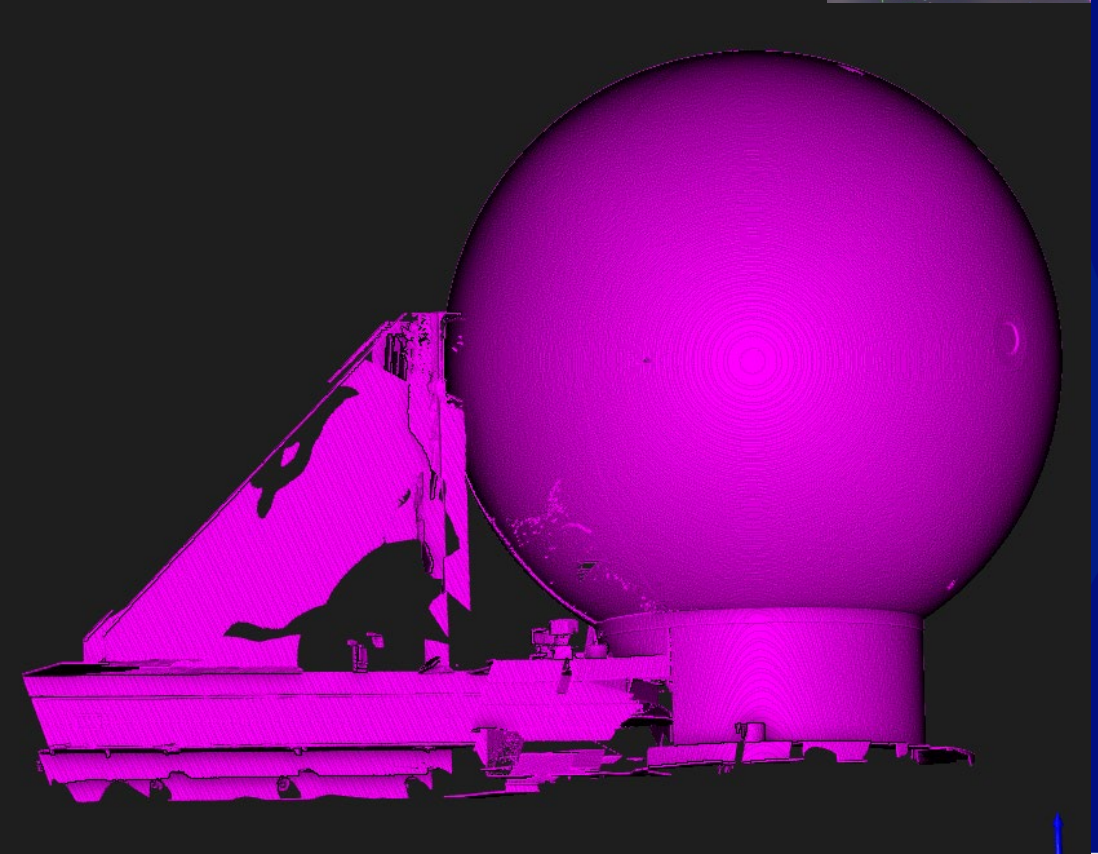

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High-Fidelity Measurements and Update for Flattop-HEU Benchmark Reevaluation

