Los Alamos
NATIONAL LABORATORY

Experimental Validation of NDA Capabilities for MSR Safeguards

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Advanced Reactor Safeguards Program
Stakeholder Meeting

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This work will enable maximum use of rapid, cost-effective nondestructive assay (NDA) to meet safeguards requirements for MSRs

Objective:

- Conduct the first modern experimental nondestructive assay campaign focused on MSR safeguards to produce a comprehensive set of validated measurement capabilities for safeguards models.
- Directly measure NDA uncertainty
- Potential to include other non-traditional fuels like TRISO

Goals

1. Measure gamma-ray and neutron signatures from nuclear material samples that have characteristics similar to material at an operating MSR

2. Assess limits of rapid anomaly detection and characterization of material compositions with traditional and advanced NDA technologies

3. Evaluate NDA concepts for harsh, high-radiation environments

Collaboration

Unique access to nuclear materials, traditional and advanced NDA measurement expertise, and quantitative analysis capabilities

Los Alamos National Laboratory EST. 1943 — Mark Croce, Matthew Carpenter, Daniela Henzlova, Katrina Koehler, Howard Menlove, David Mercer, Athena Sagadevan, Katherine Schreiber, Sophie Weidenbenner, Duc Vo

Oak Ridge National Laboratory — Michael Dion, Susan Smith, Louise Worrall

INL Idaho National Laboratory — Jeffrey Sanders

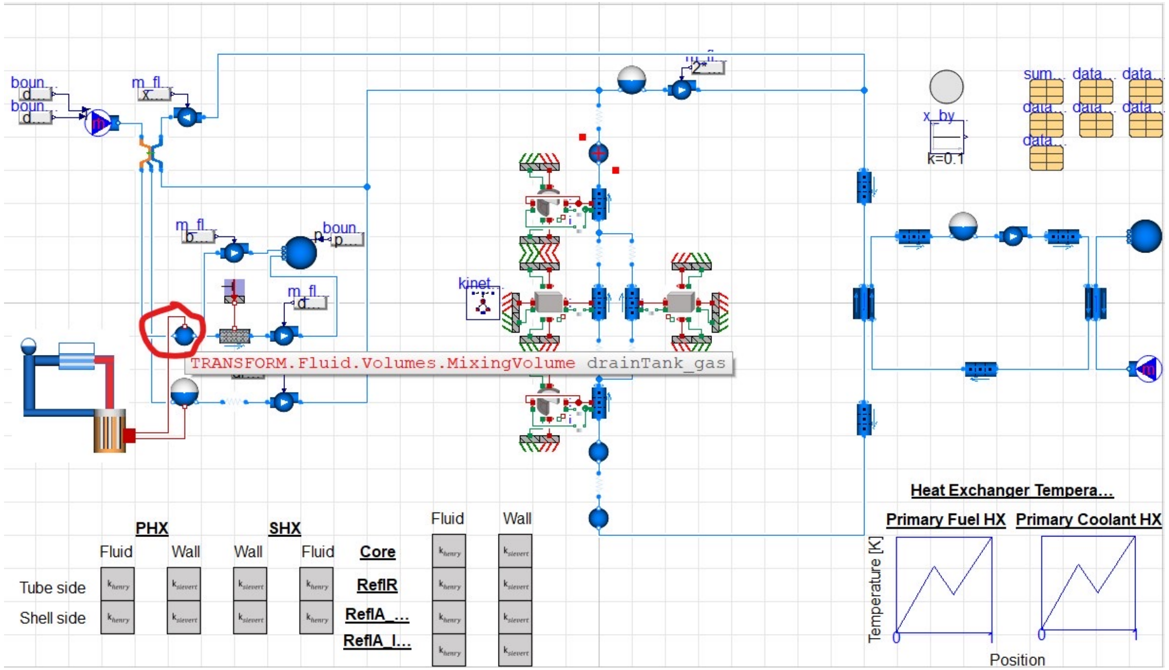
University of Colorado — Daniel Becker, Joel Ullom

Analysis Approach

- Goal is verification of, or detection of changes in fissile material content
- Establish a common analysis framework to enable comparisons between and selection of NDA technologies at key locations
- Consider two measurement scenarios:
  1. Laboratory analysis of samples
  2. Direct measurements of salt sampling loop

