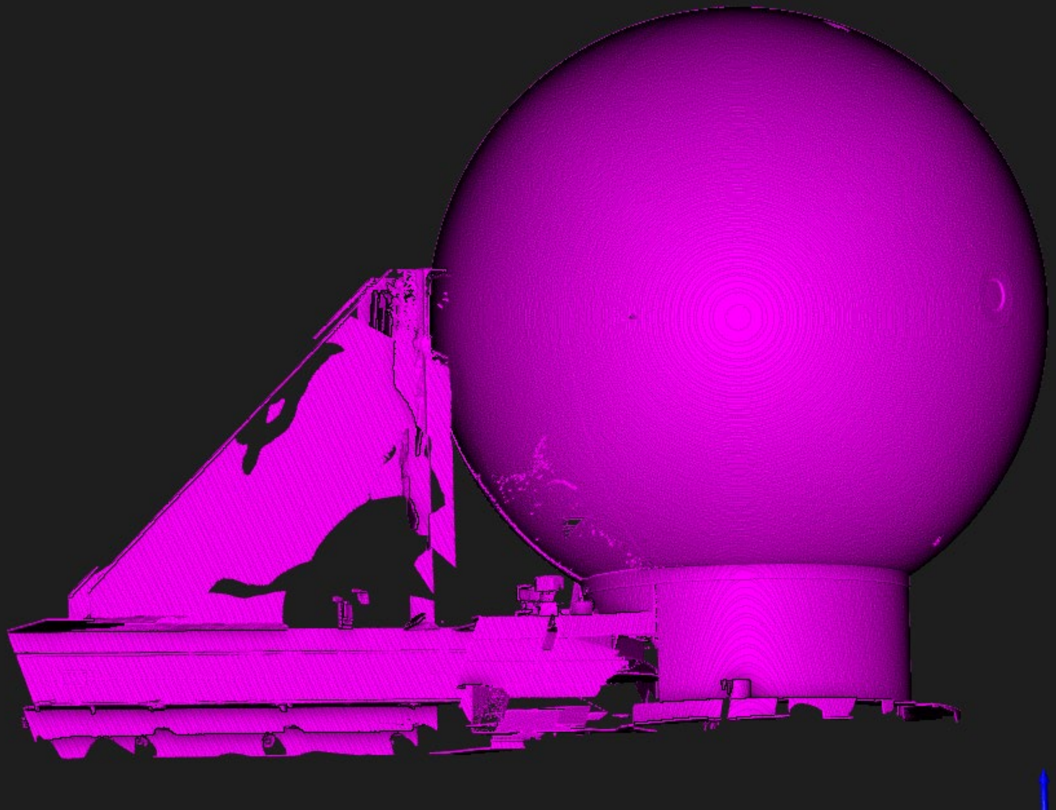

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IER 423 and Beyond: Use in Validation

Kristin Stolte, Peter Brain, Theresa Cutler

NEN-2

2025 NCSP Technical Program Review

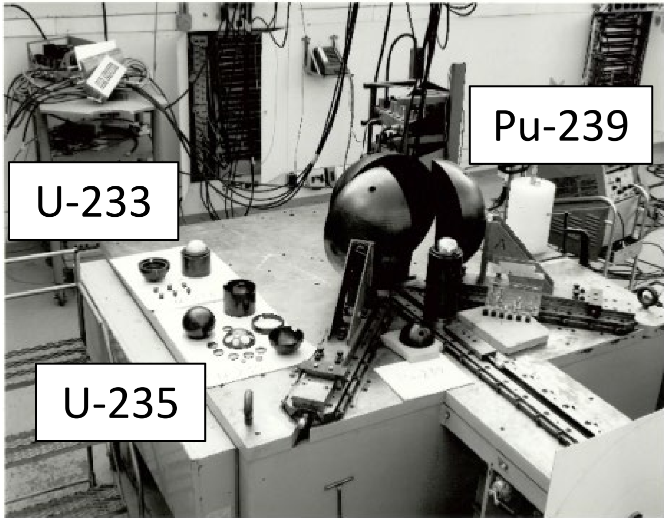
LA-UR-24-32610

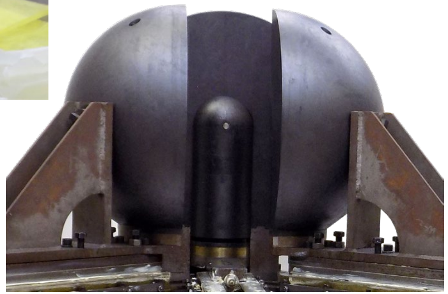
Overview

- Flattop Description
- Original Benchmark Model
- Final Revised Benchmark Models
- Computational Responses
- Modern Validation Suite
- Future Work