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NEN-2

NCSP TPR

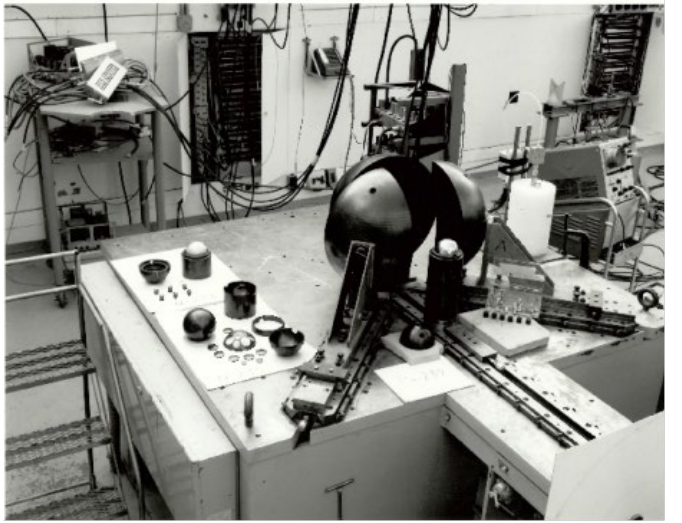
LA-UR-23-21605

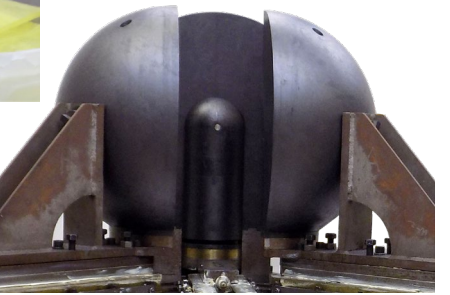
Overview

- Flattop Description
- Previous Work and Known Uncertainties
- New Measurements
  - Mass Measurements
  - Dimension Measurements
  - Volume Measurements
- Effects on k_{eff} and Uncertainty
- Conclusions and Future Work

Flattop-HEU Description

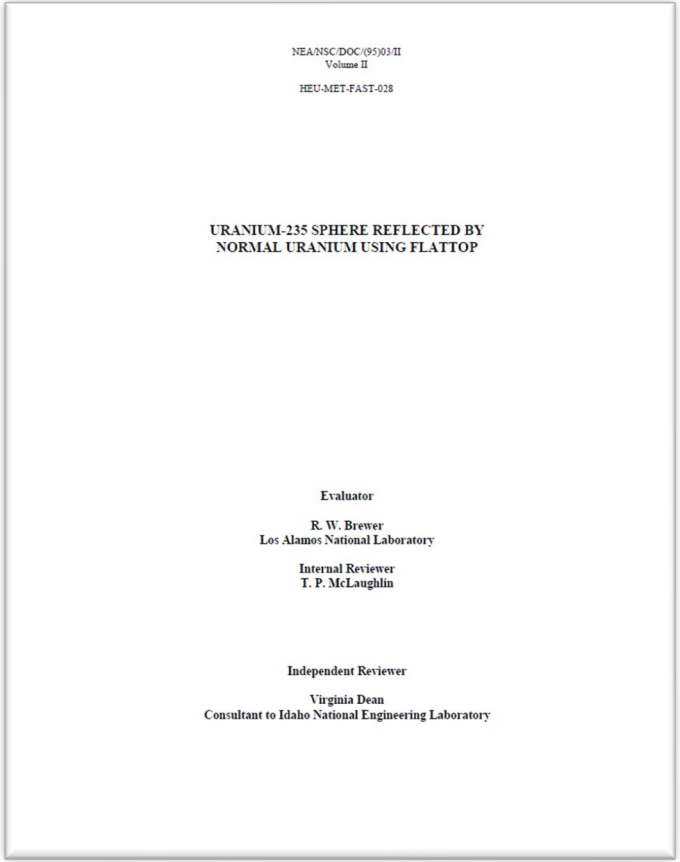
- 1950's:
  - Develop and validate nuclear data
  - One-dimensional, two-region models
- HEU Core
- NU Reflector and Control Rods
- Glory Hole
  - Allows for various configurations
  - Irradiation of samples to specified levels
- Today:
  - Fission Product and Activation Product Yield measurements; Replacement 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 a single diameter* for critical mass
- Other Flattop Benchmarks:
  - Pu Core (PU-MET-FAST-006)
  - ^{233}U Core (U233-MET-FAST-006)
  - Pu and HEU Core (MIX-MET-FAST-002)
  - ^{237}Np and HEU Replacements (SPEC-MET-FAST-003)



NEA/NSC/DOC/(95)03/II
Volume II

HEU-MET-FAST-028

URANIUM-235 SPHERE REFLECTED BY
NORMAL URANIUM USING FLATTOP

Evaluator

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Known Uncertainties

- Preliminary reevaluation in 2015
  - Explicit modeling of all components
- Largest uncertainties:
  - Mass NU components
  - Dimensions NU components
  - Mass HEU components
  - Dimensions HEU components
- Original uncertainty: ±0.00300
- Shift in benchmarks expectations

