ANALYSIS OF THE PROLIFERATION CAPABILITY OF LOW-POWERED CIVILIAN RESEARCH REACTORS

OBJECTIVE: Can a typical civilian research reactor be used to clandestinely produce a "significant quantity" of nuclear material as defined by the International Atomic Energy Agency (IAEA)?

INTRODUCTION

A common concern of the international community is the production of weapons grade nuclear material in typical civilian nuclear research reactors.

The **objective** of this project is to determine if a typical civilian research reactor can produce an IAEA significant quantity of nuclear material (specifically **plutonium-239**) in a short time frame.

The International Atomic Energy Agency (IAEA) defines a "significant quantity" to be 8 kilograms or greater of plutonium-239

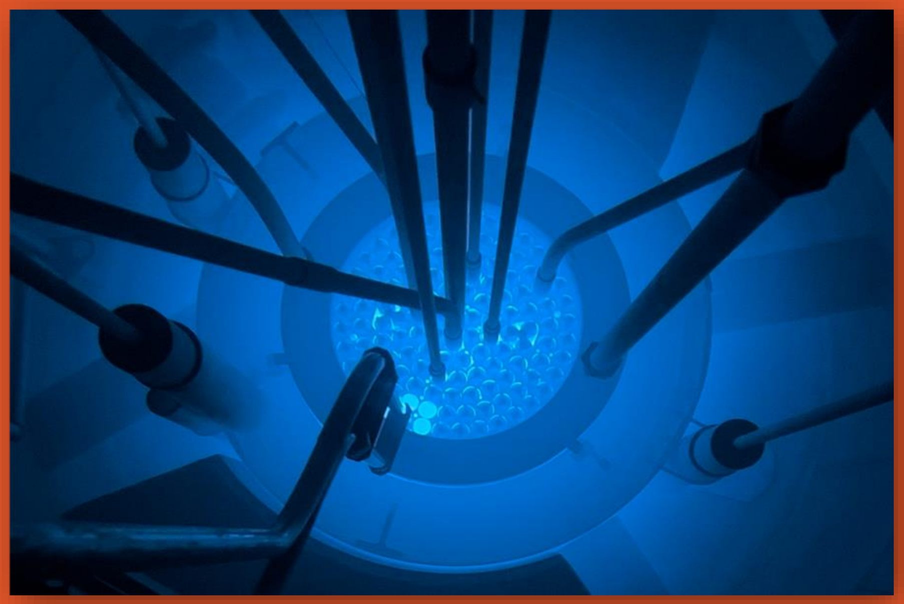

Figure 1: OSU TRIGA Reactor (Post-Pulse)

HOW IT'S MADE: PLUTONIUM

Plutonium-239 is produced by bombarding uranium-238 with neutrons, inducing a nuclear capture reaction.

The resulting uranium-239 undergoes beta decay to neptunium-239 before again decaying via beta particle emission to plutonium-239. See *Figure 2*.

$$^{238}_{92}\mathrm{U} + ^{1}_{0}n \rightarrow ^{239}_{92}\mathrm{U}$$

$$^{239}_{92}\mathrm{U} \rightarrow ^{239}_{93}\mathrm{Np} + ^{0}_{-1}\beta^{-} + \bar{\nu}_e$$

$$^{239}_{93}\mathrm{Np} \rightarrow ^{239}_{94}\mathrm{Pu} + ^{0}_{-1}\beta^{-} + \bar{\nu}_e$$

Figure 2: Reactions Involved with Pu-239 Production

RESEARCH & DATA

OSU TRIGA MCNP® MODEL

The OSU TRIGA® Reactor (OSTR) is an exemplary candidate for this study, as it is a low-powered research reactor owned and operated by a public institution. See *Figure 1*.

OSTR was modeled using the Monte Carlo N-Particle transport code, or MCNP®.

Geometry data was provided by the OSTR staff, the OSTR training manual, and General Atomics engineering drawings. See *Figure 3* and *Figure 4* below for renderings.

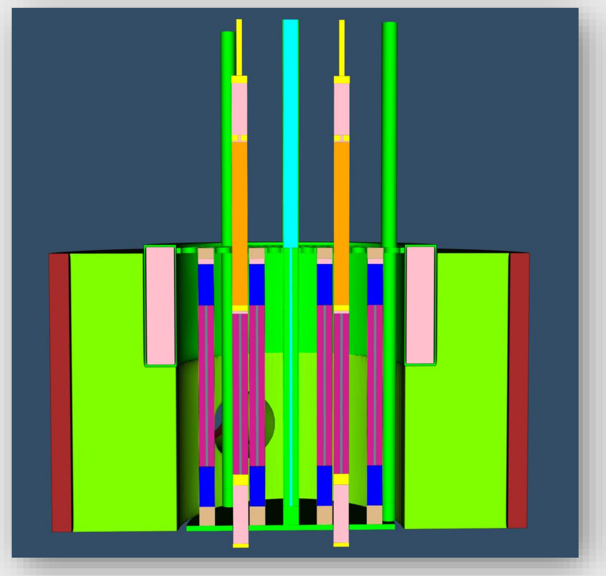

Figure 3: Radial Cross-Section of OSTR Model (GXSView)

