Agenda: SARP Shielding/Criticality Safety Analyst's Course
Course Duration: Approximately 4.5 Days

- Course Overview
  - Introduction
    - Course overview – objectives and expectations
    - Course purpose and skills
    - Course overview – Skill development
    - Course overview by day
    - Shielding course overview
    - NCS course overview
    - Chapter-to-Chapter dependencies
  - Applicable DOE requirements
    - Applicable DOE requirements
    - DOE O 460.1C "Packaging and Transportation Safety"
    - DOE G 460.1-1 "Implementation Guide for Use with DOE O 460.1A –Packaging and Transportation Safety"
    - DOE O 461.1B "Packaging and Transportation for Offsite Shipment of Materials of National Security Interest"
    - DOE G 460.1-1 "Implementation Guide for Use with DOE O 460.1A"
    - SG100, R2, "NNSA Service Center Safety Guide – Design and Development Guide for NNSA Type B Packages"
    - SG500, R3, "NNSA Service Center Safety Guide – Defense Programs Package Certification and Offsite Transportation Authorization Guide"
  - Applicable NRC Guidance
    - Regulatory Guide 7.9 "Standard Format and Content of Part 71 Applications for Approval of Packages for Radioactive Material"
    - NUREG/CR-5661 (ORNL/TM-11936) "Recommendations for Preparing Criticality Safety Evaluation of Transportation Packages"
    - For NRC Use:
      - NUREG-1609 "Standard Review Plan for Transportation Packages for Radioactive Material"
      - NUREG-1617 "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel"
  - Applicable Regulatory Documents
    - Role of DOE O 460.1C "Packaging and Transportation Safety"
    - 10 CFR Part 71 – Packaging and Transportation of Radioactive Material
- Radioactive Material Package Shielding Evaluation Training
  - Background
    - Why is there a need for shielding analysis?
    - Ionizing radiation
    - Typical sources of photons
    - Typical sources of neutrons
  - Chapter-to-chapter dependencies
  - Regulatory dose rate limits
  - Rules and Regulations
    - NCT
    - HAC

        - Storage regulations
        - Exclusive use
        - ALARA and long-term storage
    - SARP Ch. 5 shielding evaluation overview – per RG 7.9
    - Summary of methods/computer codes/nuclear data
        - ORIGINS of ORIGEN - Genealogical Tree
        - ORIGEN-S Point Depletion Method
        - Nuclear Data Sources
        - Gamma Spectral Calculations
        - Fine vs. Broad-Group Gamma Spectra – 60Co BUGLE 20g and 200g calculations
        - Neutron Source Calculations
        - ^{238}Pu Neutron Spectrum – fluorine and oxygen matrix
        - Shielding Analysis Methods
        - Point Kernel Dose Estimation
        - Boltzmann transport equation for non-multiplying media (fixed-source problem)
        - Boltzmann Transport Equation for Critical System (eigenvalue problem)
        - Interpretation of the Critical Eigenvalue
        - Techniques for Solving Transport Equation
        - Discrete Ordinates Methods
        - Representing the Discrete Spatial Meshes
        - S4 Quadrature for Cylindrical Geometry
        - Energy Mesh
        - 1D Discrete Ordinates Equation
        - Discrete Ordinates Solutions
        - Radiation Transport Monte Carlo
        - Random Walk Procedure
        - PDFs used in Random Walk
        - Estimation of Results
        - Monte Carlo Simulation of Shielding Problem
        - Monte Carlo Methods
        - Codes and Data Libraries
        - Dose Conversion Effects – Neutrons
        - Dose Conversion Effects –Photons
        - Codes and Data Libraries
        - Individual components of radioactive sources
        - Radioactive Sources – Pu
            - Neutron Spectrum for Pu Metal (9 kg)
            - Neutron Spectrum for Pu Metal (9 kg)
            - Photon Spectrum for Pu Metal (9 kg)
        - Radioactive Sources – U
            - Neutron Spectrum for HEU (25 kg)
            - Photon Spectrum for HEU (25 kg)
            - Neutron Spectrum for DU (25 kg)
            - Photon Spectrum for DU (25 kg)
        - Radioactive Sources – Th
            - Neutron Spectrum for Th (25 kg)
            - Photon Spectrum for Th (25 kg)

        - Radioactive Sources – Maximum Source
    - Shielding Design Considerations (several slides)
        - Relative spent fuel source importance
        - Spent Fuel Neutron sources
        - Spent Fuel Gamma sources
        - Spent Fuel Hardware activation
        - ORNL-6051 Table 4. Assumed elemental compositions of LWR fuel-assembly structural materials
        - PWR Scaling Factors
        - Shielding Design Considerations (3 slides)
    - Shielding Review Considerations (several slides)
        - General SARP review considerations
        - General SARP comments
        - SARP Overview – Shielding Evaluation (based on RG 7.9 and NUREG 1609 – 13 slides)
    - SARP source examples
        - Source Definition Philosophy
        - Source Definition (3 slides)
        - Source Energy Bin Resolution
            - Photon Spectrum for HEU (25 kg)
        - Source Definition (several slides)
        - Source Definition – Minimally Burned Fuel (2 slides)
        - Source Definition – PuBe Source (3 slides)
        - Crude Approximation – Neutrons
    - SARP shielding example
        - SARP Shielding Example 1 (3 slides)
        - SARP Shielding Example 2 (6 slides)
    - Safety Analysis Report for Packaging (SARP) Fundamentals (4 slides)
        - Safety Analysis Report for Packaging (SARP) Fundamentals – Conservative shielding analysis (3 slides)
        - Safety Analysis Report for Packaging (SARP) Fundamentals – Tips on modeling package
        - Safety Analysis Report for Packaging (SARP) Fundamentals – Tips on modeling payload
    - General SARP Content Strategies
    - SARP Shielding Example 3 (5 slides)
    - SARP Shielding Example 4 (11 slides)
        - *Data required*
    - Summary/Lessons Learned
        - Recommendations Summary (5 slides)
- Nuclear Criticality Safety Course Overview
- Chapter to chapter dependencies
- Regulations governing NCS requirements for the packaging and shipment of fissile material
    - Introduction
    - Applicable Department of Energy (DOE) Requirements (7 slides)
    - Applicable NRC Guidance
    - Applicable Consensus Standards
    - Applicable Guidance Documents (for NRC Use)