- What are the observable signatures of fissile material content available with each measurement technology, and how precisely can they be quantified?
- Main performance metric is sensitivity of detecting changes in material composition for a given measurement time
- Results are expressed as measurement uncertainty for relevant signatures and intended as inputs to safeguards models

Modeling informs experimental design, and experimental results inform safeguards models

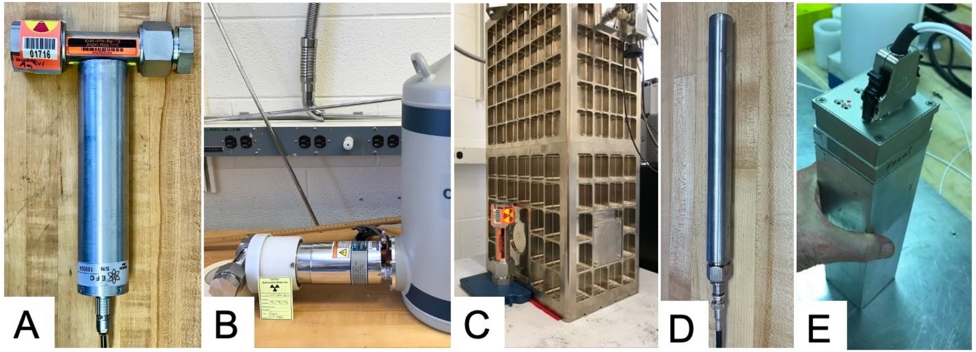


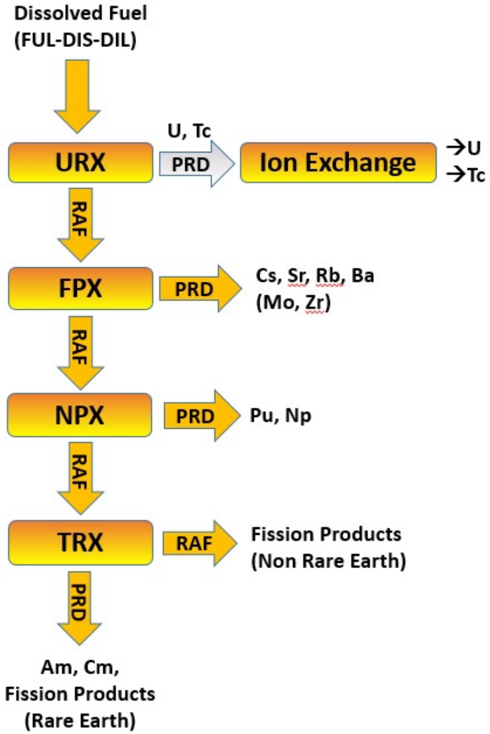
TRANSFORM model of MSDR being used for dynamic simulations of fission products at ORNL

FY20 Los Alamos Measurement Campaign

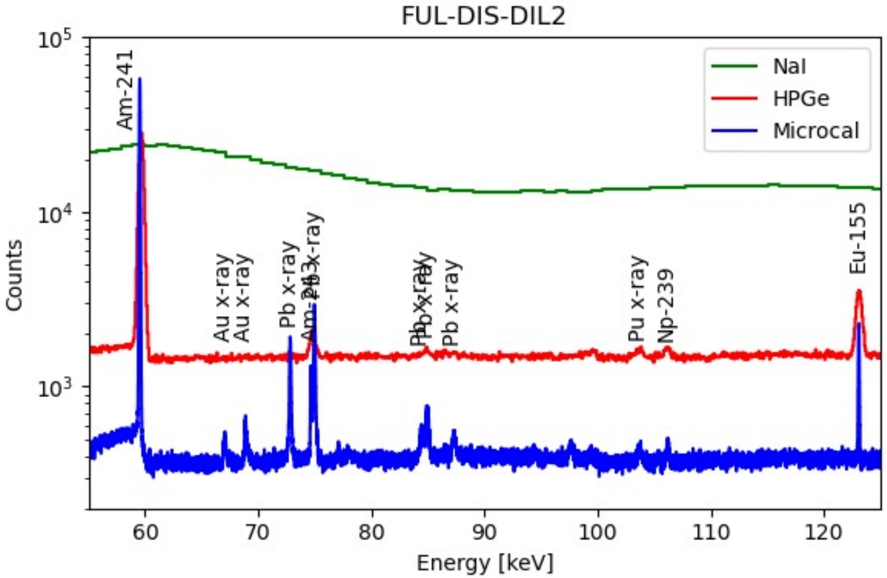
- NaI, HPGe, and Microcalorimeter measurements completed on samples from a spent fuel separation process provided by Argonne National Laboratory

