ANS Student Webinar Series:

Senior Design Pitch Competition

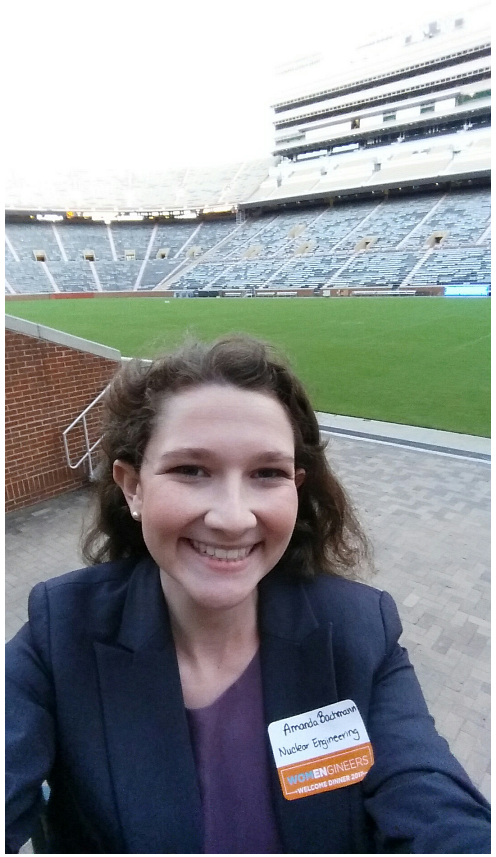
Sponsored by the Education, Training, & Workforce Development Division and the Young Member Group

SSC Commendation Award Nominees:

Hannah Brock - Georgia Tech
Samuel Joseph Cope - NC State
Zachary Deziel - University of Chicago
Tristen Ence - BYU
Alex Fanning - UIUC
Joshua Ferringo - UT-Austin
Monica Gehrig - Missouri S&T
Peter Hotvedt - UW-Madison
Deena Jaber - Texas A&M
Dimitris Killinger - VCU
Kyra Lawson - Texas A&M
Cameron Maras - NC State
Ihsan Yuksel - Texas A&M

Graduate Student Winners:

Ishita Trivedi



Amanda Bachmann

Seth Kilby

Undergrad Winners:

Alexandria Ragsdale

Mackenzie Warwick

The Salty Spittoon

North Carolina State University

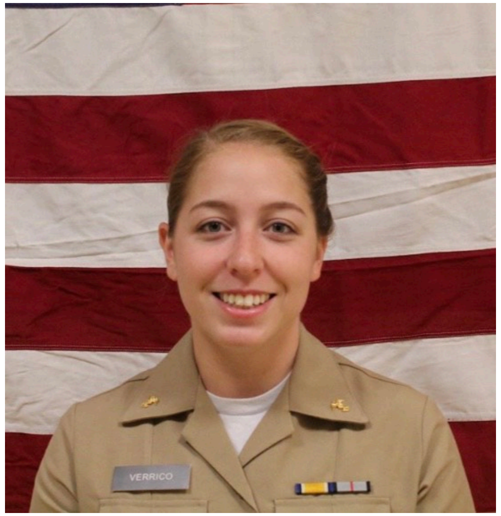
Presented by Vincent Novellino

Authors:

Vincent Novellino

Charles Goodman

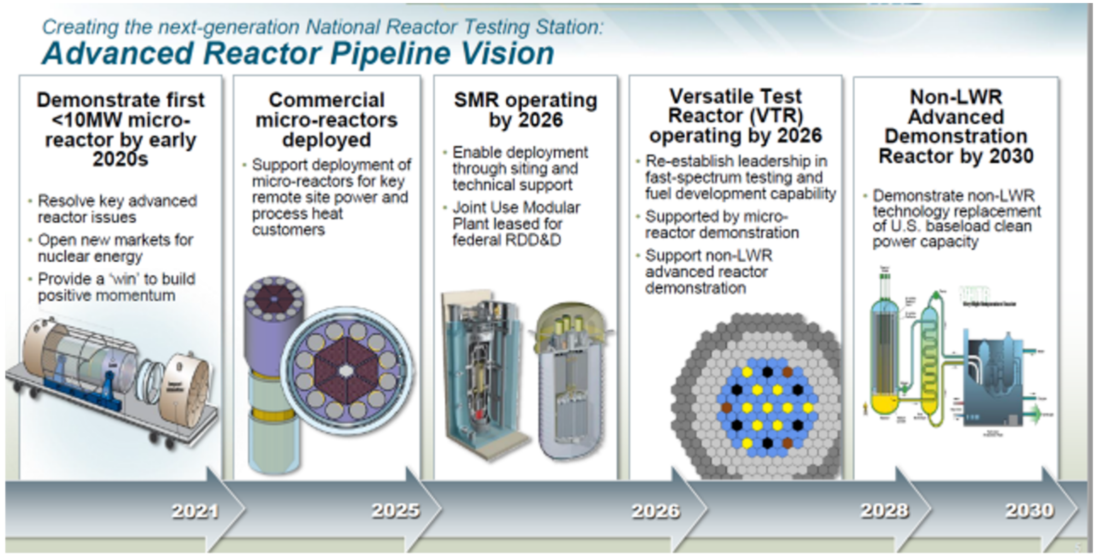
Thomas Thompson



Lindsay Verrico

Design of a Fast MSR - Presentation by: Vincent N. Novellino

Motivation:



Creating the next-generation National Reactor Testing Station:

Advanced Reactor Pipeline Vision

Demonstrate first <10MW micro-reactor by early 2020s

- Resolve key advanced reactor issues
- Open new markets for nuclear energy
- Provide a 'win' to build positive momentum

Commercial micro-reactors deployed

- Support deployment of micro-reactors for key remote site power and process heat customers

SMR operating by 2026

- Enable deployment through siting and technical support
- Joint Use Modular Plant leased for federal RDD&D

Versatile Test Reactor (VTR) operating by 2026

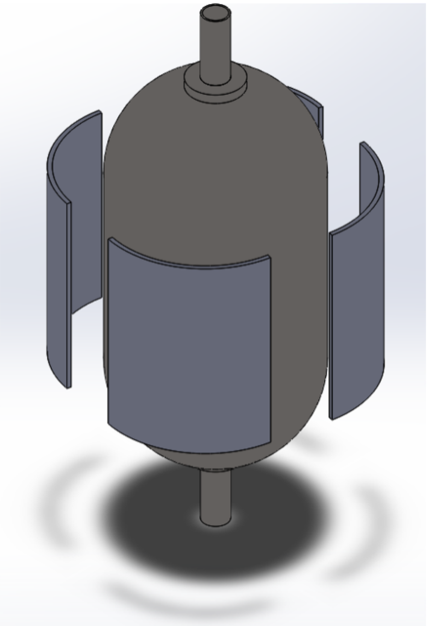
- Re-establish leadership in fast-spectrum testing and fuel development capability
- Supported by micro-reactor demonstration
- Support non-LWR advanced reactor demonstration

Non-LWR Advanced Demonstration Reactor by 2030

- Demonstrate non-LWR technology replacement of U.S. baseload clean power capacity

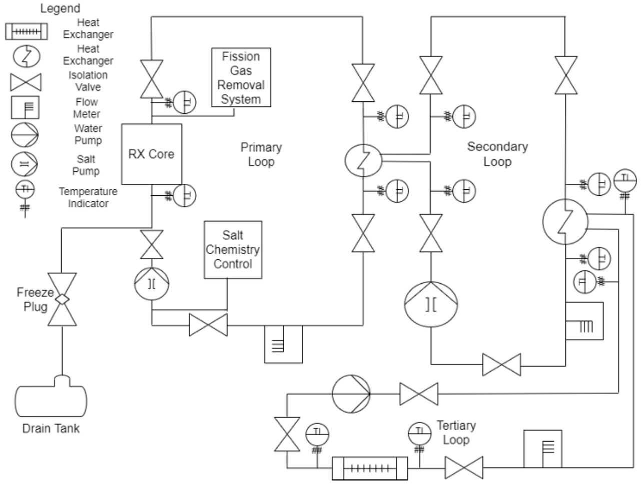
Our design:

