Constellation

Byron and Braidwood New Fuel Vault and Spent Fuel Pool Criticality Analysis Proposed License Amendment Request

November 2, 2026

Agenda

- Purpose and Scope
- Previous GAIA Application and NRC Review
- Overview of GAIA-AFM Fuel
- Methodology & Codes
- Analyses
- Preliminary Technical Specification Changes
- Key Milestones
- Summary

Purpose and Scope of This Meeting

- Discuss criticality analyses supporting GAIA-AFM fuel up to 6.5 wt% ^{235}U and 24-month-cycle operation
  - Extension of the NRC-approved GAIA criticality licensing basis to GAIA-AFM
  - GAIA-AFM-specific analyses addressing differences from the approved GAIA application
  - No physical changes to the existing NFV, SFP racks or Region 1/Region 2 configuration
- Proposed License Amendment Request (LAR) Scope
  - New fuel vault (NFV) criticality
  - Region 1 criticality (no burnup credit)
  - Region 2 criticality (burnup credit)
- NRC feedback on the proposed LAR approach before finalizing the analyses and LAR

Previous GAIA Application & NRC Review

- Original scope included GAIA-AFM fuel up to 6.5 wt% ^{235}U and 24-month-cycle operation
- Supplement reduced prior amendment scope to GAIA application up to 5.0 wt% ^{235}U and 18-month-cycle operation only
- NRC approval established the GAIA criticality licensing basis for the reduced scope
- Proposed LAR addresses the deferred GAIA-AFM scope
- Previous NRC review identified key topics relevant to the deferred GAIA-AFM scope:
  - Methodology applicability (NEI 12-16 / RG 1.240)
  - CASMO5 qualification
  - Depletion assumptions and operating parameters
  - Gadolinia treatment
  - NFV & Spent Fuel Pool (SFP) modeling
  - Accident analysis
- The following slides summarize previously approved basis & GAIA-AFM applicability justification

Constellation

Overview of GAIA-AFM Fuel

- 17x17 fuel assembly with M5 cladding and Q12 guide and instrumentation tubes
- Supports the 24-month-cycle transition at Byron and Braidwood
- GAIA-AFM used as the design basis fuel model for NFV, Region 1 & Region 2
  - Enrichment up to 6.5 wt% ^{235}U
  - Fuel-design changes (Fuel Pellet OD)
- Optional gadolinia-bearing fuel rods
  - Not credited in the design basis criticality analyses
  - NFV sensitivity studies quantify additional margin
  - Region 2 gadolinia treatment addressed through GAIA-AFM-specific depletion evaluations

Constellation

Methodology & Codes

- MCNP6.2 criticality analyses
  - ENDF/B-VII.1 cross section library
  - Benchmarking previously reviewed and accepted for GAIA criticality licensing basis
  - Benchmark enrichment range of 0.71 to 10 wt%
  - Validation bias and uncertainty applied
- CASMO5 depletion analyses (SFP Region 2 only)
  - NRC-approved CMS5 applicability through 8 wt% ^{235}U and 80 GWd/MTU
  - GAIA-AFM application remains within the approved ranges
- Methodology follows NEI 12-16 & RG 1.240, with specific evaluations for higher enrichment
- Approval references
  - GAIA approval SE: ML25148A202
  - CMS5 approval SE: ML26106A047

Constellation

NFV Analysis - Previous Approval and Proposed LAR Scope

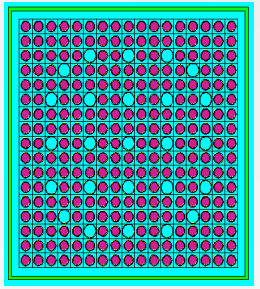
- Previously Approved (GAIA SE, ML25148A202)
  - NFV dimensions and their relationship to the as-built configuration (RAI #15)
  - Modeling of NFV steel, concrete walls and floor, and moderator outside the active fuel region
  - Fully flooded and optimum-moderation evaluation approach (RAI #15)
  - MCNP validation and treatment of applicable biases and uncertainties