    - Applicable Regulatory Documents (3 slides)
        - 10 CFR Part 71 – Packaging and Transportation of Radioactive Material
            - §71.55(d) General Requirements for Fissile Material Packages
            - §71.55(e) General Requirements for Fissile Material Packages
            - 10 CFR §71.55 General Requirements for Fissile Material Packages – Summary
            - §71.64 Special Requirements for Plutonium Air Shipments
            - §71.59 Standards for Arrays of Fissile Material Packages
            - 10 CFR §71.59 Standards for Arrays of Fissile Material Packages – Summary
- SARP Chapter 6 Overview
    - Chapter to Chapter Dependencies
    - SARP Overview – Criticality Evaluation (as per NRC Reg. Guide 7.9, Revision 2)
- Package description for Nuclear Criticality Safety
    - Introduction
    - Package Description – Contents
    - Package Description – Contents Example (1)
    - Package Description – Contents Example (2)
    - Package Description – Contents Example (3)
    - Package Description – Packaging
    - Chapter to Chapter Dependencies
    - Package Description
    - Package Description – Example (1)
    - Package Description – Example (2)
- Summary tables of criticality evaluation
    - Summary Tables of Criticality Evaluation (intro slide)
    - Summary Table of Criticality Evaluation (Single package results)
    - Summary Table of Criticality Evaluation – Example (1–Single Package Results)
    - Summary Table of Criticality Evaluation – Example (2–Single Package Results)
    - Summary Table of Criticality Evaluation (Array results)
    - Summary Table of Criticality Evaluation – Example (1–Array Results)
    - Summary Table of Criticality Evaluation – Example (2–Array Results)
    - Summary Table of Criticality Evaluation- Special requirements for Pu air shipments
    - Summary Table Example of Results (1)
    - Summary Table Example of Results (2)
    - Summary Table Example – Calculating the Criticality Safety Index
    - Criticality Content in Other Chapters
    - Chapter to Chapter Dependencies
- Nuclear criticality safety analysis models
    - NCS Analysis Models – General
    - NCS Analysis Models – Sketches
    - NCS Analysis Models – Example of a Sketch for NCS Analysis
    - NCS Analysis Models – Materials
    - NCS Analysis Models – Example of a Material Specification Table (1)
    - What Makes a Good Reference?
    - NCS Analysis Models – Example of a Material Specification Table (2)
    - NCS Analysis Models – Model/Package Differences
    - NCS Analysis Models – Package Contents

    - NCS Analysis Models – Arrays
- Method of analysis
    - On Use of Subcritical Limits and Hand Methods
    - Useful Subcritical Limits and Hand Methods References
    - Calculational Methods
    - Adequacy of Calculations
    - SARP Content
- Validation of Calculation Methods
    - Validation of Calculation Methods (intro) (2 slides)
    - Bias and Bias Uncertainty
    - Nuclear Data
    - Data Evaluation
    - Nuclear Data Bias?
    - Bias and Bias Uncertainty
    - Validation of Calculational Method
    - Selection of Critical Experiments (4 slides)
    - Calculating Bias and Bias Uncertainty
    - Documenting the Validation of the Calculational Method in the SARP (2 slides)
    - Typical USLSTATS Plot
    - Documenting the Validation of the Calculational Method in the SARP
    - Class Discussion on the importance of being normal
    - Normality Test Failure
    - Applicability of Benchmark Experiments
    - Addressing Validation Deficiencies
    - Limits, Biases & Uncertainties
- NCS Calculations and Results
    - Criticality Calculations and Results
- SARP Ch. 6 Summary
    - Summary of key points in Ch. 6
    - SARP Review Considerations – Regulatory requirements from NUREG-1609
    - Resources (1)
    - Resources (2)
- NCS Analysis Overview
    - Performing Criticality Analysis – analysis objectives
    - Performing Criticality Analysis – single undamaged package
    - Performing Criticality Analysis – single damaged package
    - Performing Criticality Analysis – array analysis
    - Performing Criticality Analysis – modeling arrays of undamaged packages
    - Performing Criticality Analysis – modeling arrays of damaged packages
    - Performing Criticality Analysis – Discussion
    - Performing Criticality Analysis – Array example
- Class exercises and discussion
    - Class Exercise (Phase I – pre-test package configuration)
        - Class Exercise – SNM Package
        - Class Exercise – Waste box
    - Class Exercise (Phase II – post-test packaging configuration)
        - Class Exercise – SNM Package
        - Class Exercise – Waste Box

- Class Exercise (Phase III – Calculate CSI and # packages that can be shipped using maximum acceptable NCT and HAC arrays)
- Class Exercise (Phase IV – Validation exercises)