- Goal:
  - Small and Economical
  - Low-power (1 MW) demonstration reactor
- 7 ft inner diameter, 7.07 ft outer diameter HT-9 Vessel
- ~2 inch thick SS-304 reflector in 4 pieces
- 5 inch diameter pipes
- 19.5 atom-% HALEU fuel
- 33%-67% UCl_3-NaCl fuel salt



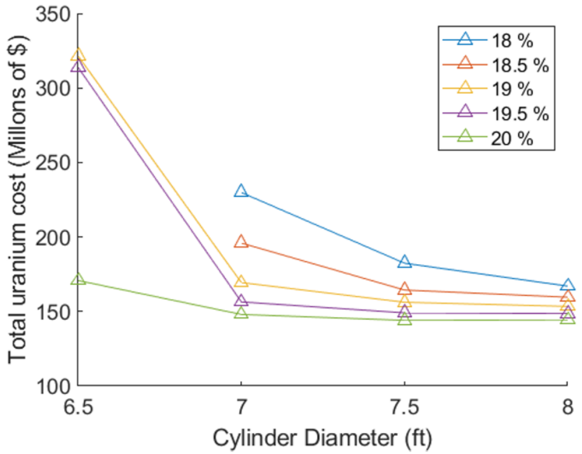
Auxiliary Systems:

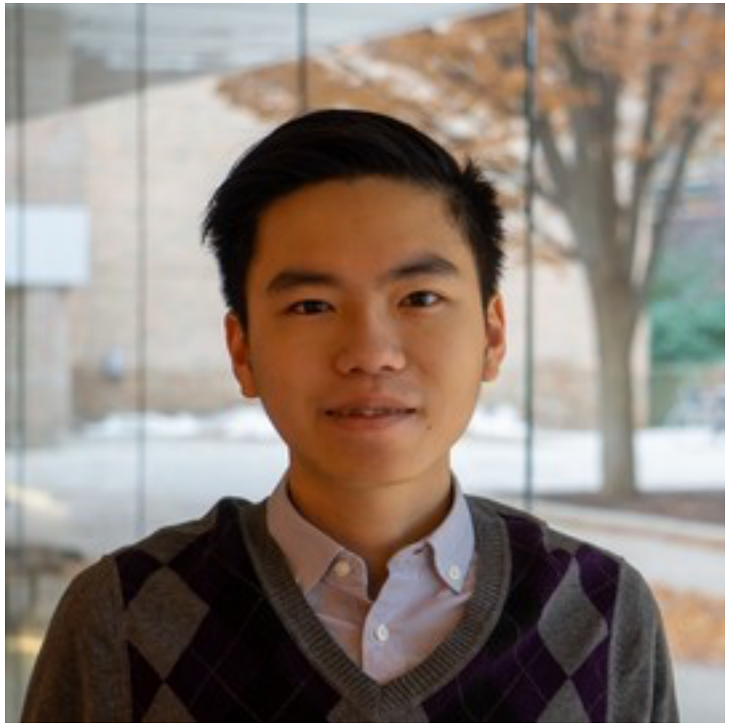
- Drain Tanks with Freeze Plug
  - Passive Safety System
- Fission Gas Removal System
- Salt Chemistry Control



Economics:

- Total Cost
  - $380,205,156
- Budget:
  - $500,000,000
- Lifetime:
  - 10 years
- Funding
  - Government Allocations





Tommy Wong

Millennial

Presented by Tommy Wong

Authors: Chun Yin (Tommy) Wong,
Aunic W. B. Goodin

Faculty Advisors: Kevin G. Field,
Gary S. Was

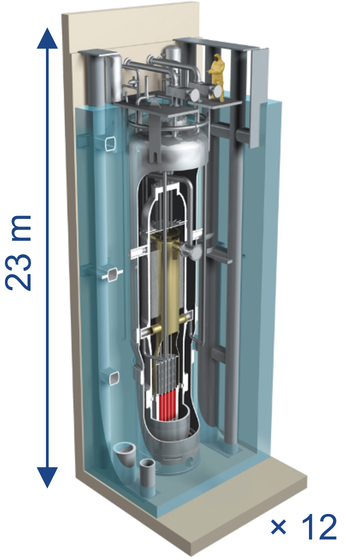
Aunic Goodin

Feasibility of SiC Cladding for Small Modular Reactors

Team *Millennial*: **Chun Yin (Tommy) Wong**, Aunic W. B. Goodin
Faculty Advisors: Kevin G. Field, Gary S. Was


Fukushima, Japan 2011 [1]

SiC has a lower H_2 release rate than Zircaloys



NuScale SMR [3]

Modeling Methods [2]

Thermal

- Constant LHGR at 8.2 and 21.3 kW/m

Radiological

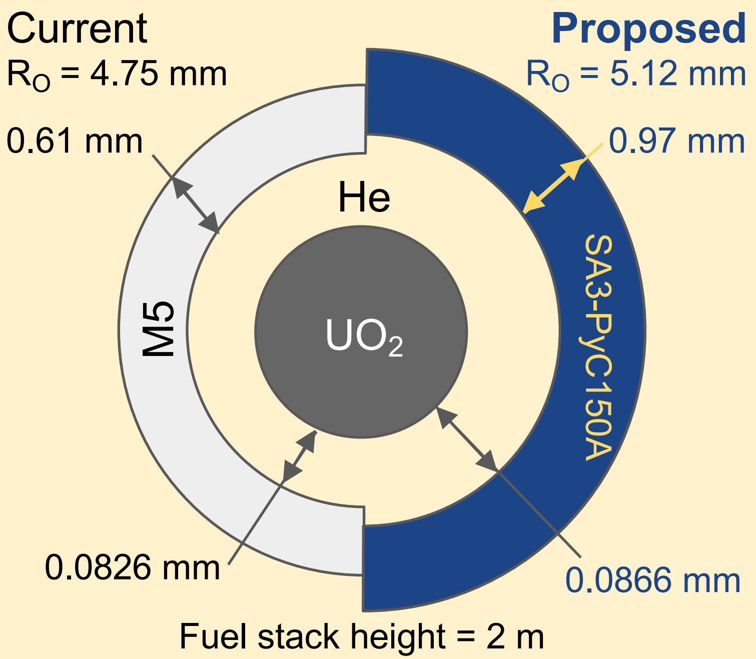
- Irradiation-induced swelling @ 6.1 dpa
- Linear fission gas release

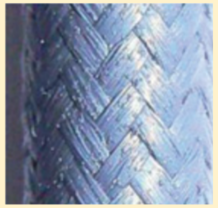
Mechanical

- Plane strain condition

Requirements

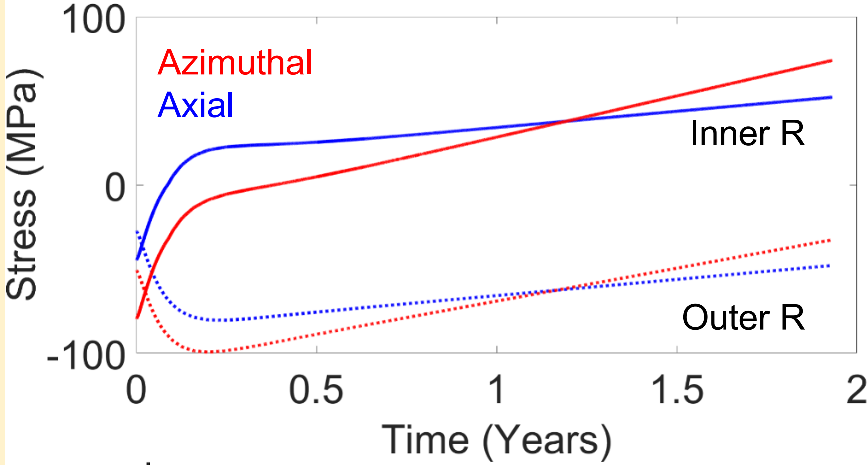
1. Failure probability < 10^{-6} after 2 years
2. Fuel does not melt at max LHGR = 21.3 kW/m

