Validation and Bias Quantification of Criticality Safety Codes for SRNS Operations

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Introduction

- SRNS Recently Completed a Full Re-Validation of our Criticality Safety Codes
- MCNP6.1 and SCALE6.1
- Required Several Person-Years to Complete
- Initiated in Response to a DOE Assessment
- Task was not Anticipated – Impacted Program

Timeline

- Decision to Perform New Validation – Fall 2013
  - All computers scheduled for replacement
  - Mandatory upgrade to operating system
  - Decided to update codes (from version 5 to version 6.1)
- Completed Computer System Updates – Summer 2014
- Performed “Quick” Validation – Summer 2014
- DOE Assessment Resulting in Negative Findings – Fall 2014
- Re-started Validation Process – Spring 2015
- Completed Re-Validation – Summer 2016

Key DOE Findings

- Out of Date Benchmark Descriptions
- Models did not Precisely Match Benchmark Specifications
- Inappropriate Rejection of Outliers
- Failure to Fully Describe Limits of AoA
- Less than Adequate Documentation

Root Causes

- Validation is an Infrequent Task
  - Maintaining continuity of staff is difficult
  - Limited opportunities for skill development
- Previous Validation Assumed to be Adequate
  - Task was given lower priority
  - Assigned to junior staff
  - Used a “fill in the blanks” approach
- Written Process Description was Incomplete and Difficult to Follow
- Differences in Interpretation of ANSI/ANS-8.24
  - Little supporting documentation
  - Largely unrecognized prior to DOE assessment

SRS Response

- Developed Guidelines for Interim Operations
- Established a Project Management Plan
- Developed a Written Guide for Performing Validations
- Developed a Technical Review Process Specifically for Validations
- Re-Created and Peer Reviewed Models for all Benchmarks
- Re-Validated all Materials and Systems
- Performed Peer Review on all Validations
- Issued New Validation Documents

Validation Requirements

- ANSI/ANS 8.1 - Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors
  - "The validity of any method used to determine the subcritical state of a fissionable material system shall be established."
- ANSI/ANS 8.24 - Validation of Neutron Transport Methods for Nuclear Criticality Safety Calculations
  - Identifies requirements for performing validations
- SRNS Governing Documents
  - Establishes Criticality Safety Program Compliant with Applicable Standards (including 8.1 and 8.24)

Validation Objectives

- Two Codes: MCNP6.1 and SCALE6.1

- Ten Materials/Systems
  - Pu metal
  - Pu oxide
  - Pu nitrate solution
  - Pu solution w/ Gadolinium
  - HEU metal
  - HEU oxide
  - HEU solutions (uranyl nitrate)
  - HEU solutions w/ Boron
  - LEU
  - MTR Fuel (uranium metal w/ Al clad, complex geometry)