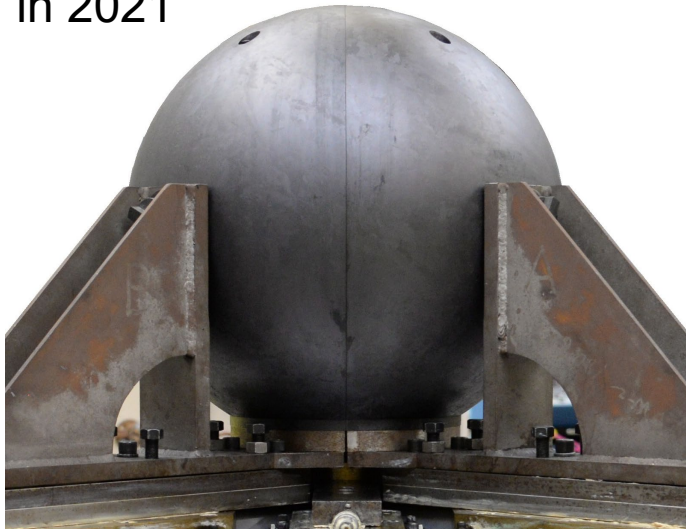
Preliminary Reevaluation Results

Effect	σ_k / k_{eff}
Mass and Volume Uncertainty HEU Components	±0.00071
Mass and Volume Uncertainty NU Components	±0.00136
HEU Isotopics	±0.00018
Structural Material Mass Densities	±0.00001
Gaps Between Reflector Pieces	±0.00025
Total	±0.00157

J. A. FAVORITE, "Preliminary Flattop-25 Reevaluation Results," LA-UR-15-29661 (2015).

New Measurements

- Effects of high-fidelity measurements estimated in 2021
- Measurements made by qualified machinist
- High-precision scales
- Coordinate Measuring Machine (CMM)
  - Addresses dimension uncertainties
  - Measures diameters of reflectors and core
- Pycnometer
  - Addresses volume and density uncertainties
  - Measures volume through gas displacement

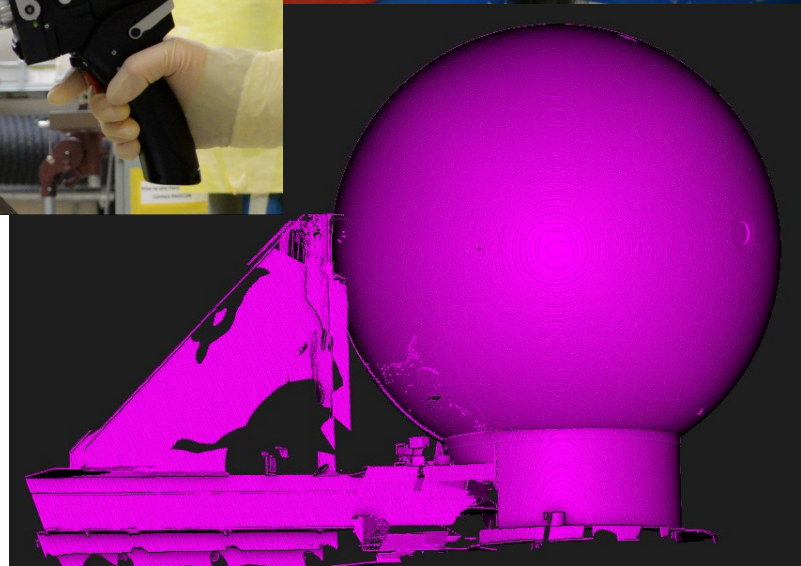


Mass Measurements

- Procedure:
  - Empty bag measured in triplicate
  - Piece cleaned and placed in bag
  - Combo measured in triplicate
  - Average mass computed
- One of four scales used
- Large reflectors not weighed
- Control rods not measured or weighed

CMM Dimension Measurements

- Primary focus was diameters
  - Core and Reflector Components
  - Measurements made on open and closed Flattop
  - Showed lack of measurable gap when closed (Accuracy: ±0.001 in)
- CMM Scanning Mode
  - Laser scan creates voxelized image
  - Dimensions can be pulled by comparing voxel locations
- CMM Point Measurements Mode
  - “Ruby Tip” Probe
  - Probe touches are recorded in software
  - Diameter inferred from locations