Flattop Description

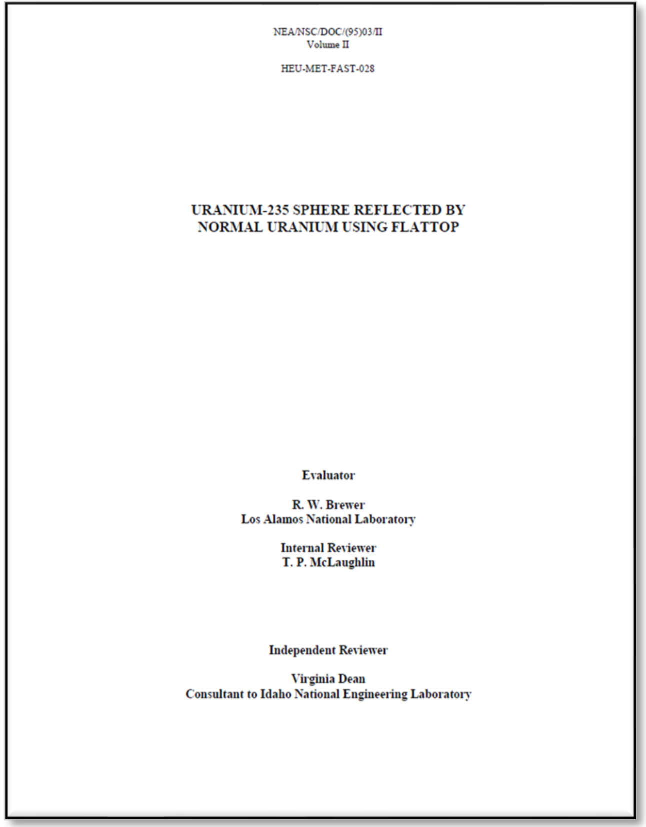
- Manufactured mid-1950s:
  - Develop and validate nuclear data
  - One-dimensional, two-region models
- SNM Cores Present
  - HEU and δ-phase Pu
- SNM Cores Past
  - U-233 and Composites
- NU Reflector and Control Rods
- Today:
  - Fission Product and Activation Product Yield measurements; Replacement Measurements; DUFF; Nuclear Accident Dosimetry Testing; Nuclear Criticality Safety Training and Demonstrations





Previous Work

- Flattop-HEU benchmark written in 1999
  - HEU-MET-FAST-028
- Based on experiments from 1960's
- Written to *provide two diameters* for reflected critical mass
- Uncertainty:
  - Original Benchmark (1999)
    - 1.0000 ± 0.0030 (300 pcm)



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Volume II

HEU-MET-FAST-028

URANIUM-235 SPHERE REFLECTED BY NORMAL URANIUM USING FLATTOP

Evaluator

R. W. Brewer
Los Alamos National Laboratory

Internal Reviewer
T. P. McLaughlin

Independent Reviewer

Virginia Dean
Consultant to Idaho National Engineering Laboratory

Original Benchmark Model

- Exact experiment unknown
- Physical dimensions of Flattop not used
  - "Corrected" based on other experiments such as Jezebel
  - "Correction" methodology discussed in:
    - Hansen, G.E and Paxton, H.C, "*Reevaluated Critical Specifications of Som Los Alamos Fast-Neutron Systems*," LA-4208 (1969).