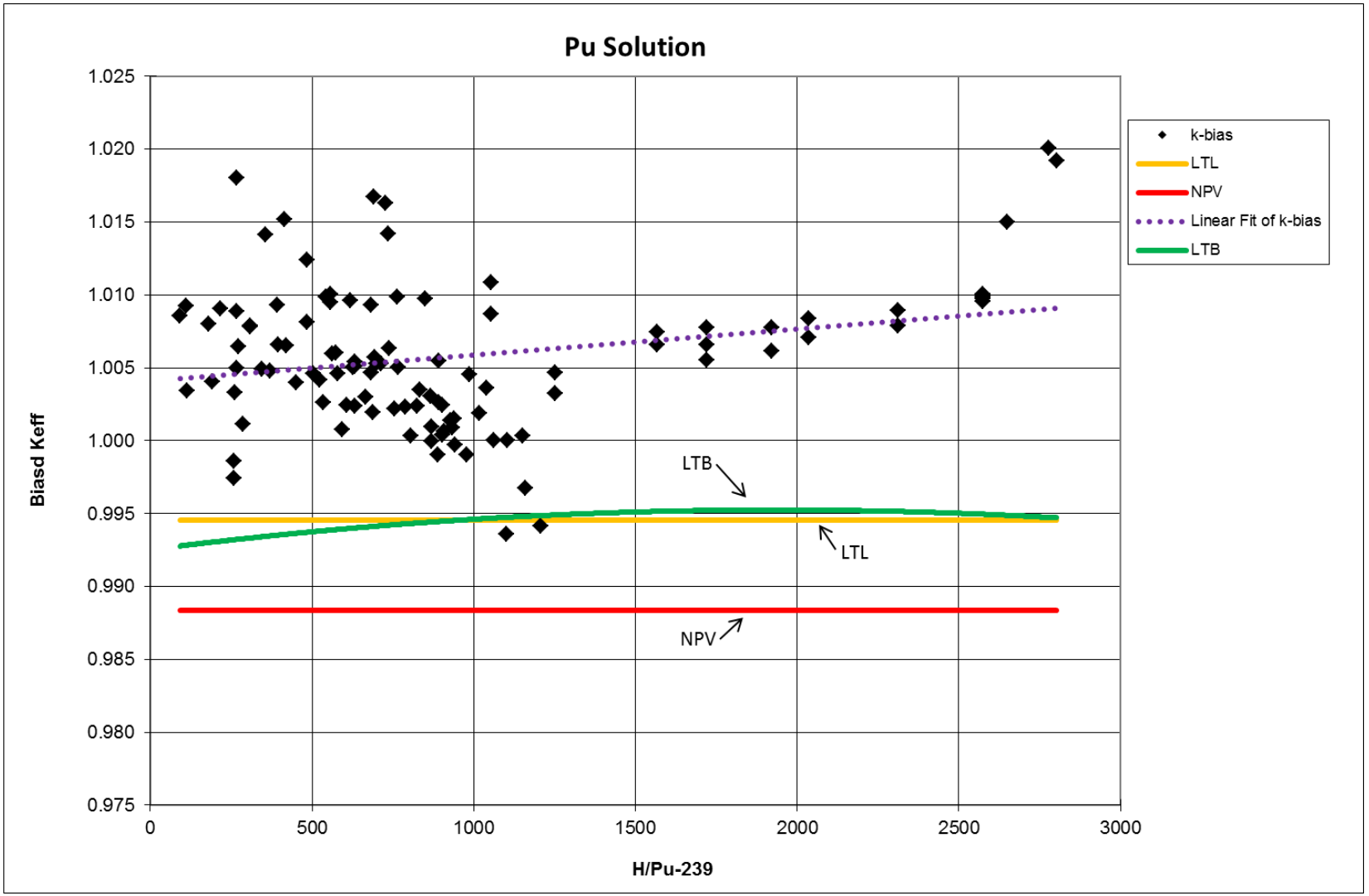
Validation Process Overview

- Identify Desired Area of Applicability
  - Typically based on an activity or facility
  - Code and hardware specific
- Benchmark Selection
  - Consider available benchmarks that closely align with desired AoA
- Modeling of the Benchmarks
  - Precise representation of benchmark specification (isotopics, geometry)
  - Ensure adequate convergence

Validation Process Overview - continued

- Bias Quantification (Calculational Margin)
  - Three methods typically used at SRS:
    - *Lower Tolerance Band (LTB)*
    - *Lower Tolerance Limit (LTL)*
    - *Non Parametric Value Method (NPV)*
  - Specific method selected according to a protocol:
    - *Look for clear trend in data, if found then apply LTB*
    - *If no trend then test data for normality, if acceptable then apply LTL*
    - *If no trend, and data fails normality test, then apply NPV*
  - Outlier Treatment

Bias Quantification Example



Validation Process Overview

- Determination Specific Area of Applicability
  - Precise range of key parameters
    - *Isotopics*
    - *Spectrum*
    - *H/X*
    - *etc*
- Develop Validation Document
  - Clearly state approach
  - Provide references for data
  - Justify decisions and exceptions
  - Present results in a clear and useful manner

Validation Documentation Example

Summary of Validation for Pu Solution Calculations with MCNP 6.1

Pu Solutions MCNP 6.1, ENDF/B-VII.1 (.80c)				
Method of determining k_{be}:				NPV
k_{be}				**0.9884**
AoA Ranges:				
Parameter	**Units**	**Min**	**Max**	**Description**
Fissionable Material	gPu/L	9.5	268.7	Pu in aqueous plutonium nitrate solution
Isotopics: ^{239}Pu ^{240}Pu	 wt % wt.%	 59.2 0	 100 22.88	
Neutron Spectrum (EALF)	eV	0	1	Thermal
Moderator: H/^{239}Pu	 N/A	 91.2	 2802.8	Aqueous Solution – See moderator discussion
Reflectors				None, partial water, full water, thin steel
Poisons				None
Temperature	K	270	340	

Conclusions

- MCNP6.1 and SCALE6.1 Successfully Re-Validated for use at SRS
- Significant Cost in Resources
- Some Negative Impact on Program and Operations

Recommendations

- Treat Validation Tasks as a Project
  - Written plan
  - Defined scope, schedule, and resources
- Have a Written Process for Performing Validations
  - Specify good engineering practices
  - Technical review
- Involve a Wide Array of People
  - Both junior and senior staff
  - Develop a skilled pool for next revision
- Take the Time to do it Right the First Time