VERIFICATION & VALIDATION PROGRAM AT LAWRENCE LIVERMORE NATIONAL LABORATORY: GOALS, METHODS, TIMELINES, AND ISSUES

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This work briefly summarizes the current status of the V&V Program at LLNL regarding goals, methods, timelines, and issues for Verification and Validation (V&V) with Uncertainty Quantification (UQ). Our goals are to evaluate various V&V methods, to apply them to computational simulation analyses, and integrate them into methods for Quantitative Certification techniques for the nuclear stockpile. Methods include qualitative and quantitative V&V processes with numerical values for both (qualitative) V&V Level, and (quantitative) validation statements with confidence-bounded uncertainty bands. Only with *quantitative validation statements* can *quantitative* tradeoffs of various scenarios be made.

Part of the tradeoff and planning process involves short and long term prioritization of V&V needed for various certification capabilities. Sensitivity studies are part of the prioritization process and examples of this are provided. We note the circular dilemma of V&V prioritization because we wish to use sensitivity studies to prioritize our V&V efforts, and yet the sensitivity values are only as credible as the V&V we have already done. V&V must therefore be viewed as an evolutionary process in planning, quantification level, and results. We obtain a working balance of code development, SQA, and V&V for specific applications. Next, models with quantified confidence bounds (Quantitative Validation Statements) of performance and safety margins for various scenarios are applied in assessments of Quantified Reliability at Confidence (QRC).

We summarize with a brief description of how these V&V generated QRC quantities fold into a Value-Engineering methodology for evaluating investment strategies. V&V contributes directly to the decision process for investment, through quantification of uncertainties at confidence for margin and reliability assessments. We quantify this extension of V&V using a Benefit/Cost Ratio (BCR) for tradeoffs and timing decisions. Although there is not a unique BCR, we should explore the bounds of its values for any given decision and we show its relationship to quantified V&V. These concepts are evaluated for particular system requirements. Quantified V&V will show us that there is not a unique BCR – we must explore its bounds for any given decision. Due to the non-uniqueness of any given BCR, we use 3 bins for the decision inputs:

1. High BCR within our V&V bounds: Positive decision indicator [i.e. “do it”]
2. Low BCR within our V&V bounds: Negative decision indicator [i.e. “don’t do it”]
3. BCR varies high to low depending on V&V bounds: more quantification is needed

The end product methodology and dollar benefit can be explained using a Risk=Likelihood*Consequence Matrix. “Risk” can also be quantified and viewed, as we will illustrate, as the “Risk” due to inadequate or mistimed V&V. The use of the BCR enables us to balance the benefits of qualitative and quantitative V&V and timing in a demonstrable way. It is obvious to most that too little V&V is insufficient, while too much V&V is inefficient. The use of a quantified Risk Matrix and the BCR method lets us show how we can determine the level V&V we feel is just right. The evolution from V&V to Reliability at Confidence to Risk is suggested as a tangible way to justify the benefits of investment in V&V.