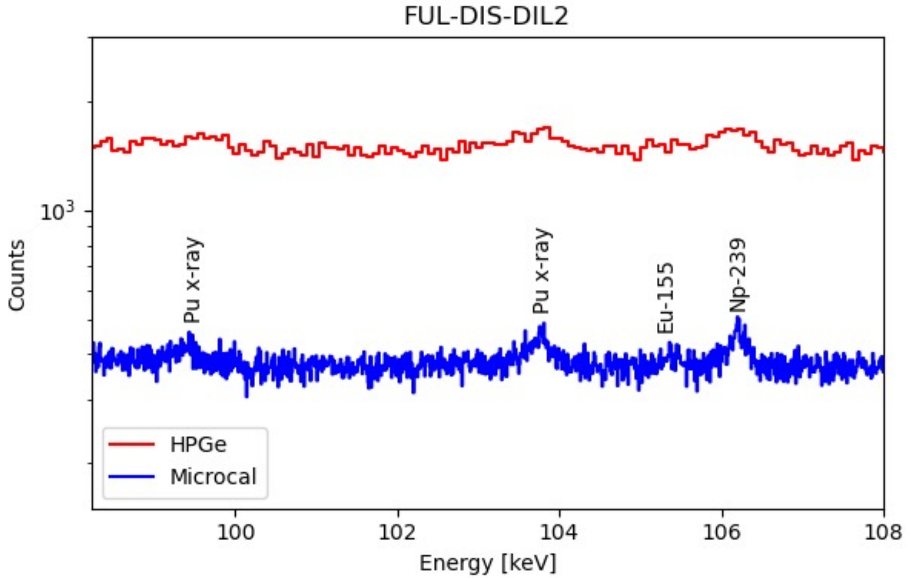
- Ideal starting point to evaluate gamma spectroscopy in the presence of varying fission product and actinide concentrations