Spheres of U(93), Plutonium, and ^{233}U in Thick Uranium. Critical masses reported for the Flattop assemblies[5] have been modified slightly to include the effect of a 0.004-in. to 0.005-in. gap between cores and reflector. The three cores were reflected by 19.00-in.-diam normal uranium at a density of 19.0 g/cm^3. Critical masses are:

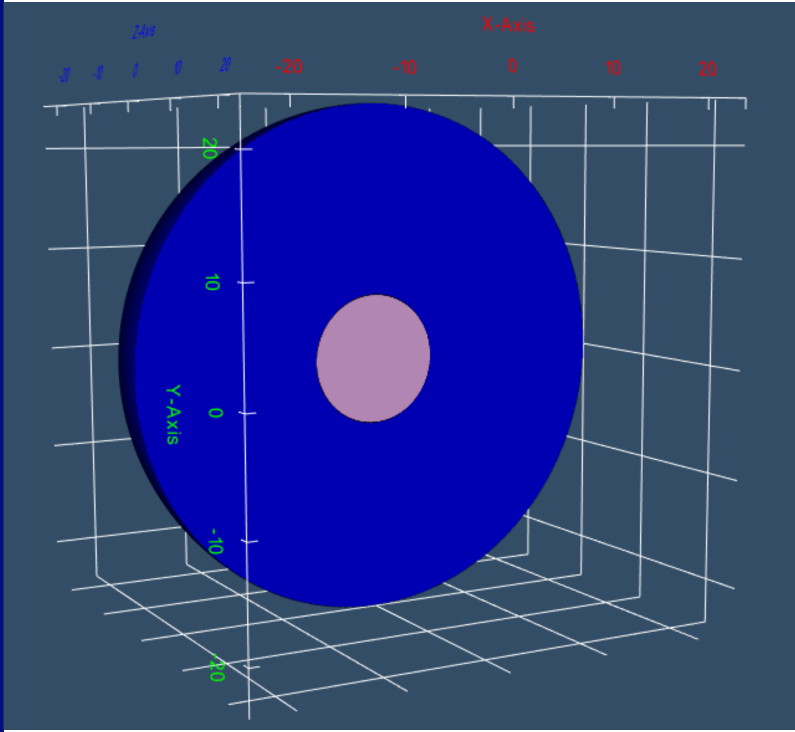
17.84 ± 0.04 kg U(93.24) at the uranium density 18.62 g/cm^3 (reflector thickness 7.09 in.);

6.06 ± 0.03 kg Pu alloy, 4.80 wt% ^{240}Pu, 0.30 wt% ^{241}Pu, 1.10 wt% Ga, at the alloy density 15.53 g/cm^3 (reflector thickness 7.72 in.);

5.74 ± 0.03 kg ^{233}U(98.13 wt%), 1.24 wt% ^{234}U, 0.03 wt% ^{235}U, 0.60 wt% ^{238}U, at the uranium density 18.42 g/cm^3 (reflector thickness 7.84 in.).

Original Benchmark Model

- Created an “idealized” two-region model
  - HEU Core Radius: 6.1156 cm
  - HEU Core Density: 18.62 g/cm^3
  - NU Reflector Thickness: 18.0086 cm
  - NU Reflector Density: 19.00 g/cm^3



Benchmark Revision Approval

- Presented at the 2024 ICSBEP TRG
  - Approved pending subgroup review
  - Final approval August 2024
- Major revision (not new evaluation)
  - Prevents confusion
  - Keeps consistency with Jezebel revision process
- Publication in 2025 edition of ICSBEP Handbook

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URANIUM-235 SPHERE REFLECTED BY NORMAL URANIUM USING FLATTOP

Evaluator

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Internal Reviewers

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Los Alamos National Laboratory

John Bess
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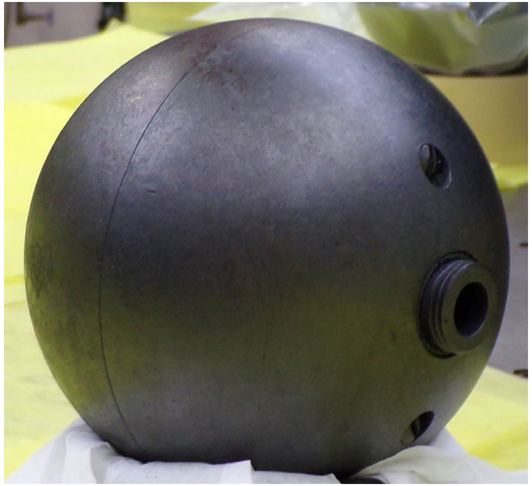
Independent Reviewers