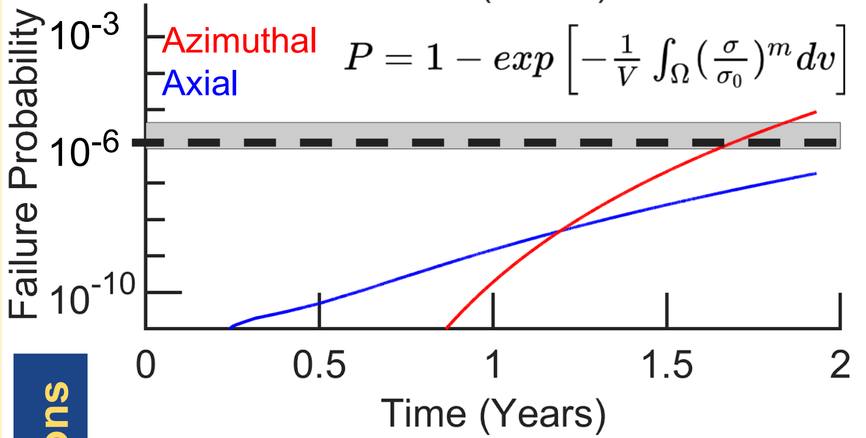




CVI SiC/SiC [4]

0°/90° 2D braiding, $v_f = 33\%$
PyC coating
E = 200 GPa, $\nu = 0.16$





Conclusions

- Centerline T = 1681 K < Melting T
- **Competitive with current design**
- **Safer in a LOCA**
- ↓ azimuthal stress by ↓ fission gas P

[1] *Digital Globe,* [2] M. BEN-BELGACEM, V. RICHET, K. A. TERRANI, Y . KA TOH, and L. L. SNEAD, ‘Thermo-mechanical analysis of LWR SiC/SiC composite cladding’, J. Nucl. Mater., vol. 447, no. 1, pp. 125–142, (2014)., [3] *Nuclear Power International,* [4] T. KOYANAGI, Y. KATOH, G. SINGH, M. SNEAD, ‘SiC/SiC Cladding Materials Properties Handbook’, ORNL/TM-2017/385, (2017)

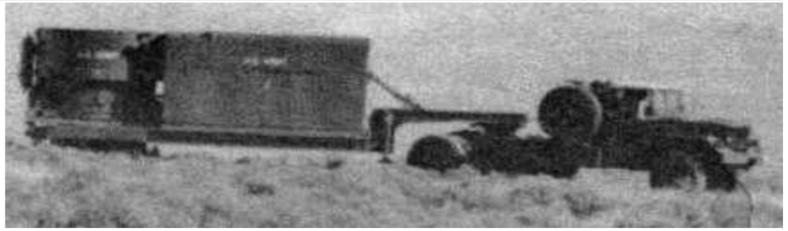
Army Nuclear Power for Land Operations

United States Military Academy West Point

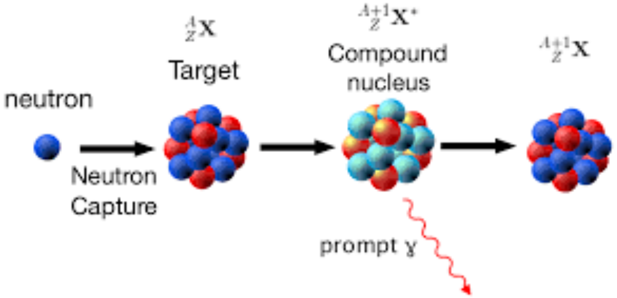
Presented By Ricardo Damiani

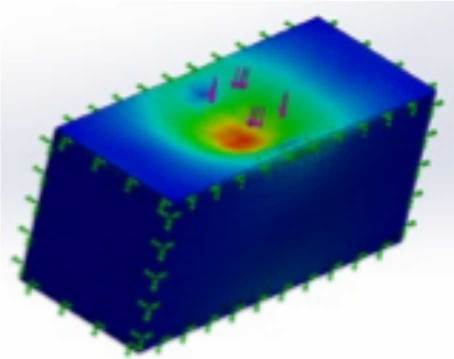
Authors: Kenneth Allen, Ricardo Damiani, Demar Gale, Justin Knoll, Ryan Rocca

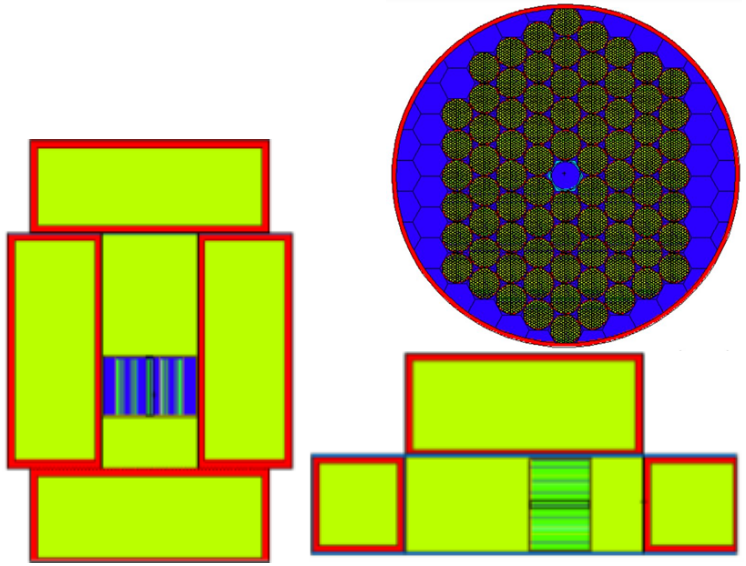
Feasibility and Safety of Mobile Nuclear Power



- Casualty and cost reduction
- Constraints and mobility
- Battle damage mitigation
- Final reactor area
- Human safety and environmental considerations
- Emergency procedures and recommendations







High-Enrichment/High-Burnup Loading Pattern Optimization for a 2-Loop Westinghouse PWR

Amadu Toronka, Chris Gozum, Spencer McNeil

Dr. Maria Avramova
Dr. Kostadin Ivanov

Mr. Baxter Durham
Mr. Blaine Taylor

Department of
NUCLEAR ENGINEERING

High-Enrichment/High-Burnup Loading Pattern Optimization for a 2-Loop Westinghouse PWR

Primary Core Considerations	Constraints	Most Limiting - Actual
Energy (Boron) @ 690EFPD	≥10 ppm	**16.4 ppm**
ARO F*Δ*H Peaking Factor	≤1.550	**1.535**
RIL F*Δ*H Peaking Factor	≤1.660	**1.539**
Peak Pin Burnup	≤70,000 MWD/MTU	**69893 MWD/MTU**
MTC (all Power Levels)	≤0.00 pcm/°F	**-2.065 pcm/°F**
Shutdown Margin	≥1700 pcm	**1981.7 pcm**
Feed Assemblies	<60	**56**