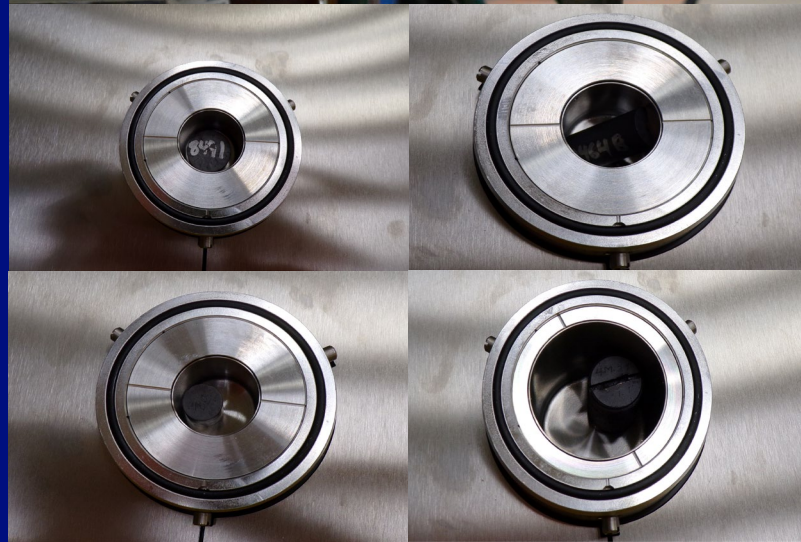


Caliper Dimension Measurements

- Digital readout
  - Resolution: 0.01 mm
- Measurements:
  - Glory Hole Pieces
  - Mass Adjustment Pieces
  - Various smaller features
- Measured in triplicate
  - Varied locations to span component
- Great agreement between CMM and Caliper measurements

Volume Measurements

- Anton Paar Ultrapyc 5000 pycnometer
- Measures volume through gas displacement
- Settings are key!
  - 16°C to match room temperature
  - 10 psi target pressure
  - Recalibrated at start of each session
- Measurement settings
  - At least three independent measurements
  - Last three to have percent deviation less than 0.05%
  - Most samples had three to five measurements



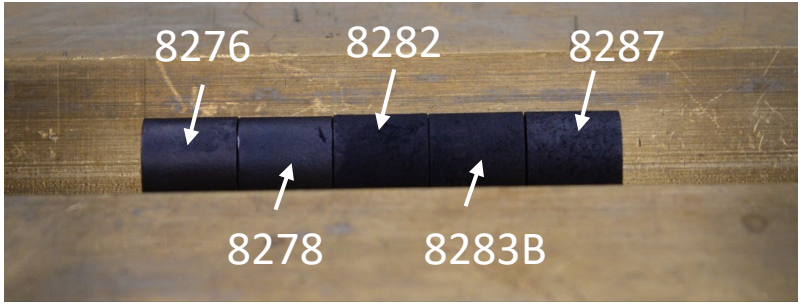
Benchmark Configuration

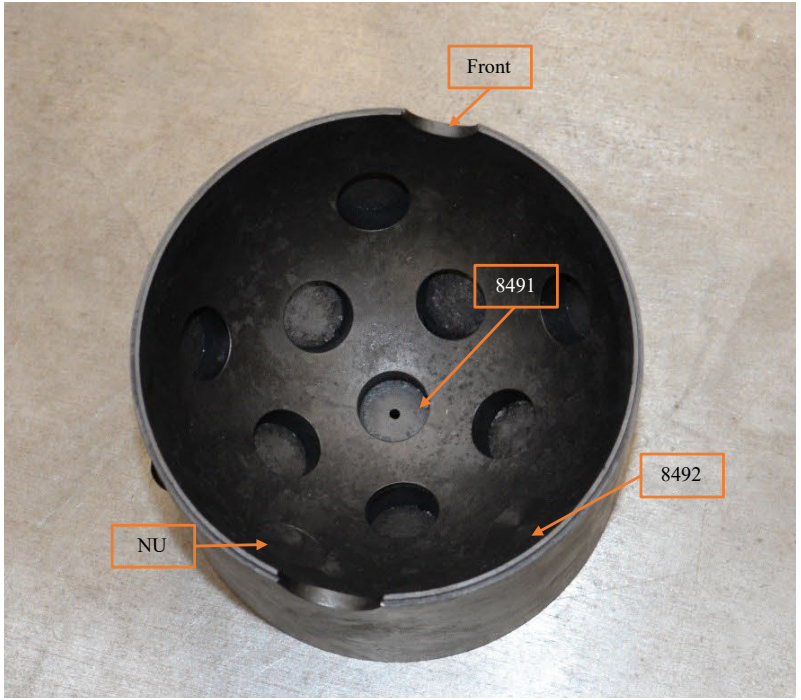
- Five HEU glory hole pieces
- Two HEU mass adjustment buttons
- One NU mass adjustment button