Comparison of Spectra

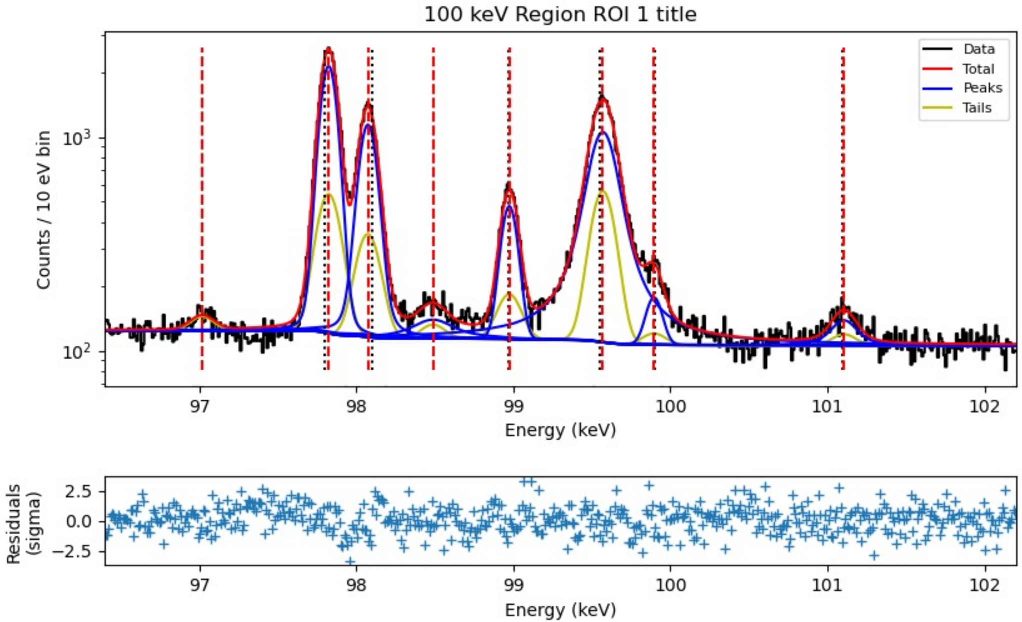




LWR fuel is a starting point to develop the analytical framework

Quantitative analysis with SAPPY code

Rigorous uncertainty analysis for HPGe and microcalorimeter data



χ^2_{red} = 1.29 | Main FWHM = 116.9 eV | Tail FWHM = 170.7 eV

Line Centroid (keV) Ref. / fit	Source		Area (uncert)	Lorentzian FWHM (eV)
97.020 / -0.026	x-ray	*	1681.9 (34.897 %)	112536.9 (42020.7 %)
97.800 / 97.825	x-ray	*	34471.7 (0.888 %)	7.6 (29.5 %)
98.100 / -0.050	x-ray	*	19326.2 (1.196 %)	21.3 (14.2 %)
98.490 / -0.025	x-ray	*	1512.4 (22.950 %)	261.9 (44.2 %)
98.970 / -0.020	Am241	*	5778.3 (1.784 %)	
99.550 / -0.004	x-ray	*	36805.0 (1.663 %)	149.3 (12.1 %)
99.900 / -0.028	Pu238	*	1135.0 (7.915 %)	
101.100 / -0.018	x-ray	*	1095.4 (22.876 %)	117.6 (37.3 %)

Dotted Lines above indicate tabulated peak locations

Dashed lines above indicate best-fit locations

* and red indicate peak used in efficiency curve fit

Results expressed as %RSD for input to safeguards models

- Similar to "International Target Values": what is feasible in a real-world measurement?

- Encouraging initial results suggest that **direct quantification of actinides** (like ^{241,243}Am, which correlates with Pu) **may be possible by NDA** for salt samples or in a salt sampling loop

Sample	Description	Pu	Np	Am	Eu	Cm
07-FUL-DIS-DIL2	Input Fuel	--	[a]	0.029	0.12	1.2*
07-URX-RAF-T2	U/Tc removed	--	[a]	0.047	0.55	0.96*
07-FPX-RAF-T2	U/Tc/Cs/Sr removed	2.3	[a]	0.0098	0.067	0.1*
07-FPX-PRD-T2	Cs/Sr fraction	--	--	11.5	--	--
07-NPX-RAF-T3	U/Tc/Cs/Sr/Np/Pu removed	--	--	0.0094	0.072	0.22*

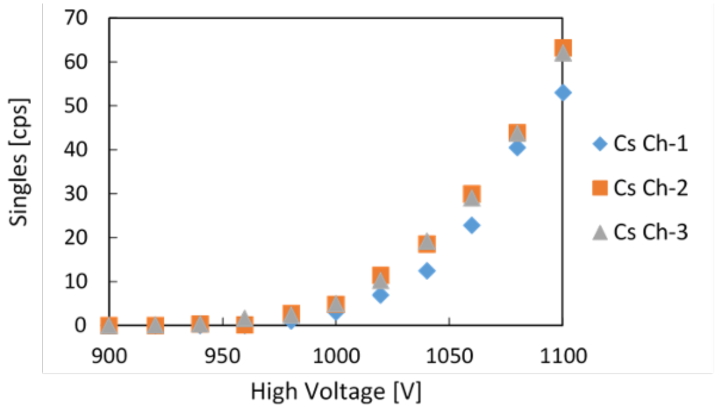
Microcal

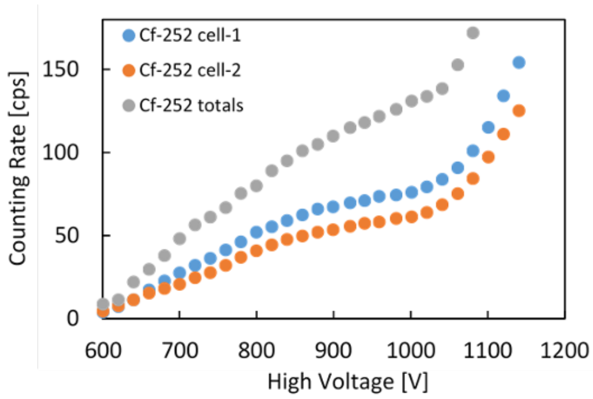
Pu	Np	Am	Eu	Cm
--	--	0.024	0.13	1.0*
--	--	0.027	0.15	1.4*
8.5	2.9	0.0047	0.015	0.054*
--	--	--	--	--
--	--	0.0049	0.015	0.058*