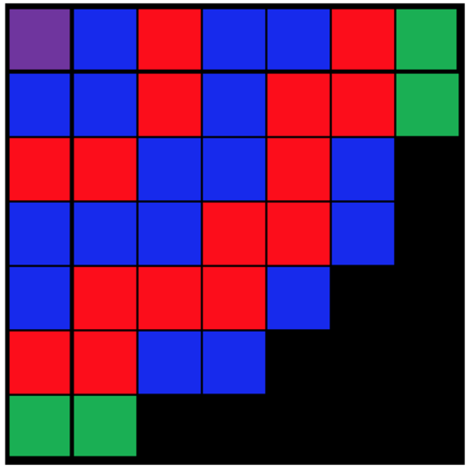
Safety Considerations - Rod Ejection		BOL Limits vs. Actual		EOL Limits vs. Actual	
HZP Conditions	Max Ejected Rod Worth ($\Delta\rho$)	0.200	**0.027**	N/A	N/A
	Max Fq	2.800	**2.738**	N/A	N/A
	Max Burnup @ Hotspot (MWD/MTU)	31034	**25478**	N/A	N/A
HFP Conditions	Max Ejected Rod Worth ($\Delta\rho$)	0.200	**0.181**	0.100	**0.006**
	Max Fq	2.800	**1.914**	3.800	**1.924**
	Max Burnup @ Hotspot (MWD/MTU)	31034	**24470**	48276	**33260**

🟨	6% Feed
🟥	5% Feed
🟦	Once Burned
🟩	Twice Burned
🟪	3.90% Twice

Fuel Cycle Cost

Component	Requirement	Price/KgUe	Value	Fraction	Plot Name	Price/MWHre
Yellowcake Requirement (Lb)	751,640.1	$ 791.78	$ 18,640,675	24.72%	Ore	$ 1.178
Conversion Requirements (KgUn)	289,066.9	$ 116.52	$ 2,743,245	3.64%	Conversion	$ 0.173
Separative Work (Kg-SWU)	230,851.9	$ 1,131.76	$ 26,644,928	35.34%	Enrichment	$ 1.683
Fabrication + BA (KgUe)	23,542.8	$ 276.46	$ 6,508,600	8.63%	Fabrication	$ 0.411
Pre-Operation Carrying Charges		$ 83.95	$ 1,976,403	2.62%	PreOp Interest	$ 0.125
Operating Carrying Charges		$ 282.69	$ 6,655,264	8.83%	Operating CC	$ 0.420
Spent Fuel Disposal		$ 519.30	$ 12,225,855	16.22%	SF Disposal	$ 0.772
Total Fuel Cost		**$ 3,202.46**	**$ 75,394,969**	**100.00%**		**$ 4.763**

Before (Cycle 30)



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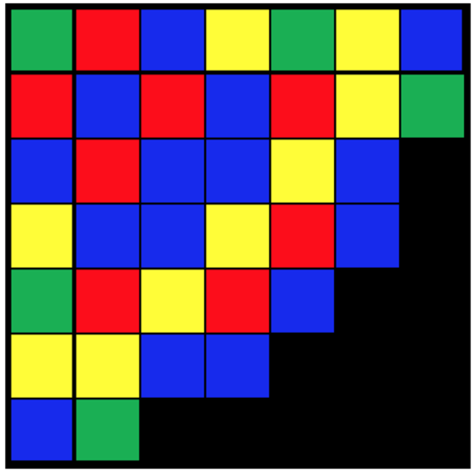
After (Final Iteration)



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🟨	🟦	🟦	🟨	🟥	🟦	⬛
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🟦	🟩	⬛	⬛	⬛	⬛	⬛

- Using higher enriched fuel with higher burnup limits we:
  - Successfully met extended cycle length (24 months)
  - Sufficiently met all required safety criteria
  - And is economically viable

Westinghouse

The Hot Rods

North Carolina State University

Presented by Patrick Hartwell

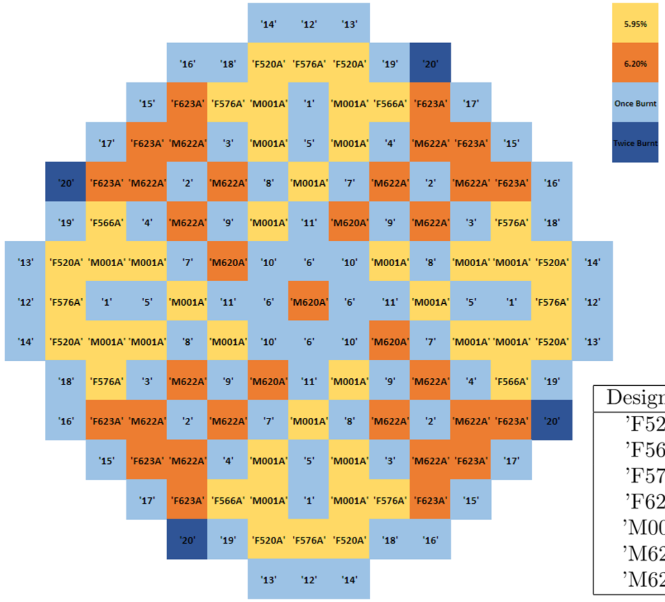
Authors: Nicholas Meehan, Jonathan Crozier, Patrick Hartwell, and Amelia Manhardt

NC STATE UNIVERSITY

Core Optimization Comparison between FORMOSA’s Native Solver and PRISM

Nick Meehan, Patrick Hartwell, Jonathan Crozier, Amelia Manhardt

Manually Optimized Core

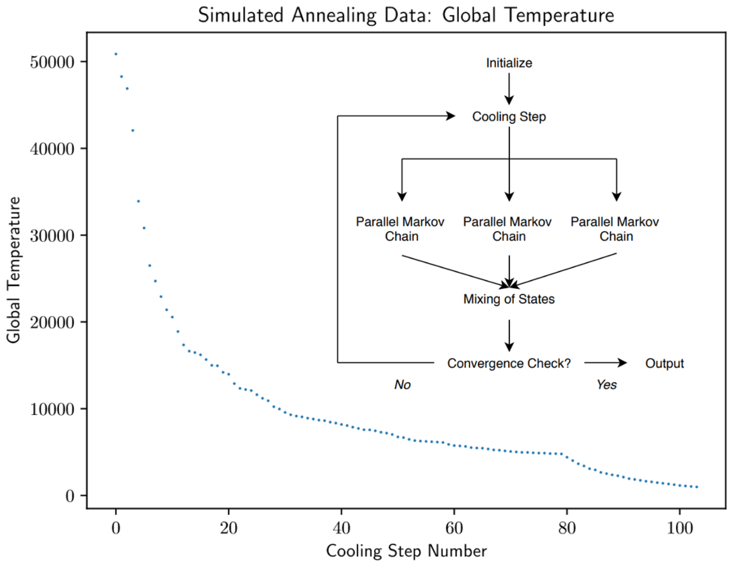


						'14'	'12'	'13'						
				'16'	'18'	'F520A'	'F576A'	'F520A'	'19'	'20'				
			'15'	'F623A'	'F576A'	'M001A'	'1'	'M001A'	'F566A'	'F623A'	'17'			
		'17'	'F623A'	'M622A'	'3'	'M001A'	'5'	'M001A'	'4'	'M622A'	'F623A'	'15'		
	'20'	'F623A'	'M622A'	'2'	'M622A'	'8'	'M001A'	'7'	'M622A'	'2'	'M622A'	'F623A'	'16'	
	'19'	'F566A'	'4'	'M622A'	'9'	'M001A'	'11'	'M620A'	'9'	'M622A'	'3'	'F576A'	'18'	
'13'	'F520A'	'M001A'	'M001A'	'7'	'M620A'	'10'	'6'	'10'	'M001A'	'8'	'M001A'	'M001A'	'F520A'	'14'
'12'	'F576A'	'1'	'5'	'M001A'	'11'	'6'	'M620A'	'6'	'11'	'M001A'	'5'	'1'	'F576A'	'12'
'14'	'F520A'	'M001A'	'M001A'	'8'	'M001A'	'10'	'6'	'10'	'M620A'	'7'	'M001A'	'M001A'	'F520A'	'13'
	'18'	'F576A'	'3'	'M622A'	'9'	'M620A'	'11'	'M001A'	'9'	'M622A'	'4'	'F566A'	'19'	
	'16'	'F623A'	'M622A'	'2'	'M622A'	'7'	'M001A'	'8'	'M622A'	'2'	'M622A'	'F623A'	'20'	
		'15'	'F623A'	'M622A'	'4'	'M001A'	'5'	'M001A'	'3'	'M622A'	'F623A'	'17'		
			'17'	'F623A'	'F566A'	'M001A'	'1'	'M001A'	'F576A'	'F623A'	'15'			
				'20'	'19'	'F520A'	'F576A'	'F520A'	'18'	'16'				
						'13'	'12'	'14'						