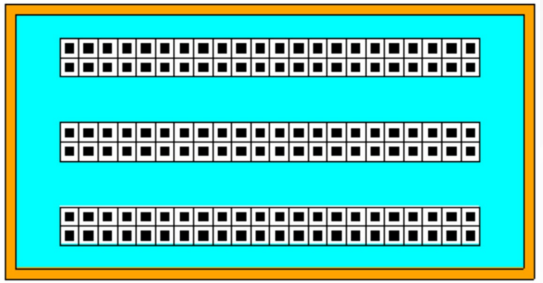
- Proposed LAR Scope
  - Directly model GAIA-AFM fuel up to 6.5 wt% ^{235}U
  - Evaluate NFV geometry and material effects for GAIA-AFM fuel
  - Complete fully flooded and optimum-moderation evaluations for GAIA-AFM fuel
  - Demonstrate compliance without gadolinia credit
  - Evaluate gadolinia separately to demonstrate additional margin

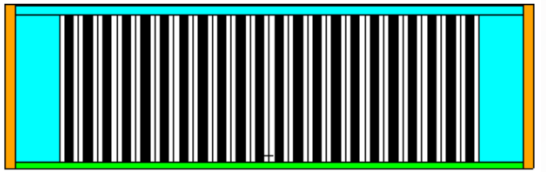
Constellation

NFV Analysis - Approach

- GAIA-AFM 17x17 design basis model at 6.5 wt% ^{235}U
- Moderator conditions:
  - Fully flooded: 1.0 g/cm³
  - Optimum moderation: 0.04 g/cm³
- Applicable biases and uncertainties included in $k_{\max}(95/95)$
- Key conservatisms:
  - No gadolinia credit (sensitivity studies quantify additional margin)
  - Fuel blankets conservatively modeled with the central-zone enrichment
  - Conservative fuel, material, and NFV geometry assumptions







Constellation

NFV Analysis - Preliminary Results

Moderator Condition	Margin to Limit
Fully flooded	0.0009
Optimum moderation	0.1347

- Both moderator conditions satisfy the applicable acceptance criteria
- Fully flooded condition limiting
- Compliance demonstrated w/o gadolinia credit
- Gadolinia sensitivities demonstrate additional margin
- Limited fully flooded margin driven by maximum-reactivity GAIA-AFM fuel in every NFV location & bounding fuel/rack assumptions

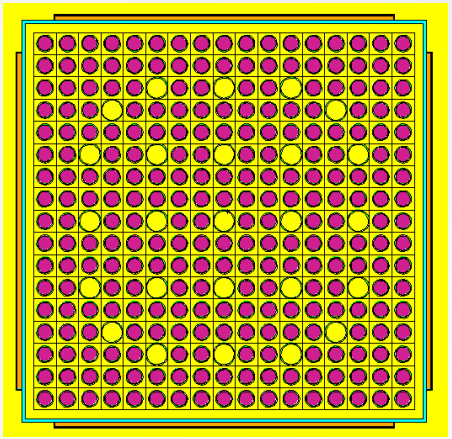
Region 1 Analysis - Previous Approval and Proposed LAR Scope

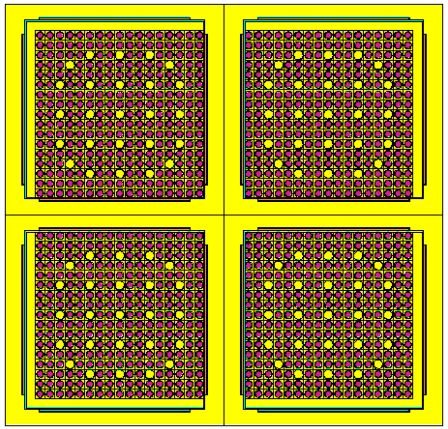
- Previously Approved (GAIA SE, ML25148A202)
  - Region 1 rack, fuel, and moderator modeling (RAI #4)
  - Boral degradation, B-10 reduction, and blistering (RAI #5)
  - Moderator temperature and loss-of-cooling conditions (RAI #14)
  - Treatment of gadolinia in fresh fuel (RAI #10)