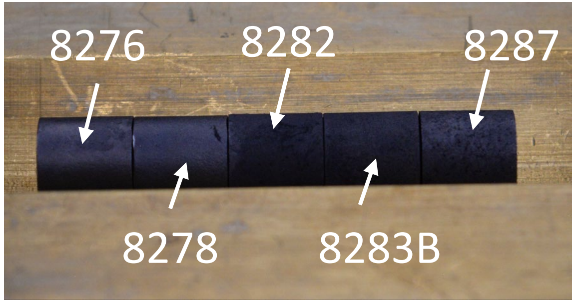
Alfie O'Neill

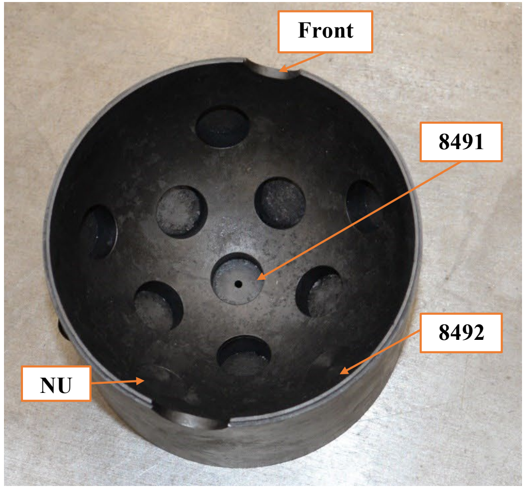
National Nuclear Laboratory - United Kingdom

NEW Revised Benchmark Models



- Exact experimental configuration
  - HEU Core
  - 2 HEU mass adjustment buttons
  - 1 NU mass adjustment button
  - 5 HEU glory hole pieces
  - Control rods fully inserted
  - Safety blocks fully closed
- Measured ρ = 22.69 ± 0.02 ¢

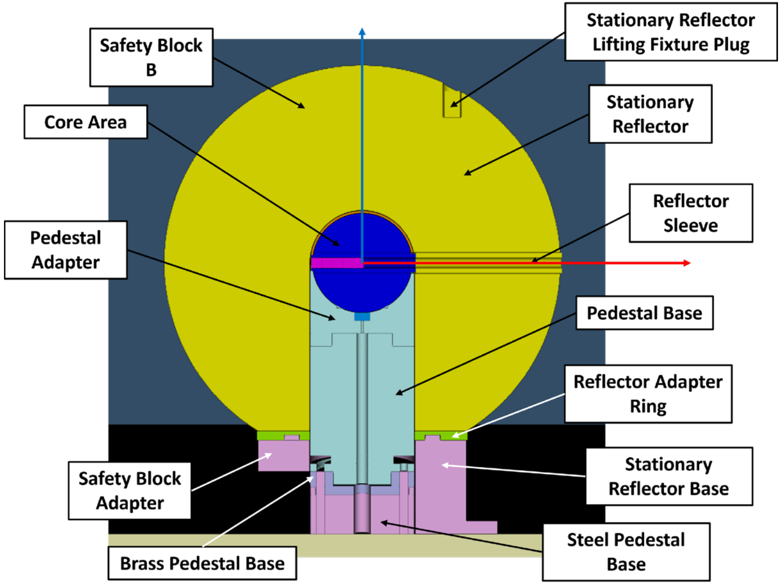


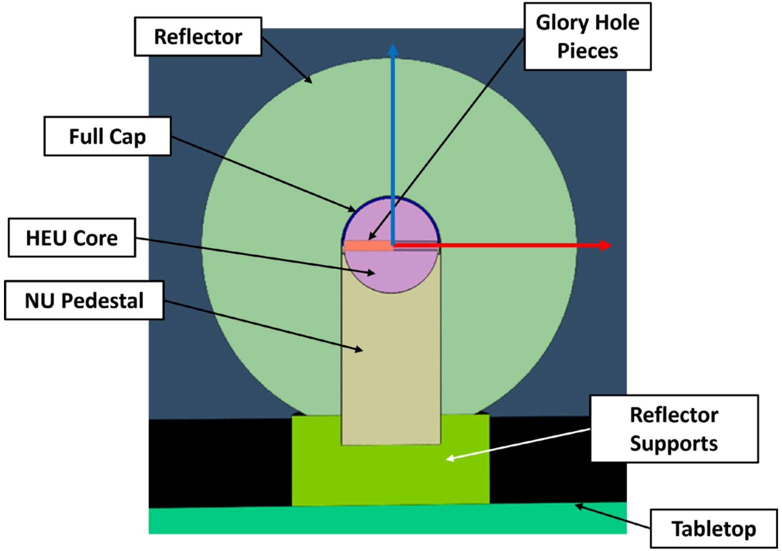


NEW Revised Benchmark Models

- Based on extensive physical measurements
- Two models created
  - Detailed and Simplified