5.95%
6.20%
Once Burnt
Twice Burnt

Designation	Composition
’F520A’	x595.12x8+04x4
’F566A’	x595.16x8+16x4
’F576A’	x595.16x8+16x2
’F623A’	x620.12x8+04x4
’M001A’	x595.32x8+12x2
’M620A’	x620.32x8+12x2
’M622A’	x620.32x8+12x4

Optimization Approach: Simulated Annealing



Core Performance Criteria and Results

TABLE I. Constraint Parameters

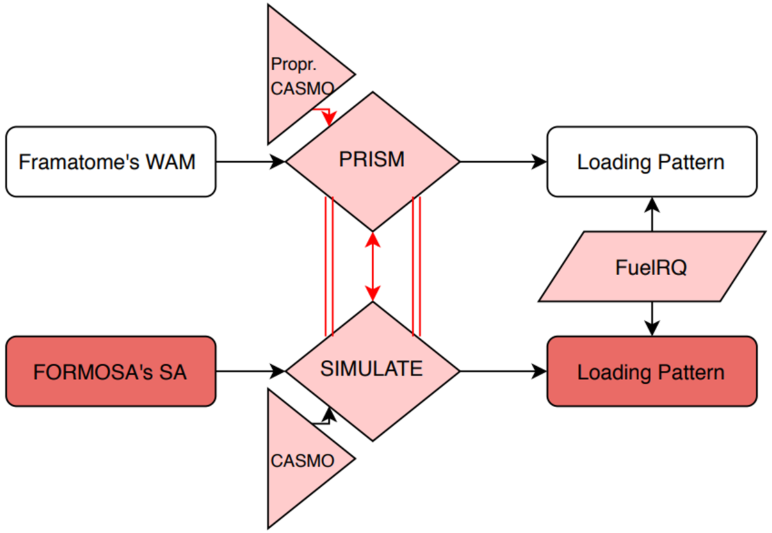
Parameter	Limit	Ideal	Actual
Radial Peaking (Fdh)	1.596	1.520	1.55
Power Peaking (Fq)	2.410	2.295	1.98
Enrichment	6.95†	<4.95	6.2
Fresh Assemblies	78*	< 72	77
Rod Exposure (GWd/MTU)	72	62	68.1
End Of Cycle (EOC) Boron	-24 ppm	n/a	1.1
Boron Concentration	1600 ppm	n/a	1476

† Accounting for a .05% manufacturer error
* can use up to 79 but only every other cycle

TABLE II. Cost Analysis

	2018 – 2019 Design		**2019 – 2020 Design**	
Cost Type	Amount	Cost	Amount	Cost
Fuel Fabrication	35,040 kgU	$10,510,000	34,980 kgU	$10,500,000
U_3O_8	1,183,735 lbs	$59,190,000	1,122,165 lbs	$56,110,000
Conversion	1,183,735 lbs	$5,330,000	1,122,165 lbs	$5,050,000
SWU	368,871 kg-SWU	$29,510,000	345,553 kg-SWU	$27,660,000
	Total:	$104,540,000	**Total:**	$99,320,000

Formosa & PRISM Coupling



Propr. CASMO
Framatome's WAM
PRISM
Loading Pattern
FuelRQ
FORMOSA's SA
SIMULATE
Loading Pattern
CASMO

Project OLS

United States Military Academy West Point

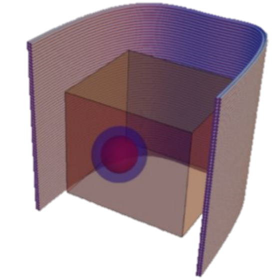
Presented by Sally Varner

Authors: Kamryn Brinson, Gregory Smith, Sally Varner, Chad Schools

Organic Liquid Scintillator for a Deployable Neutron Multiplicity Counter

Kamryn Brinson*, Gregory Smith*, Sally Varner*, Chad Schools†

**Cadet, United States Military Academy, Department of Physics and Nuclear Engineering, West Point, NY 10996*
† Director, Nuclear Science and Engineering Research Center, Defense Threat Reduction Agency, West Point, NY 10996



Concept drawing of a flexible multiplicity counter.

Purpose

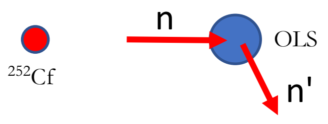
Characterize the use of an organic liquid scintillator (OLS) for a field deployable multiplicity counter that would allow first responders to rapidly determine if an unknown neutron source contained special nuclear material (SNM)

Objective

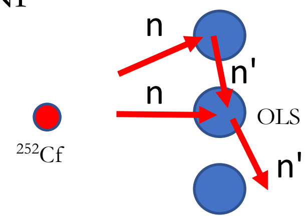
Determine if an elastically scattered neutron will be incorrectly detected twice altering the neutron count per time window required for multiplicity counting.

Accomplishments

- Design, build, and perform experiment using ^{252}Cf
- Model experimental set-up in MCNP

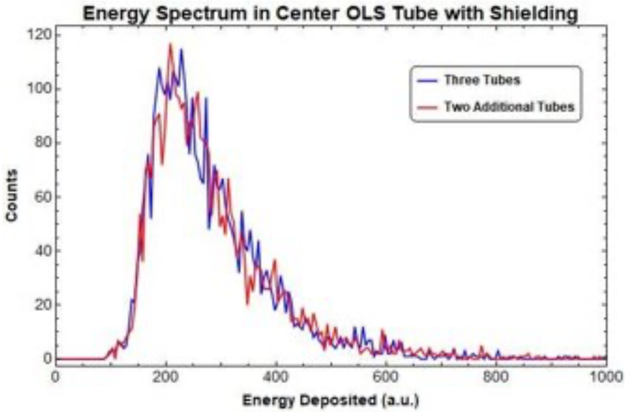


Single OLS Tube

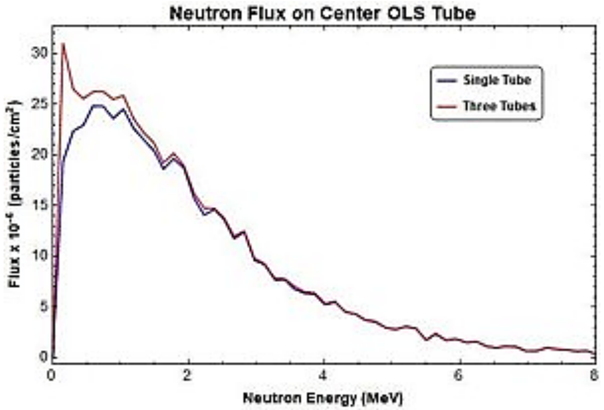


Three OLS Tubes

An increase of neutrons detected in the center OLS would suggest neutrons elastically scattered in the adjacent tubes are being detected in the center OLS. This could adversely affect an OLS system's multiplicity counting performance.



Energy spectra from center OLS tube suggests double counting scattered neutron is not an issue.



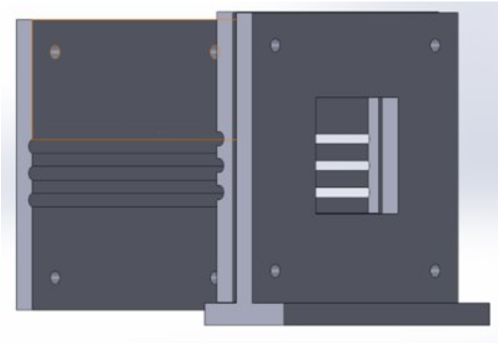
MCNP model shows higher flux on low energy neutron that may result in scattered neutrons being double counted.

