

TREAT Motivatio T-ReX Model Updates Conclusio

# Refinements of a TREAT Model for Transient Analysis

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- Motivatio T-ReX Model Updates
- Conclusion
- Future

#### 1 Describe the Transient Reactor Test Facility

- Describe the need for time-dependent modeling.
- Overview of T-ReX.
- 4 KENOVI model of TREAT
- Opdates to model
- 6 Future work



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# Transient Reactor Test Facility (TREAT) Overview

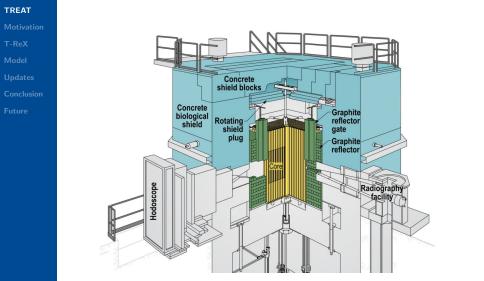
#### TREAT

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- Transient Reactor Test Facility (TREAT).
- Designed to evaluate fuel performance.
- Rapid energy deposition.
- No resultant core damage.
- Short, high energy neutron pulses.
- Highly enriched uranium (93.1%)
- $UO_2$  fuel particles in graphite matrix
- Dispersed in graphite matrix 1:10000  $^{235}U/C$



# Transient Reactor Test Facility (TREAT) Overview





# Full Core Representation of TREAT



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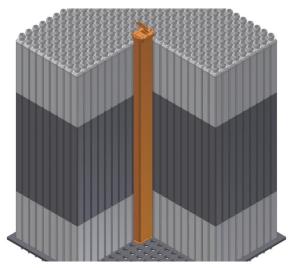
T-ReX

Model

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#### Motivation

#### Motivation T-ReX Model

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- Overall goal of modeling and simulation efforts is to minimize experimental calibration time.
- If calibrations are minimized then experiments will be conducted more quickly.
- Allow for better optimization of test vehicles before irradiation in TREAT.
- Help verify new multi-physics codes.



### How to Model TREAT

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- Why typical analysis methods fail?
  - Deterministic codes face the challenge of creating meshes.
  - Diffusion based approaches have difficulty modeling streaming and high leakage.
- Motivates the use of Monte Carlo methods with time-dependent capabilities.
  - Models are very close to actual configuration.
  - Models are easier to generate.
  - Streaming and leakage are properly accounted for.



#### Feedback

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- Feedback is an essential component to transient simulations.
- Core is 100 ppm HEU  $\rightarrow$  little resonance absorption in 238U.
- As core heats, a shift in the thermal spectrum takes the core back to a new critical state
  - $\bullet \rightarrow$  Eventually rods are driven in to completely shut down the reactor.
- Temperature distribution throughout the core determines the feedback.



## T-ReX Approach

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- Solve the time-dependent transport equation with the explicit representation of delayed neutrons.
- Incorporate models that match the geometry exactly.
- Obtain the flux with a method that is able to resolve streaming issues.
- $\bullet \rightarrow$  We use a time-dependent Monte Carlo solver.
  - Now called the Transient-Reactor eXperiment simulator (T-ReX)



# Improved Quasi-Static (IQS) Method

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- Neutron flux ( $\phi$ ) is factored into two components:
  - Amplitude function  ${\cal A}(t)$ 
    - Highly dependent on time
    - Accounts for rapid reactivity/power changes
  - Shape function  $\Phi(r,E,\Omega,t)$ 
    - Accounts for spatial variation of neutrons over time.

#### Flux Factorization

 $\phi(r,E,\Omega,t)=A(t)\Phi(r,E,\Omega,t)\to \text{Transport Equation}$  Result: coupled functions solved on different time scales



# Typical IQS Time Scale

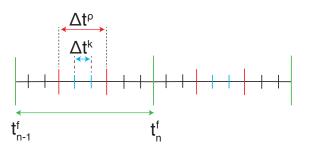
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- Flux shape found at  $t_n^f$  times (largest)
- Reactivity parameters found on  $\Delta t^{\rho}$  intervals
- Amplitude found on  $\Delta t^k$  intervals (smallest)
- Below is the proto-typical time scale in IQS.



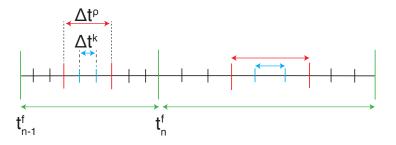


### Time Scale in T-ReX



Conclusion

• Better representation of the time scale in T-ReX.



• The flux shape update interval may vary and in turn change the intervals at which the point kinetics equations and reactivity parameters are evaluated.