- Proposed LAR Scope
  - Directly evaluates fresh GAIA-AFM fuel at 6.5 wt% ^{235}U
  - 5% reduction in B-10 areal density modeled as a bias and included in $k_{\max}(95/95)$
  - Evaluates temperature and fuel-positioning effects for GAIA-AFM fuel
  - Demonstrates compliance without burnup or gadolinia credit

Region 1 Analysis - Approach

- Fresh GAIA-AFM 17x17 design basis fuel model at 6.5 wt% ^{235}U
- 500 ppm borated water & unborated water cases
- Moderator temperatures from 4°C to 124°C, including voiding
- Manufacturing tolerances and eccentric positioning
- Applicable abnormal & accident conditions
- Applicable biases and uncertainties included in $k_{\max}(95/95)$
- Key conservatisms
  - Fresh fuel w/o burnup credit
  - Gadolinia rods modeled as UO_2 fuel rods w/o gadolinia credit
  - Maximum GAIA-AFM enrichment of 6.5 wt% ^{235}U
  - Minimum credited B-10 areal density with an additional 5% reduction





Constellation

Region 1 Analysis - Preliminary Results

Moderator Condition	Margin to Limit
500 ppm borated water	0.0184
Unborated water	0.0230

- Both moderator conditions satisfy the applicable acceptance criteria
- Compliance demonstrated w/o burnup or gadolinia credit
- 500 ppm borated-water condition provides the smaller margin
- 4°C moderator temperature with centered fuel positioning is limiting

Constellation

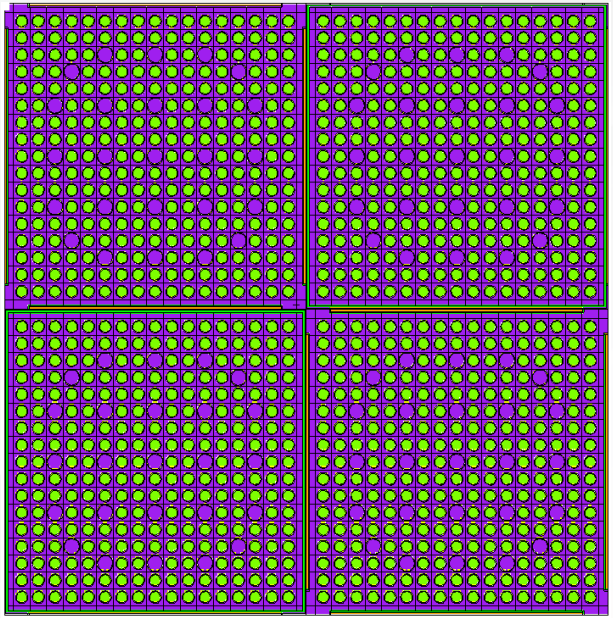
Region 2 Analysis - Key Methodology Question

- Previous NRC question (GAIA SE, ML25148A202, RAI #2):
  - Demonstrate that NEI 12-16 and RG 1.240 remain applicable to GAIA-AFM fuel up to 6.5 wt% ^{235}U and 24-month-cycle
- Existing supporting basis
  - Industry studies indicate no significant new criticality-physics effects for LEU+ & HBU fuel
  - EPRI benchmarking supports 5% depletion uncertainty for the evaluated LEU+/HBU range
  - CASMO5 applicability range extends to 8 wt% ^{235}U and 80 GWd/MTU (ML26106A047)
- GAIA-AFM applicability justification
  - Demonstrate the supporting basis remains applicable to GAIA-AFM and 24-month-cycle
  - Complete the specific GAIA-AFM evaluations summarized on the following slides
  - Pursue an exemption from 10 CFR 50.68(b)(7) if the 5.0 wt% ^{235}U limit remains in effect when the LAR is submitted