Results

- Experimental data suggests scattering is not an issue
- Improved counting statistics needed
- Lowering trigger threshold may capture scattered neutrons
- MCNP suggests there are some additional low energy neutrons incident on the center tube
- Scattered low energy neutrons may not produce enough scintillation light to be detected

Future Work

- Continue to improve and stabilize optical coupling between the OLS tubes and PMT face
- Optimize design to an 8-tube holder
- Improve MCNP model to track energy deposited in OLS



SolidWorks Design for the tube holder

Department of Physics and Nuclear Engineering, West Point ***DTRA Nuclear Science & Engineering Research Center***

Group 7

North Carolina State University
Presented by Jennifer Jeffcoat
Authors: By: Benjamin Austin, W. Cade Brinkley, Jennifer Jeffcoat, Jacob Weinberg, Dr. Benjamin Beeler Sponsors: Savannah River Site , Dr. Tracey Stover & Ms. Tara Smith

An Analysis on Mark-18A Target Irradiation History and Inventory of Plutonium and Heavy Curium

By: Benjamin Austin, W. Cade Brinkley, Jennifer Jeffcoat, Jacob Weinberg, Dr. Benjamin Beeler Sponsors: Savannah River Site , Dr. Tracey Stover & Ms. Tara Smith

Problem Statement: The Savannah River Site houses the world's largest supply of heavy curium and Pu-244 in 65 targets from their Cf-252 production campaign. The amount of heavy curium and plutonium in the targets is unknown, so a computational analysis was performed to aid in isotope inventory and analysis of these targets.

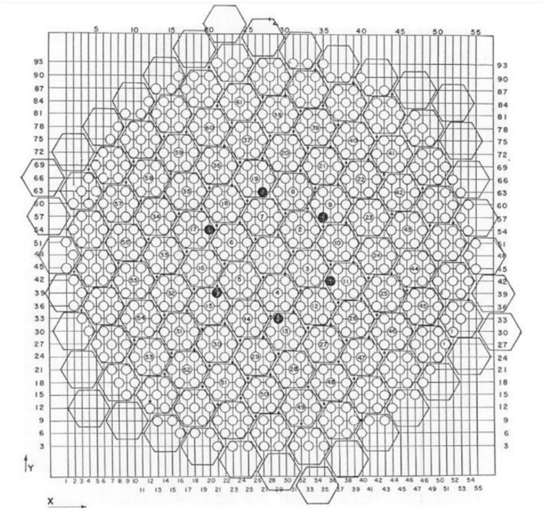


Figure 1

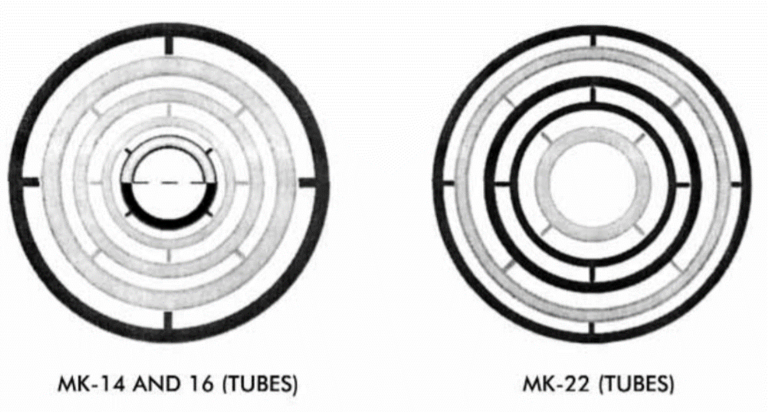


Figure 2

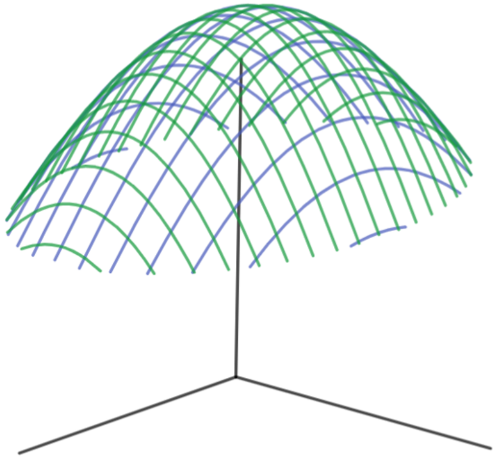
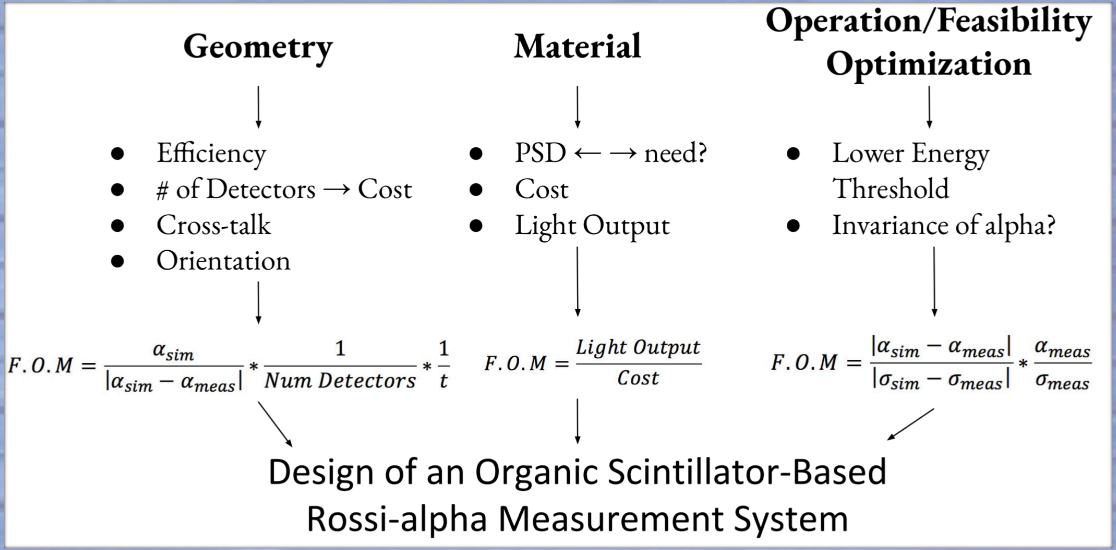


Figure 3

University of Michigan Senior Measurements Team

Presented by John-Tyler J. Iacovetta

Authors: Ricardo Lopez, John-Tyler J. Iacovetta, Aaron T. MacDonald, Thomas A. Plummer, Michael Y. Hua, Sara A. Pozzi



Geometry

- Efficiency
- # of Detectors → Cost
- Cross-talk
- Orientation

$$F.O.M = \frac{\alpha_{sim}}{|\alpha_{sim} - \alpha_{meas}|} * \frac{1}{Num\ Detectors} * \frac{1}{t}$$

Material

- PSD ← → need?
- Cost
- Light Output

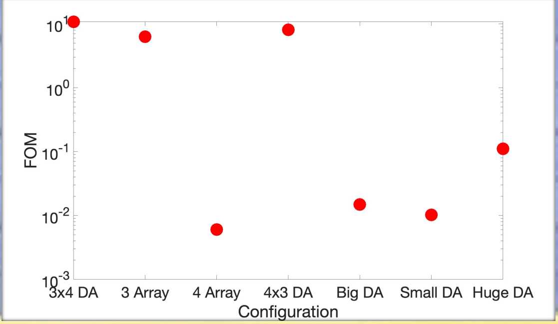
$$F.O.M = \frac{Light\ Output}{Cost}$$

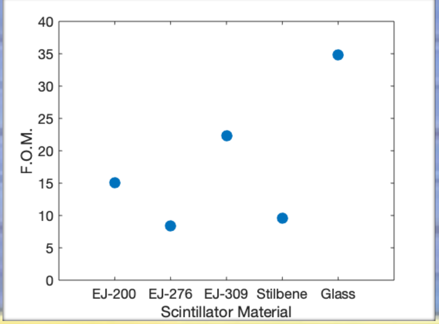
Operation/Feasibility Optimization

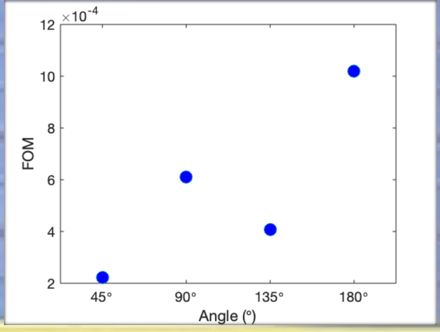
- Lower Energy Threshold
- Invariance of alpha?