HPGe

Neutron Measurement Campaign

- Comparison of ^{3}He-based detectors, fission chambers, and miniHDND
- FY21 measurements will test performance with increasingly realistic materials and measurement environments
- Procurement of miniHDND modules in progress for hot cell evaluation

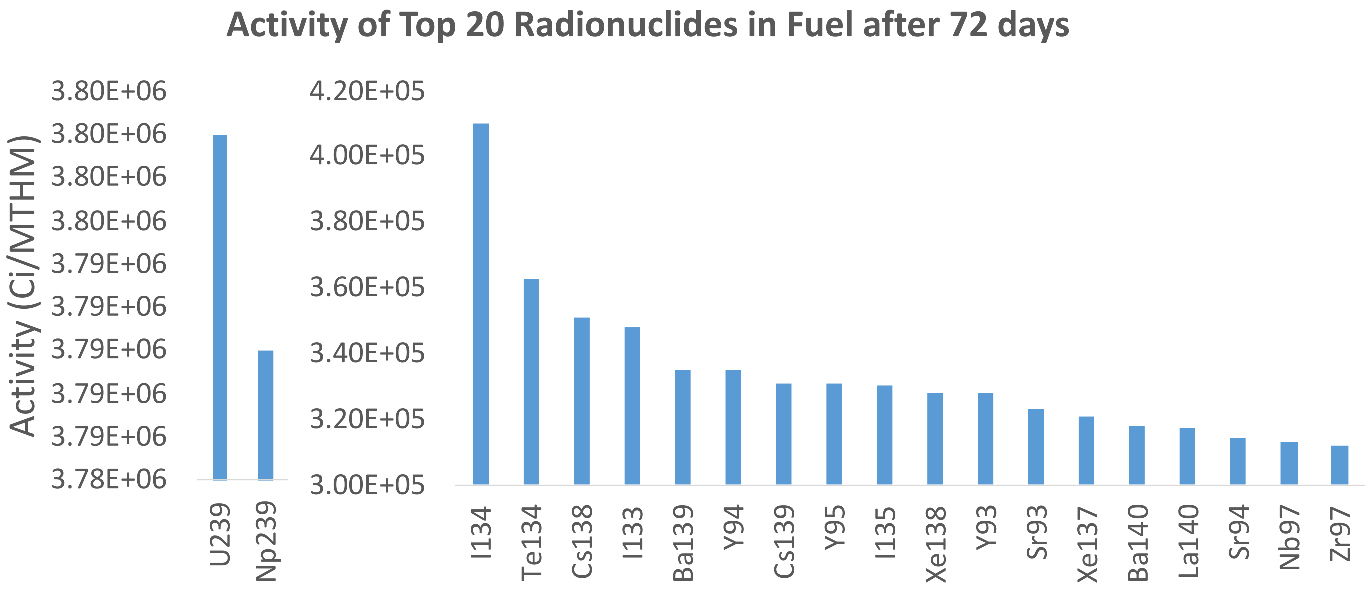




Measured miniHDND high voltage plateaus in response to ^{137}Cs and ^{252}Cf

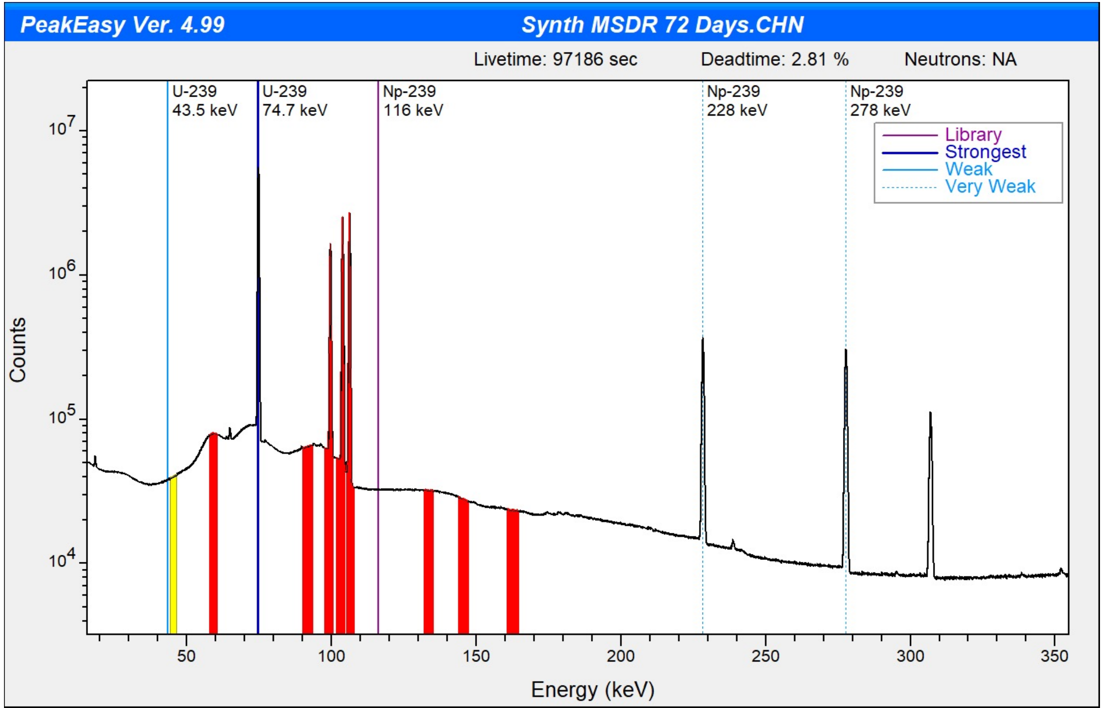
Towards increasingly realistic materials

Short-lived fission products present a unique challenge for on-line fuel characterization



Towards increasingly realistic materials

GADRAS simulations for specific detector configurations using SANDIA MSDR isotopic model results help to define experimental configurations (e.g. peak to background, spectral interferences…)



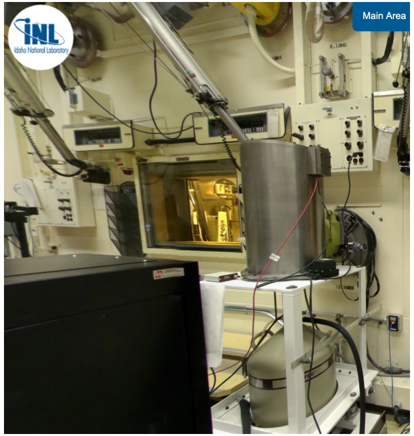
FY21 Oak Ridge Measurement Campaign

- More representative of MSR environments (high radiation dose, intense fission product activity)
- Measurements planned at Irradiated Fuels Examination Laboratory
  - NaI, HPGe, Microcalorimetry, ^{3}He, miniHDND
- Some fuel rods are being processed; enables comparison between intact fuel rods and cut elements where gaseous fission products have been released

Irradiated Fuels Examination Laboratory (From ORNL/SPR-2017/535)

FY21 Idaho Measurement Campaign

- Samples available from spent fuel separations using molten salt technology
- Measurements planned at Materials and Fuels Complex Analytical Laboratory (AL)
  - Microcalorimeter spectrometer to be deployed to AL in FY21 through separate funding
- Potential for measurements at Hot Fuel Examination Facility (HFEF)



Hot Fuel Examination Facility

Summary

- Experimental validation of nondestructive assay capabilities will enable maximum use of rapid, cost-effective NDA to meet MSR safeguards requirements
- Results suggest that direct quantification of indicator actinides may be possible by NDA for a sampling loop in an operating MSR, or for salt samples with no (or minimal) cooling time
- FY20 systematic evaluation of traditional and advanced gamma spectroscopy on spent fuel separation process samples
- FY21 measurement campaigns at ORNL and INL access increasingly realistic measurement environments and materials
- As reactor designs become established and test facilities become available, the team's experimental capability can be applied to more specific scenarios

Thank you to the Advanced Reactor Safeguards Program and our collaborators

What are your specific measurement priorities or opportunities?
Please contact us!
mpcroce@lanl.gov

Experimental Validation of NDA for MSR Safeguards FY20 Report **available on workshop web site**

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