Constellation

Region 2 Analysis - Proposed LAR Approach

- Follow the guidance in NEI 12-16 and RG 1.240
- CASMO5 depletion and MCNP6.2 criticality calculations using ENDF/B-VII.1 cross section library
- GAIA-AFM 17x17 design basis fuel up to 6.5 wt% ^{235}U
- Burnup credit and soluble boron credit applied
- Proposed evaluations include:
  - Development of burnup vs. enrichment loading curves
  - Use of bounding depletion parameters and axial burnup profiles
  - Applicable biases and uncertainties in $k_{\max}(95/95)$
  - Fresh water design basis cases & confirmatory cases with 500 ppm soluble boron
  - Rack and region interface evaluations
  - Applicable accident conditions



Constellation

Region 2 GAIA-AFM Applicability Justification, Depletion Parameters

- Previous NRC question (RAI #9)
  - Demonstrate that depletion inputs bound plant operation & fuel design
- Previously approved GAIA basis
  - Inputs compared with historical operating conditions
  - Sensitivity studies performed to address fuel temperature, moderator temperature, soluble boron & specific power for 18-month-cycle operation
- GAIA-AFM applicability justification
  - Establish bounding core operating parameters for 24-month-cycle
    - Compare core parameters with historical and projected operating conditions to show they are bounding
    - Compare NUREG vs. GAIA-AFM axial profiles; NUREG profile expected to bound
    - Evaluate whether planar/radial burnup tilt requires separate treatment
  - Perform depletion calculations through 6.5 wt% ^{235}U

Region 2 GAIA-AFM Applicability Justification, Nuclides and Fission Gas Release

- Previous NRC question (RAI #8)
  - Identify credited nuclides and quantify reactivity effect of fission gas release
- Previously approved GAIA basis
  - Used CASMO5-generated actinides and fission products
  - Fission-gas release was evaluated using RG 1.183, Rev. 0
  - The positive reactivity effect was included as a bias
- GAIA-AFM applicability justification
  - Use the credited nuclide set from the approved GAIA analysis for GAIA-AFM fuel
  - Use RG 1.183, Rev. 1 fission gas release fractions and demonstrate applicability to the GAIA-AFM enrichment and burnup range
  - Perform the applicable calculations through 6.5 wt% ^{235}U
  - Incorporate the positive reactivity effect as a bias into the Region 2 loading curve

Region 2 GAIA-AFM Applicability Justification, Gadolinia Treatment

- Previous NRC question (RAI #10)
  - Explain gadolinia treatment and demonstrate neglecting gadolinia is conservative
- Previously approved GAIA basis
  - Gadolinia was not credited in the GAIA depletion or criticality calculations
  - Previous evaluations and NEI 12-16 supported neglecting gadolinia as conservative for fuel up to 5.0 wt%
- GAIA-AFM Applicability Justification
  - Confirm applicable GAIA-AFM gadolinia design inputs
  - Demonstrate neglecting gadolinia remains conservative and omit gadolinia from the design basis model w/o a separate bias
  - Include radial enrichment distribution effects in the gadolinia evaluations

Region 2 GAIA-AFM Applicability Justification, Reconstituted Fuel

- Previous NRC question (RAI #12)
  - Define the evaluation method and licensing controls for reconstituted and nonstandard fuel
- Previously approved GAIA basis
  - Described fuel elevator isolation and surrounding Boral protection
  - Established methodology to evaluate missing-rod configurations for fuel up to 5.0 wt% ^{235}U
  - Stainless-steel replacement rods were bounded by the analyzed fuel configuration
- GAIA-AFM applicability justification
  - Evaluate reconstituted fuel up to 6.5 wt% ^{235}U for any positive reactivity effect
  - If needed, store in Region 1 using available margin
  - Additional options include adjacent empty cells or gadolinia credit
  - Configuration-specific calculations demonstrate compliance
  - Establish applicable storage controls in the licensing basis/TS, as needed

