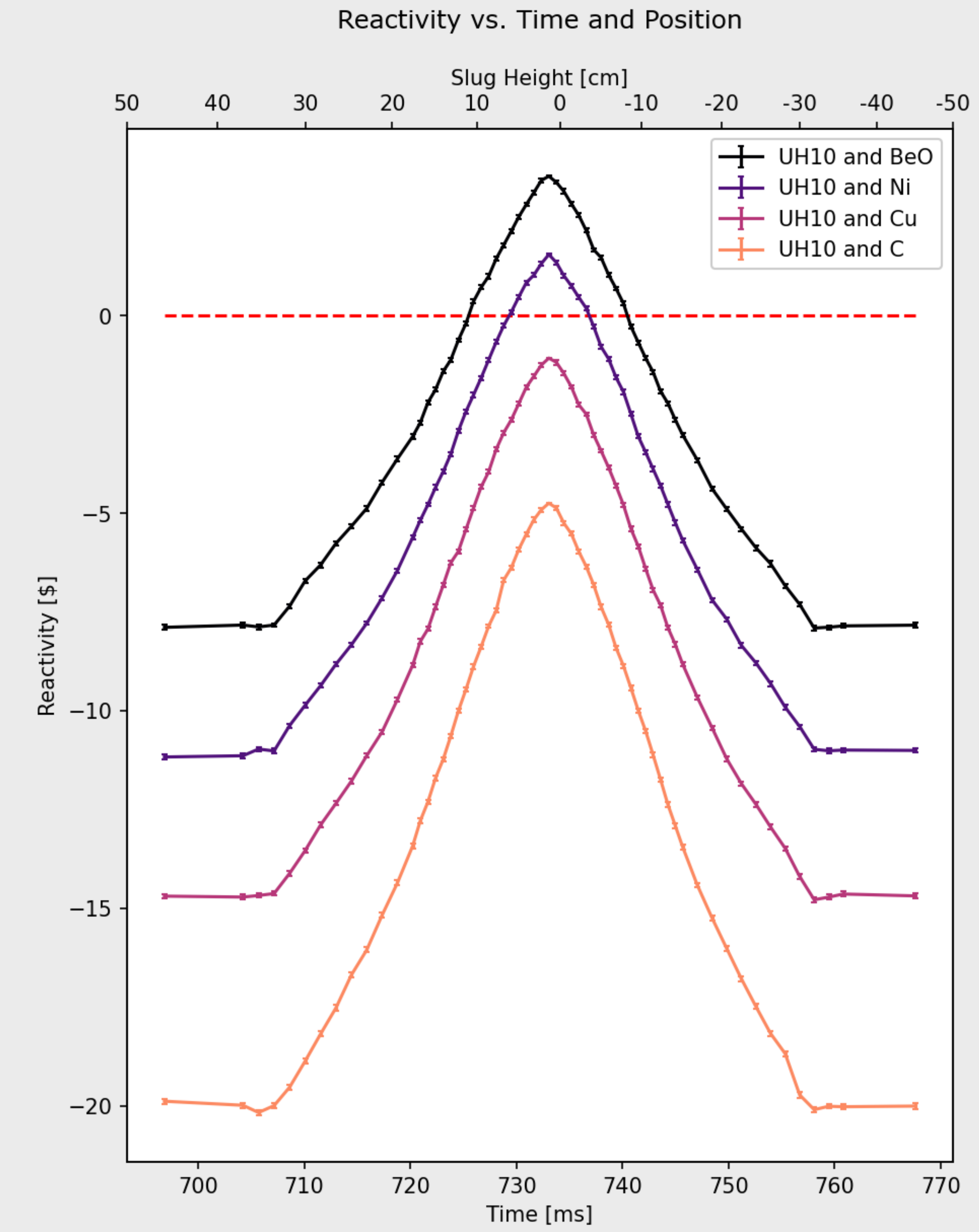

Figure 4: Relative Change in Reactivity vs Time and Position throughout the Transient with Different Tamper Materials

MODERN REDESIGN

The original materials of the Dragon Experiment are problematic under a modern lens due to the health hazard of the beryllium oxide tamper along with the fuel's high enrichment.

Introduction of a new fuel and tamper will require the addition of a separate moderator material and a significant change in geometry.

UZrH fuel produces a peak k of 0.57330 ± 0.00012.

DOSE CALCULATIONS

The dose is calculated using the MCNP6.2 energy deposition tally in water to simulate a human response.

The dose at 1 meter is 8.9048E-11 MeV/g-particle.

TEMPERATURE FEEDBACK

An exploration into the temperature coefficient of reactivity was established to determine the importance of temperature feedback in the system.

$$\alpha_T = -0.0040 \pm 0.0015\ \$/K$$

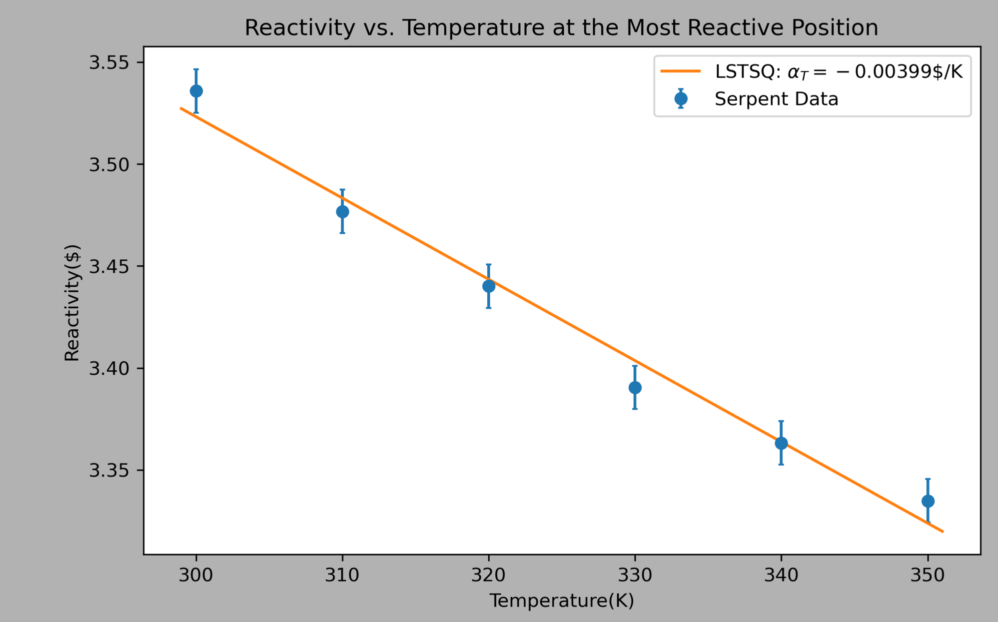

Figure 5: Reactivity vs Temperature at the System's Most Reactive Position

RESULT UNCERTAINTY

Several geometric and material parameters were inconsistent or omitted from the literature. Material and geometry in the assembly design were iterated upon to produce a model that agrees with explicitly defined parameters from the literature [2].

CONCLUSIONS

Monte Carlo Codes such as Serpent are well equipped to model highly transient systems like that of the Dragon Machine.

A redesign is possible, but notable changes in geometry and materials are required.

Temperature feedback does not significantly affect the system due to a low temperature coefficient of reactivity along with the small change in temperature.

REFERENCES

1. Kimpland R., et. al. (2021). Critical Assemblies: Dragon Burst Assembly & Solution Assemblies. Los Alamos National Laboratory.

2. O.R. Frisch, et. al. Controlled Production of an Explosive Nuclear Chain Reaction. (1945).