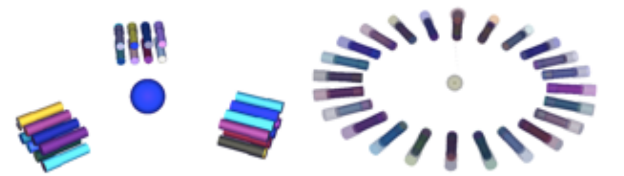
$$F.O.M = \frac{|\alpha_{sim} - \alpha_{meas}|}{|\sigma_{sim} - \sigma_{meas}|} * \frac{\alpha_{meas}}{\sigma_{meas}}$$

Design of an Organic Scintillator-Based Rossi-alpha Measurement System

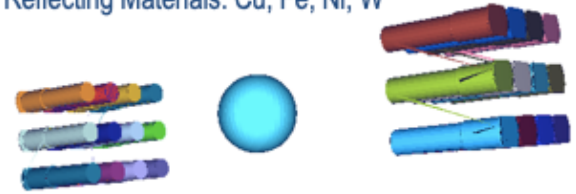


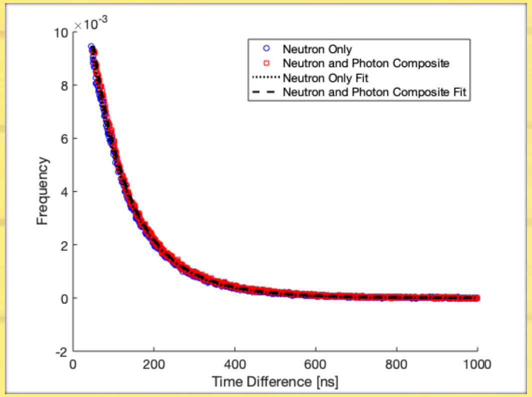






- Examples of Configurations Evaluated
- Source → WGPu
- Reflecting Materials: Cu, Fe, Ni, W





Conclusions

- Detector Orientation → 180º Detector Offset
- Detector Geometry → Dual Array 3x4
- Lower energy threshold selection invariant
- PSD → not needed for configurations evaluated

ONE Energy

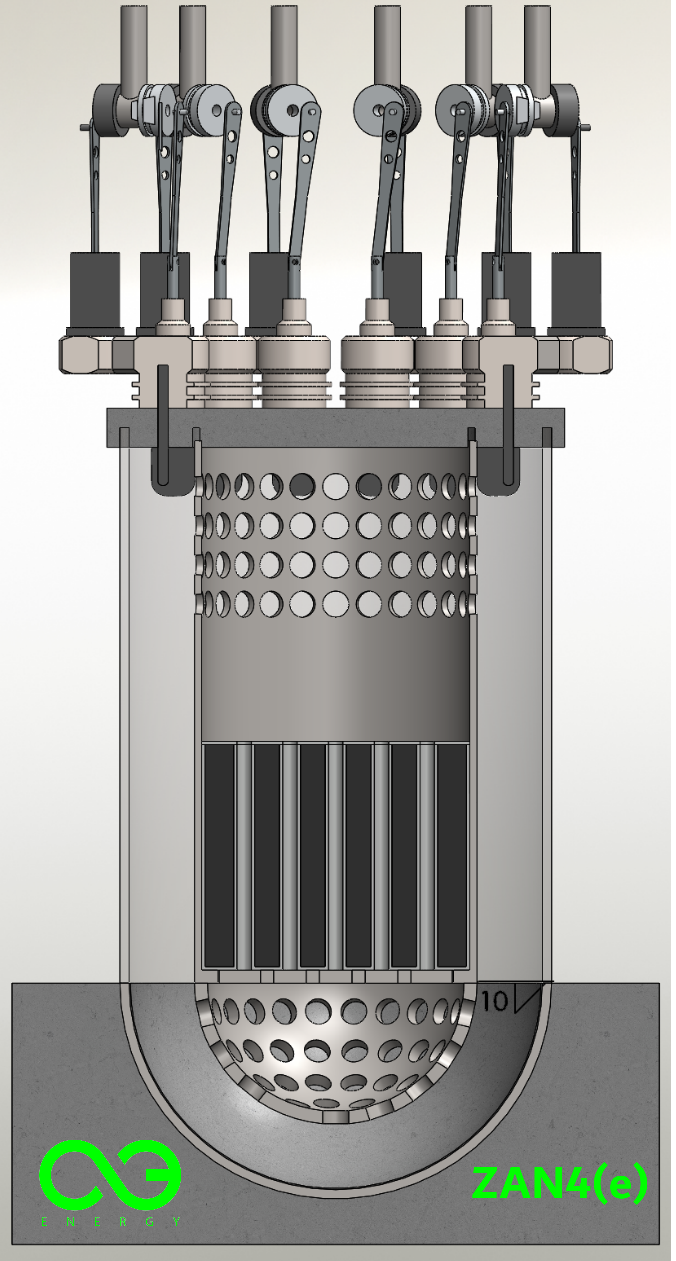
Ontario Tech University

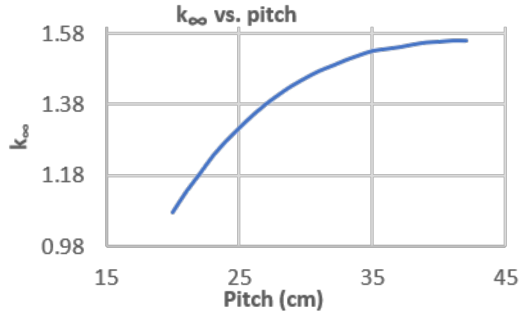
Presented by Jordan Crowell

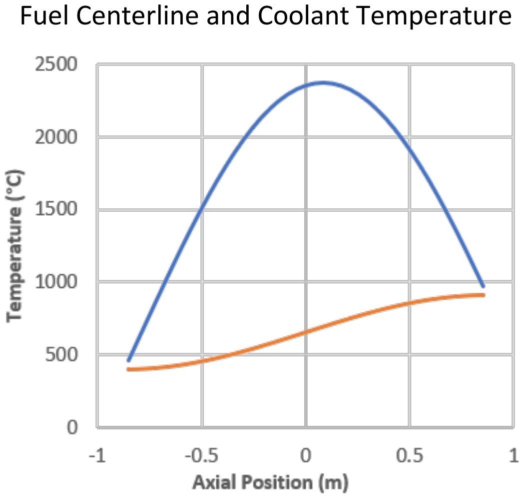
Supervisor: Eleodor Nichita, Faculty of Energy Systems and Nuclear Science