. Period measurement for Flattop-HEU experiment.

Linear Channel Number	Measured Reactor Period (s)	Reactivity (¢)
1	26.084 ± 0.036	22.685 ± 0.019
2	26.328 ± 0.044	22.562 ± 0.022
3	26.064 ± 0.072	22.696 ± 0.037
Average	26.159 ± 0.031	22.648 ± 0.016

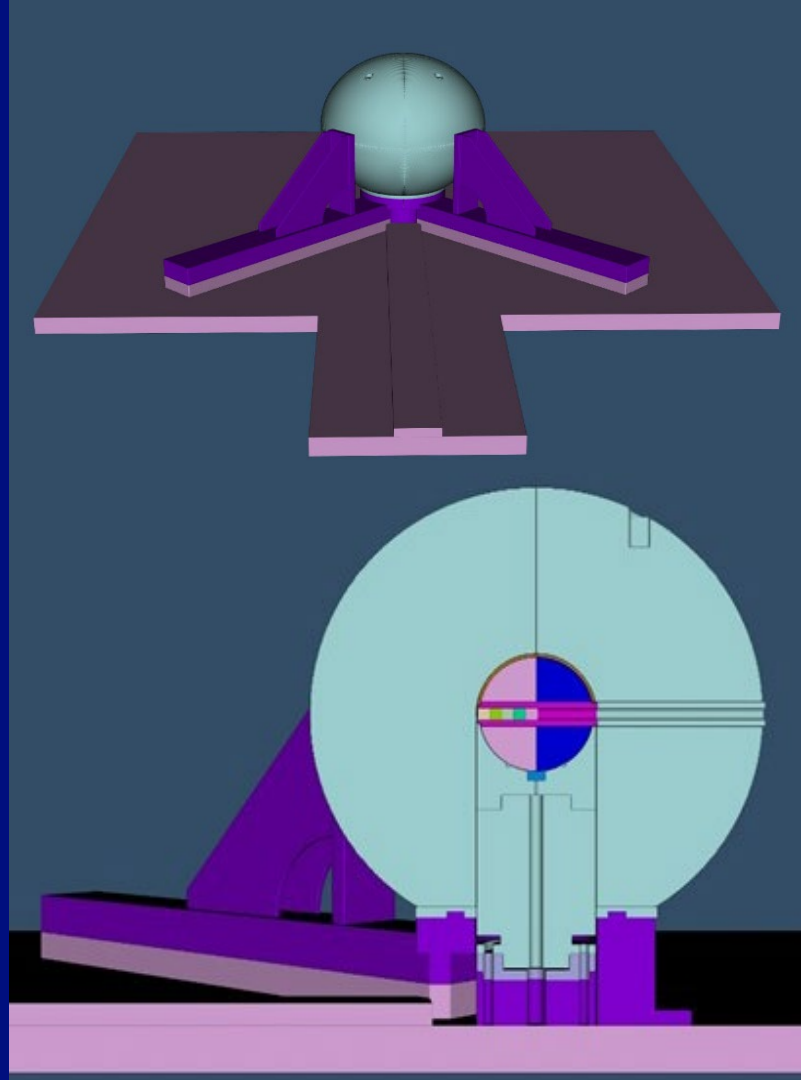
- Using 12 group Inhour parameters
  - 6 groups for HEU core
  - 6 groups for NU reflector