Constellation

Region 2: Other Applicability Confirmations

- Methods established for GAIA are expected to remain applicable; the following evaluations demonstrate applicability to GAIA-AFM fuel up to 6.5 wt% ^{235}U
  - Depletion-related geometry changes (RAI #7)
    - The previous GAIA analysis evaluated fuel rod growth, cladding creep, and grid growth during depletion
    - Extend the evaluations for GAIA-AFM fuel up to 6.5 wt% ^{235}U using applicable inputs
    - Include any positive reactivity effect as a bias with associated uncertainty
  - Control rod effect (RAI #11)
    - The previous GAIA analysis included a conservative control rod insertion sensitivity
    - Establish a bounding 24-month-cycle control rod insertion history for GAIA-AFM depletion
    - Extend the evaluation for control rod effect for GAIA-AFM fuel up to 6.5 wt% ^{235}U
    - Include any positive reactivity effect as a bias with associated uncertainty

Region 2: Other Applicability Confirmations

- Methods established for GAIA are expected to remain applicable; the following evaluations demonstrate applicability to GAIA-AFM fuel up to 6.5 wt% ^{235}U
  - Module G (RAI #4)
    - Use the current Module G repair configuration and modeling inputs
    - Extend applicable accident evaluations
    - Identify the limiting configuration and soluble boron requirement
  - Moderator temperature (RAI #14)
    - Evaluate temperature and voiding effects
    - Identify the limiting moderator condition
    - Demonstrate that loss of cooling remains bounded
  - Multiple misload controls (RAI #13)
    - Retain applicable inventory, independent verification, procedure & training controls established for GAIA
    - Evaluate applicable misload configurations and identify the limiting soluble boron requirement

Region 2: Licensing Basis & Document Updates

- Actions primarily involve licensing-basis confirmation and documentation updates
  - CASMO5 qualification (RAI #3)
    - NRC-approved applicability extends to 8 wt% ^{235}U and 80 GWd/MTU (ML26106A047)
    - Update references and address applicable limitations and conditions
  - Boral degradation (RAI #5)
    - Retain the 5% B-10 areal-density reduction as a bias
    - Confirm existing Boral surveillance & no-blistering basis remains applicable to GAIA-AFM fuel
  - Region 2 storage and decay time (RAI #1)
    - Affected assemblies that did not meet the GAIA loading curve were relocated to Region 1
    - Region 2 compliance does not rely on assembly-specific cooling time credit

Proposed Technical Specification Changes

TS 3.7.15, Spent Fuel Pool Boron Concentration

- Revise as applicable, SFP soluble boron requirements based on updated normal and accident analyses

TS 3.7.16, Spent Fuel Assembly Storage

- Revise LCO 3.7.16(a) Region 1 enrichment limit to support GAIA-AFM fuel
- Update Region 2 acceptable burnup domain in Figure 3.7.16-1
- Revise SR 3.7.16.1 and SR 3.7.16.2 to support the revised enrichment and loading requirements

TS 4.3.1, Fuel Storage, Criticality

- Revise TS 4.3.1(a) maximum ^{235}U enrichment
- Revise TS 4.3.1(b) soluble boron requirement, if required by the updated analyses

Key Milestones

- Pre-submittal Meeting – November 2026
- Submit LAR – May 2027
- NRC Review Complete – May 2028 (12-month review)
- Fuel Receipt – ~January 2029

Constellation

Summary

- Builds on the NRC-approved GAIA criticality licensing basis
- Supports GAIA-AFM fuel up to 6.5 wt% ^{235}U and planned 24-month-cycle operation
- Methodology generally follows NEI 12-16 & RG 1.240, with specific evaluations for higher enrichment
- Updated NFV and Region 1 analyses demonstrate compliance using conservative assumptions
- Region 2 evaluations address the technical topics identified during the previous NRC review
- NRC feedback will support finalization of the analyses and LAR

Questions



Constellation