NEW Revised Benchmark Models





Detailed Benchmark Model

Experiment k_{eff}: 1.001510
Experiment Uncertainty: +0.001287 / -0.001304
Simplification Bias: 0.000308 ± 0.000073
Benchmark Model k_{eff}: 1.001818 +0.001289 / -0.001306

Simplified Benchmark Model

Experiment k_{eff}: 1.001510
Experiment Uncertainty: +0.001287 / -0.001304
Simplification Bias: 0.003934 ± 0.000106
Benchmark Model k_{eff}: 1.005444 +0.001292 / -0.001309

Computational Reponses for New Model

Detailed Benchmark Model k_{eff}: 1.001818 +0.001289 / -0.001306
Simplified Benchmark Model k_{eff}: 1.005444 +0.001292 / -0.001309

Code	Cross Section Library	Detailed Model		Simplified Model	
		k_{eff}	C-E (pcm)	k_{eff}	C-E (pcm)
MCNP6.3	ENDF/B-VII.1	1.000641	-117.7	1.004275	-116.9
MCNP6.3	ENDF/B-VIII.0	0.998641	-317.7	1.002267	-317.7
MCNP6.3	ENDF/B-VIII.1	0.998575	-324.3	1.002147	-329.7

Contributors to 200 pcm Difference in the Detailed Model

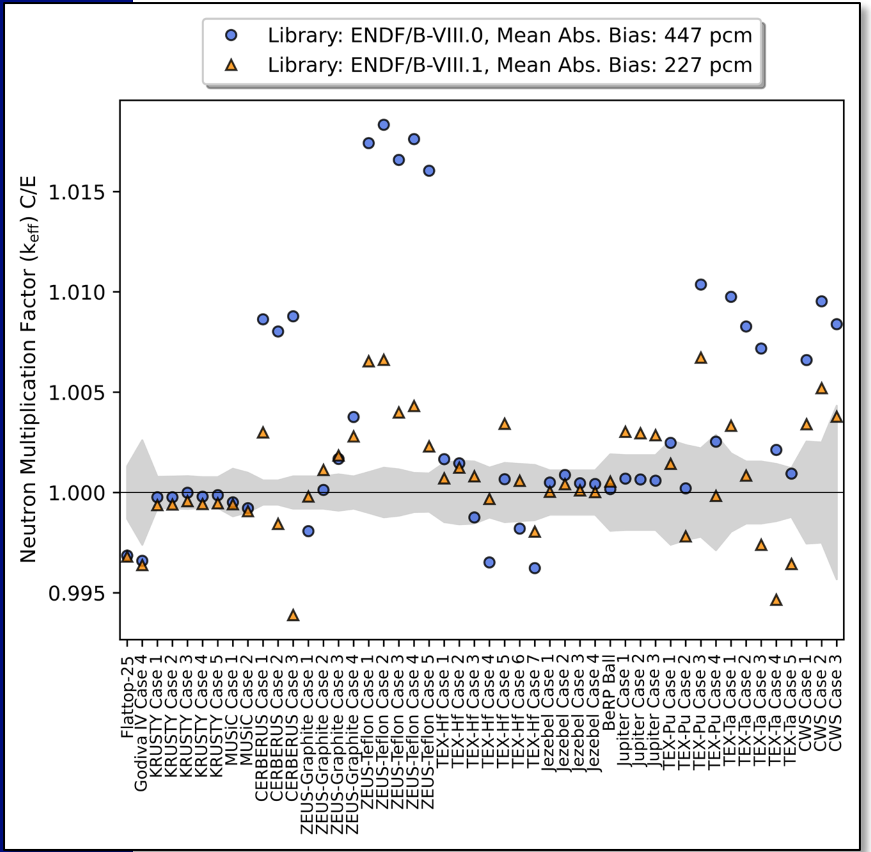
- Using ENDF/B-VII.1 as the base (k_{eff} = 1.000641)
- Changing a single uranium isotope to ENDF/B-VIII.0 and ENDF/B-VIII.1