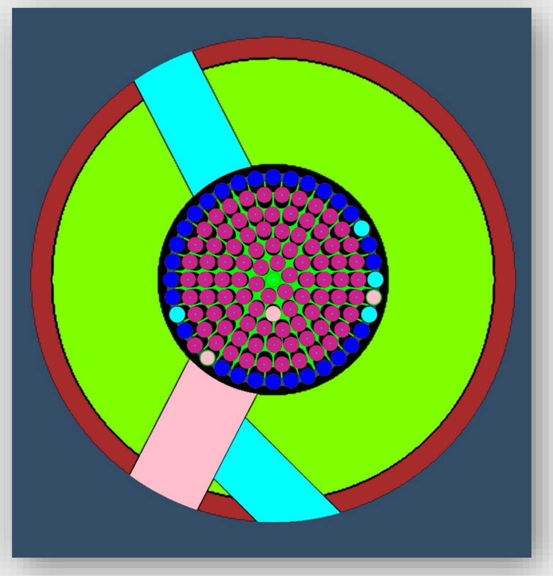

Figure 4: Axial Cross-Section of OSTR Model (GXSView)

The model was verified using experimental data from the OSTR Post-Conversion Startup Report from 2008 when OSTR switched from 8.5/70 HEU to 30/20 LEU fuel.

In addition, control rod calibration data was pulled from OSTR logbooks. See *Figure 5* below for example data.

AVERAGE MCNP® MODEL BIAS:
$0.85 or **637.5 pcm** or **0.6375% Δk/k**

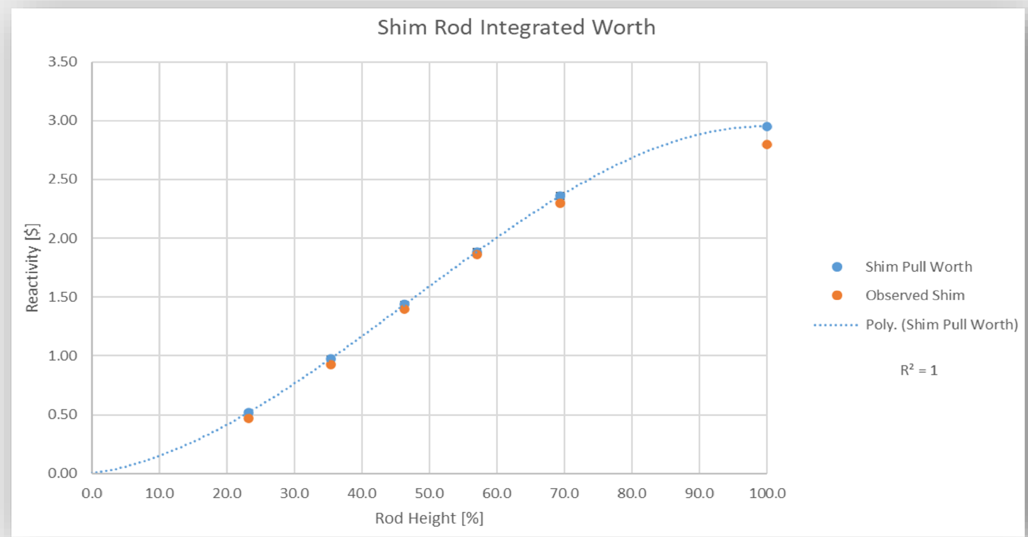

Figure 5: Sample Control Rod Integrated Rod Worth
Observed vs. Simulated

TARGET DESIGN & DATA

Natural uranium in the form of triuranium octoxide (U_3O_8) was chosen as our production material. Multiple designs were generated for a production target that would fit in the OSTR core. A burn period of **50 megawatt-days** was chosen for analysis, roughly **one year** of operations at OSTR.

Figure 6: SOLIDWORKS® Rendering of a Pu-239 Production Target

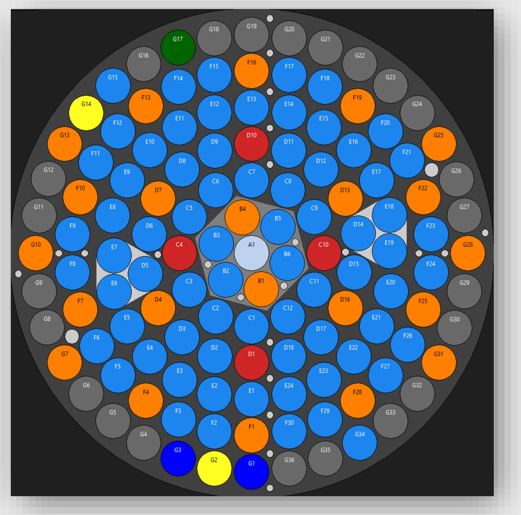

Figure 7: Core Configuration with Targets Installed (**Orange**)

To evaluate how much Pu-239 is produced, the **BURN** function of MCNP was called. It was found that a total of 22 targets could be placed in the core (see *Figure 7*) with control rods withdrawn to 100% to maintain criticality.