New Model Created

- Based on new measurements
- Model yields:
  - k_{eff} of 1.000327 ± 0.000021
  - β_{eff} of 0.00688 ± 0.00002
  - ρ of 4.715 ± 0.305 ¢
- Used: MCNP6.2 and ENDF/B-VIII.0 data
- Difference between experiment and model
  - k_{eff}: 123.3 pcm



Preliminary Mass Effects on k_{eff}

- Used KSEN card on cell-by-cell basis
- Uncertainty on unweighed pieces set to percent difference between measurements in 1954 and 2006
- Material uncertainty based on quadrature sum of individual uncertainties

Mass Uncertainty by Material Type

Category	Δk (pcm)
HEU	21
NU	86
Structure	0
Total Mass	88

Largest Mass Uncertainty Components

Component	Δk (pcm)
Stationary Reflector	63
Safety Block A	41
Safety Block B	40
HEU Core	21
Control Rod F	7

Conclusions and Future Work

- New measurements reducing benchmark evaluation uncertainty
- Initial results are on par with expected uncertainty levels
- CED-3B report consisting of ICSBEP Section 1 approved
- Mass uncertainties complete
- On target for ICSBEP submission 2024

Acknowledgements

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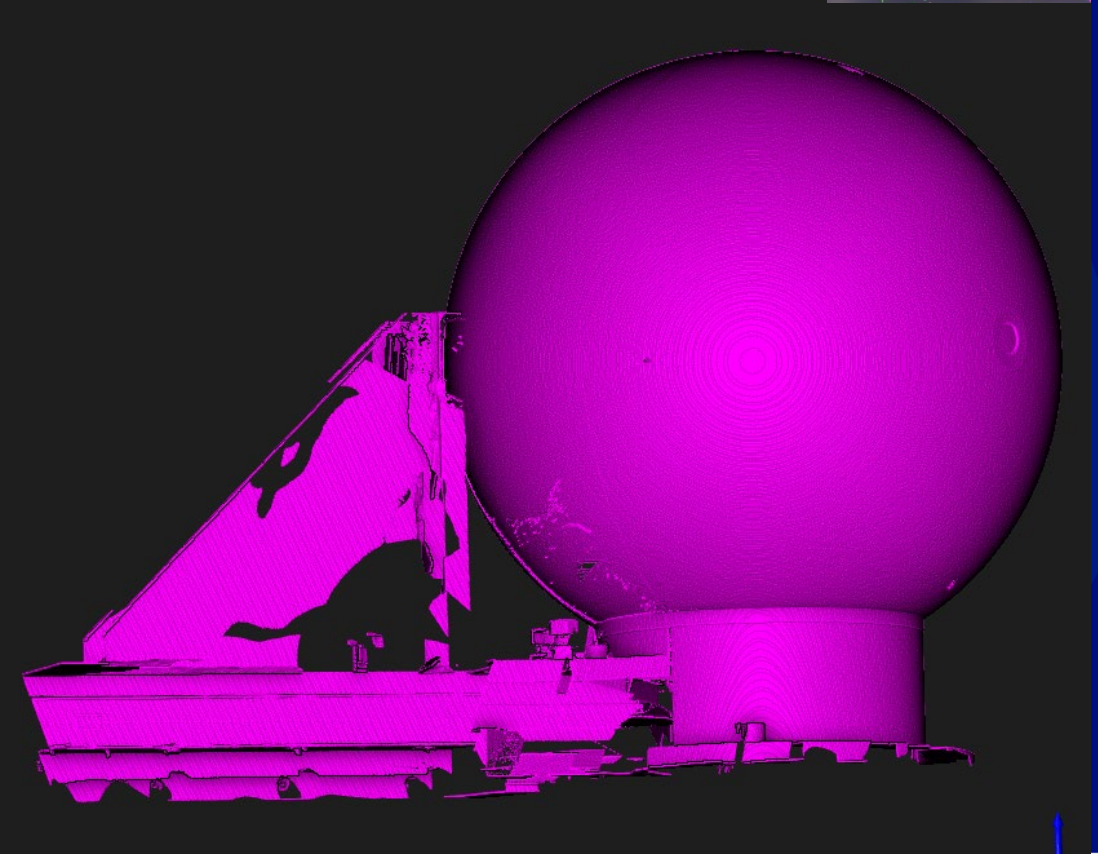

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Questions?

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