Perturbed Isotope	ENDF/B-VIII.0		ENDF/B-VIII.1	
	Δk_{eff} (pcm)	Total Δk_{eff} (pcm)	Δk_{eff} (pcm)	Total Δk_{eff} (pcm)
^{233}U	3.2	3.2	4.1	4.1
^{234}U	3.5	6.7	-7.7	-3.6
^{235}U	-50.1	-43.4	-64.3	-67.9
^{236}U	0.1	-43.3	0.9	-67.0
^{238}U	-145.6	-188.9	-128.5	-195.5

- Remaining 11 pcm assumed to be from steel support structure

Modern Validation Suite

- Suite of modern benchmarks
- Large improvement for many benchmarks
- Flattop-HEU stayed consistent
  - Updated to include new detailed model
- Discussed more by Mike Rising



From Noah Kleedtke

Future Work

- Complete "press tour" to introduce new Flattop-HEU models to validation community
- Measure the Pu configuration components
  - Pu core, adapter, cap, mass adjustment buttons
- Measure β_{eff} of Flattop-Pu
- Revise the Flattop-Pu benchmark (PMF-006)
- Based on knowledge gained, revise Flattop-U233 benchmark (UMF-006)

Spheres of U(93), Plutonium, and ^{233}U in Thick Uranium. Critical masses reported for the Flattop assemblies[5] have been modified slightly to include the effect of a 0.004-in. to 0.005-in. gap between cores and reflector. The three cores were reflected by 19.00-in.-diam normal uranium at a density of 19.0 g/cm^3. Critical masses are:

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Acknowledgements

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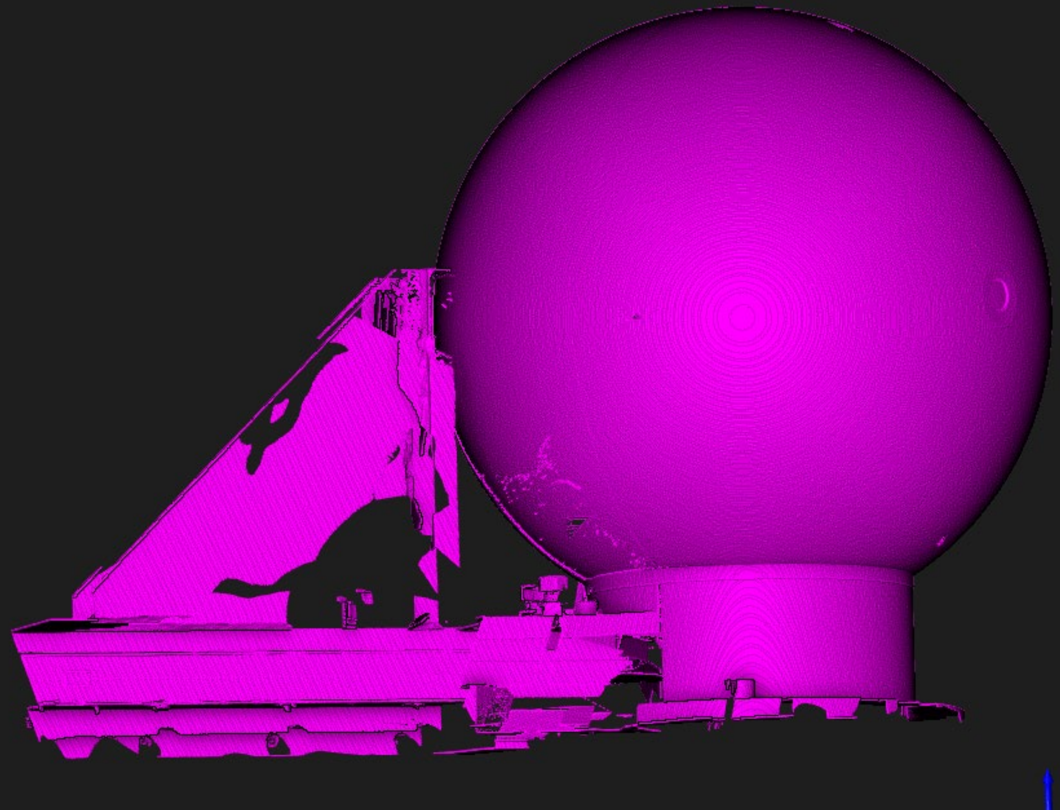

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Questions?

Kristin Stolte
kristins@lanl.gov

NNSA