Target Type	Initial U-238	Total Pu-239
Vented	78.07 kg	5.392 g
Solid U_3O_8	61.16 kg	4.645 g
Graphite-Encased	43.52 kg	3.650 g
In-Fuel Pin Array	41.85 kg	2.752 g
Annular Fuel Cuff	38.85 kg	3.024 g

Table 1: Sum of Plutonium Yield for Various Target Designs (22 Target Core Configuration)

The neutronic impact was substantial as a significant amount of fuel was removed. *Figure 8* below demonstrates the impact of the targets on the core flux profile.

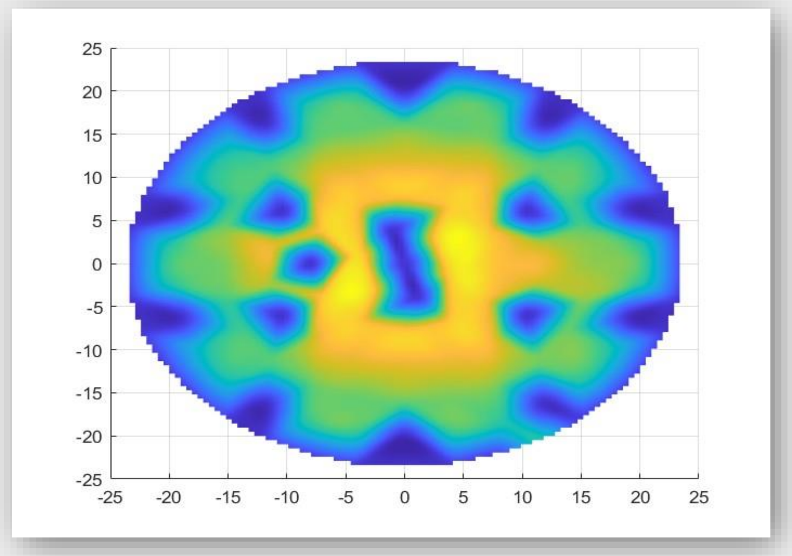

Figure 8: Core Neutron Flux Profile With Targets Installed.
Blue is low flux, **Yellow** is high flux.

CONCLUSION

SAFEGUARDS ANALYSIS

Using MCNP®, gamma spectroscopy was performed on a TRIGA fuel element and a plutonium-producing target to simulate an IAEA safeguards inspection.

This was achieved by using the `f5z:p` ring detector tally that is built in to MCNP®.

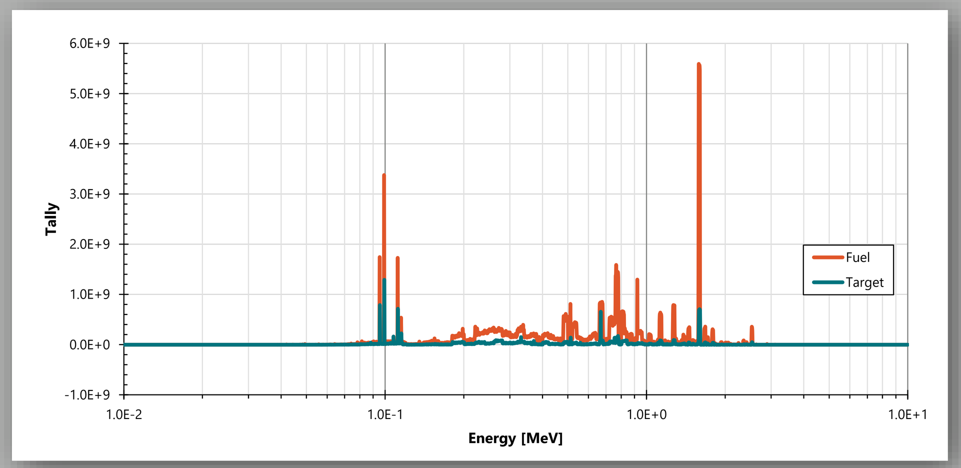

Figure 9: Gamma Radiation Energy Spectrum for TRIGA Fuel and Production Target

Figure 9 shows that although the fuel and the target produce the same fission products, **the TRIGA fuel produces significantly more.**

This difference would be noticed by an IAEA inspector.

RESULTS

A TYPICAL, LOW-POWERED, CIVILIAN RESEARCH REACTOR **CANNOT** FEASABILY PRODUCE AN IAEA SIGNIFICANT QUANTITY OF PLUTONIUM-239.

AT THE PRODUCTION RATE OF THE HIGHEST PRODUCING TARGET (SEE *TABLE 1*), IT WOULD TAKE **1,483 YEARS** OF STANDARD OPERATION (OR **203 YEARS** OF CONTINUOUS OPERATIONS) FOR OSTR TO PRODUCE THE MINIMUM 8 KILOGRAMS OF PLUTONIUM-239.

MEET THE GROUP

Pictured from left to right: Nathaniel McNichols, Paul Sprague, Alexander Westerberg, and Hunter Wagner

Not pictured: Dr. Steven R. Reese, *Project Advisor*

Oregon State University