# M8 Calibration (M8CAL) Experiments

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- M8CAL experiments performed prior to placing TREAT on standby.
- Series of calibrations designed to understand core before evaluating fuel.
- Has the most complete data set.
- Includes experiments done post facility upgrade in late 1980s.
- *Note,* these experiments were only to optimize the core, not to evaluate fuel.



#### Recent Improvements

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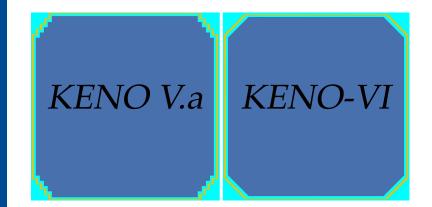
- T-ReX now supports calculations of the flux shape in parallel with KENO-VI from SCALE 6.2.1.
  - Previously, only the simplistic KENO V.a was available.
- M8CAL 2855, 2856 and 2857 temperature-limited transients were modeled
- KENO-Va model had insufficiently large regions



#### Recent Improvements

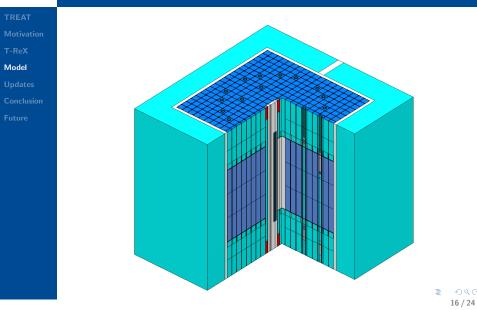


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# KENO-VI TREAT Model





#### Representation of M8CAL

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9000	9000	20	30	40	150	160	170	180	8090	180	170	160	150	40	30	20	9000	9000
9000	11	21	31	41	151	161	171	181	8090	181	171	161	151	41	31	21	11	9000
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03	13	23	33	43	4153	163	173	183	8090	183	173	163	4153	43	33	23	13	03
04	14	24	34	44	154	164	174	184	8090	184	174	164	154	44	34	24	14	04
05	15	25	5135 •	45	155	165	175	185	8090	185	175	165	155	45	5135 •	25	15	05
06	16	26	36	46	156	166	176	186	8090	186	176	166	156	46	36	26	16	06
07	17	5127	37	47	3157	167	177	187	8090	187	177	167	3157 •	47	37	5127 •	17	07
08	18	28	38	48	158	168	178	188	2098	188	178	168	158	48	38	28	18	08
09	19	29	39	49	59	69	79	89	6099	89	79	69	59	49	39	29	19	09
08	18	28	38	48	58	68	78	88	7098	88	78	68	58	48	38	28	18	08
07	17	5027 •	37	47	3057	67	77	87	97	87	77	67	3057 •	47	37	5027	17	07
06	16	26	36	46	56	66	76	86	96	86	76	66	56	46	36	26	16	06
05	15	25	5035 •	45	55	65	75	85	95	85	75	65	55	45	5035 •	25	15	05
04	14	24	34	44	54	64	74	84	94	84	74	64	54	44	34	24	14	04
03	13	23	33	43	4053	63	73	83	93	83	73	63	4053	43	33	23	13	03
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9000	9000	20	30	40	50	60	70	80	90	80	70	60	50	40	30	20	9000	9000



# Geometric Modeling Challenges

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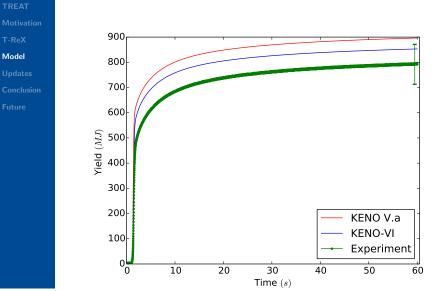
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- T-ReX requires pre-transient and forward geometric inputs to be identical
  - Geometry-based transients require "tricking" the program with overlapping regions
- KENO-VI does not naturally use octagons
- KENO-VI does not allow 2nd-order grouping of regions ("or")



# Comparison to Experiment (2855)





#### Recent Updates

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- Several aspects of geometry were updated to reflect best current understanding of reactor.
- Several material definitions were updated- graphitization caused k-eff to increase, and zircaloy caused k-eff to decrease.
- Rod insertions were modified.



#### Rod Insertions

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- Rod insertion values had been taken from earlier models, which had been altered to get correct k-eff.
- When corrected to best estimated insertion, pretransient was slightly supercritical and reactivity insertion was 5.5-7.0% too high.
- Rods were modified to agree with experimental values of k-eff and reactivity insertion by adjusting rods by 1-5 cm.



#### Conclusion

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- Modeling TREAT and simulating TREAT experiments is challenging.
- Our full-core simulations with T-ReX are generally in good agreement with the experiments.



#### Future Work

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- Use updated TREAT model for energy studies
- Look at 'shaped transients' from M8CAL.
- Use heat transfer in reactivity feedback



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# Questions?





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