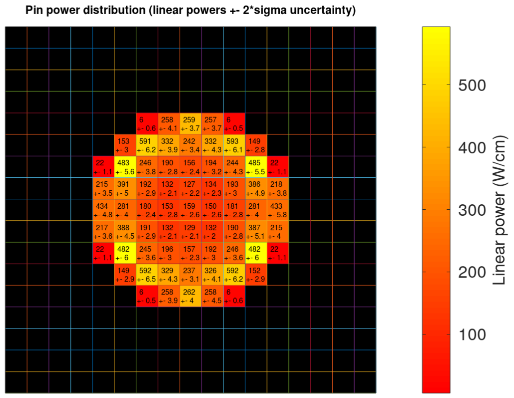
Micro-Reactor for the Canadian Arctic

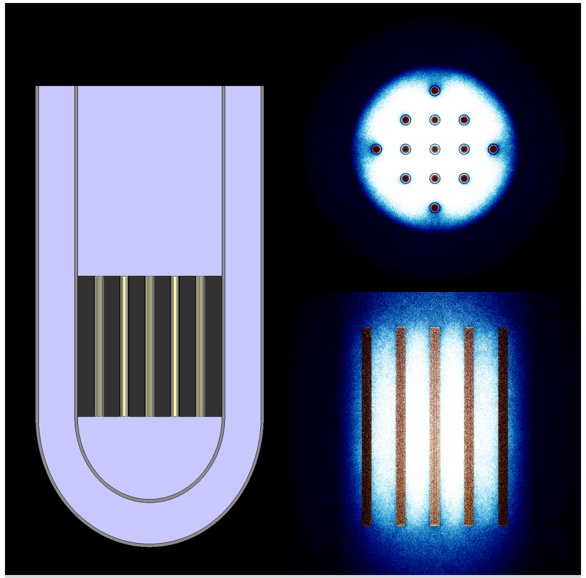
Jordan Crowell, Supervisor: Eleodor Nichita, Faculty of Energy Systems and Nuclear Science





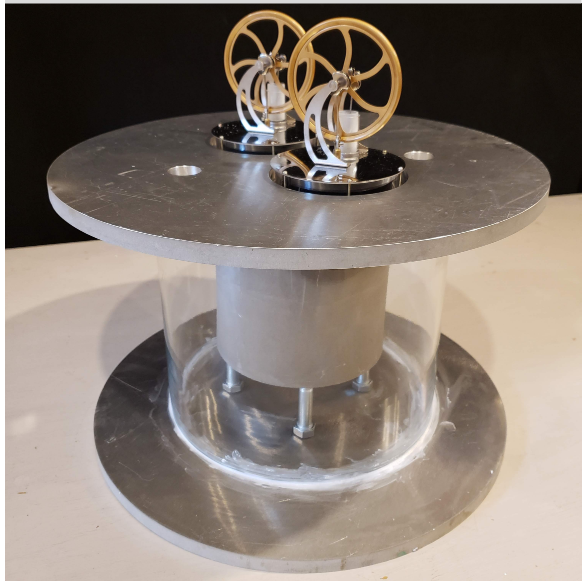






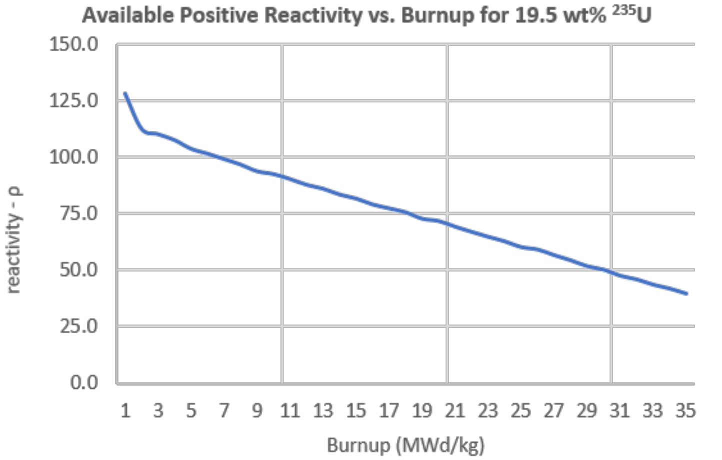
SERPENT 3D Model

Scaled Physical Model



Two-Group 3D Diffusion Approximation

$$k_{eff} = \frac{v_1 \Sigma_{f_1}}{\Sigma_{R_1} + D_1 B^2} + \frac{\Sigma_{s_{12}}}{\left(\Sigma_{R_1} + D_1 B^2\right)} \frac{v_2 \Sigma_{f_2}}{\left(\Sigma_{a_2} + D_2 B^2\right)}$$



Cost of ZAN4(e): $< \$128\ million$

Cost of Electricity: $\sim \$0.20/kWh$

Core Parameters

Reactor Core (Pb-208)		Stirling Engine (Helium)	
D_{core}/H_{core}	$2m/1.7m$	D_{piston}/H_{piston}	$35\ cm$
T_{inlet}	400℃	P_{max}	$10\ MPa$
T_{exit}	900℃	$n_{eng.}$	13
$Pitch$ (cm)	$35\ cm$	$\dot{w}_{cycle}$	$4\ MW_e$
MW_{th}	$10\ MW_{th}$	T_H	900℃
$\dot{m}_{avg}$	$25.25\ kg/s$	T_C	75℃
Power Density	$11.4\ W/kgU$	η_{eff}	41%
q'_{max}	$450\ W/cm$	V_{tot}	$0.76\ m^3$

Team RADBOT

United State Military Academy West Point

Presented by Brendan Huhlein

Authors: Brendan Huhlein, Kaelynn Mayes, Keith McManus, William Vanderlip

RADBOT ANS Overview

- RADBOT is a robotic system designed to localize radiation sources and map an indoor environment in order to protect soldiers or clean up crews in a hazardous facility.
- An array of 5 detectors provides radiation directionality data that integrates with a LiDAR map as the robot drives through the environment.
- The array design is novel due to the interior depressed detector.
- Testing results in Figure 3 show promising signal response from the array as a source passes by

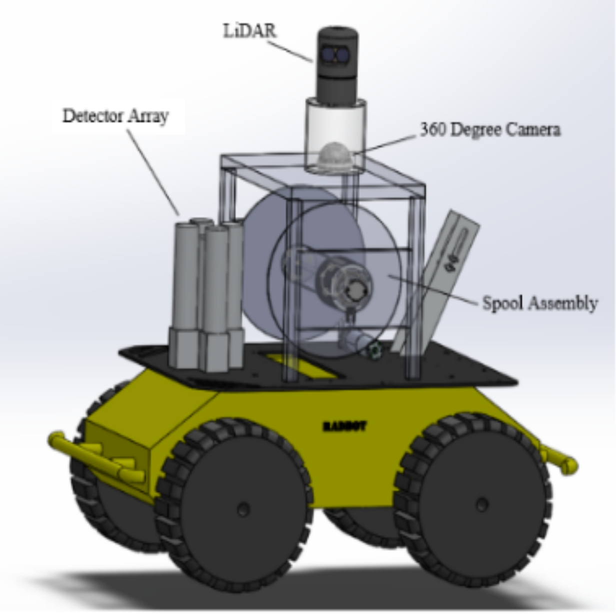


Figure 1. CAD model of the completed RADBOT

Figure 2. Arrangement of detectors in the directionality array

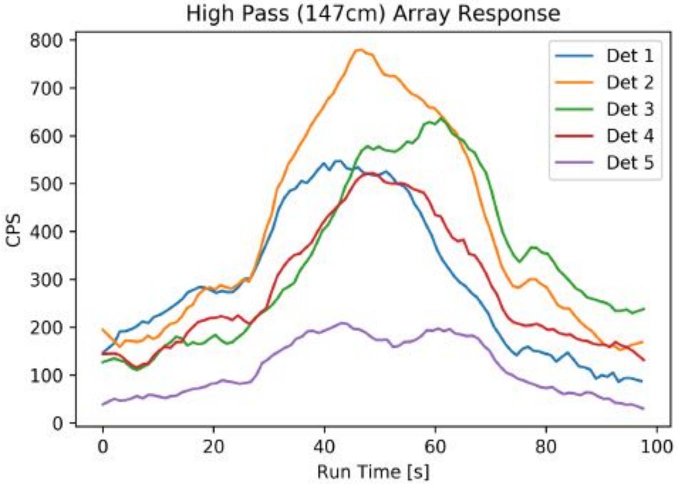


Figure 3. Detector signal response as a source moves past the array from front to rear at a constant 1m to the right

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