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Risk Management for Operations of the Los Alamos Critical Experiments Facility

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1. Introduction

The Los Alamos Critical Experiments Facility (LACEF) currently operates two burst reactors (Godiva-IV and Skua), one solution assembly (SHEBA II—Solution High-Energy Burst Assembly), two fast-spectrum benchmark assemblies (Flattop and Big Ten), and five general-purpose remote assembly machines which may be configured with nuclear materials and assembled by remote control. SNM storage vaults support these and other operations at the site.

With this diverse set of operations, several approaches are possible in the analysis and management of risk. The most conservative approach would be to write a safety analysis report (SAR) for each assembly and experiment. A more cost-effective approach is to analyze the probability and consequences of several classes of operations representative of operations on each critical assembly machine and envelope the bounding case accidents.

Although the neutron physics of these machines varies widely, the operations performed at LACEF fall into four operational modes: steady-state mode, approach-to-critical mode, prompt burst mode, and nuclear material operations which can include critical assembly fuel loading. The operational sequences of each mode are very nearly the same, whether operated on one assembly machine or another.

These four activities also correspond to operational modes defined in the LACEF Technical Safety Requirements (TSR). Steady-state mode is for operations between delayed critical and prompt critical with known configurations on well-characterized assemblies. Approach-to-critical operations are used for inverse multiplication approaches to delayed critical with a new configuration. Prompt burst mode is used in conjunction with specific machines to produce reproducible superprompt excursions.

2. Accident Probability Analysis

A fault tree analysis was performed for each of the four activities. The lower levels of each fault tree represent various accident initiators arising from failures of hardware, control channels, or operating personnel. An important part of operations safety is the reliability and response of the operating crew. For many of the accident paths to proceed to completion, the crew must either produce a significant error in predicting criticality or to ignore the loss of an important piece of equipment. A fault tree for steady-state mode operations is shown in Figure 1.

The differences between burst mode operations and steady-state or approach-to-critical operations is readily apparent from this analysis. Steady-state and approach-to-critical operations have the benefit of protecting channels or operators initiating a scram in time to prevent a major excursion and damage to the core. In general, reactivity transients with initial reactor periods greater than 100 ms will be detected and a scram initiated by log-N protect circuits or the operating crew. Burst reactor pulse transients with initial periods of 10 to 100 μs cannot be stopped by mechanical or human intervention before reaching the damage threshold of the core.

Furthermore, accident fault trees reinforce the connection between the LACEF SAR and the TSR. The hardware failures which can initiate a possible accident have been made TSR Limiting Conditions of Operation (LCO). These AND and OR gates are labeled LCO on Figure 1. If an operator continues operation with one of these hardware items failed, a TSR violation is incurred. Operating crews receive training and testing on TSR LCOs and their connection as a possible accident initiator.

3. Bounding Accident Consequence Analysis

The postulated accidents analyzed are a set of ramp and step reactivity insertions which establish an envelope of operations at the LACEF. Point kinetics models with linear reactivity feedback are adequate to provide the source terms for these scenarios in all cases, except where possible hydrodynamic disassembly occurs. The magnitude of the fission energy that may be released in the criticality accident is a function of the intrinsic properties of the material, the geometry of the system, and the amount and rate of reactivity addition beyond critical.

A requirement in critical assembly operations is for flexibility in altering fuel loading and other material inventories. In defining the upper bound of possible energy release resulting from a critical experiment, it is important to define the initial configuration, including reactivity insertion rate, fuel geometry (including any constraining effects), land any operational considerations. Bracketing the magnitude of the energy release by general considerations of fuel material can be insufficient and overly conservative.

These hypothetical accidents cover the operations with the full range of potential fuel types under the broadest range of operational conditions. Each critical assembly and critical experiment assembly machine is housed in a confinement building that is designed to provide confinement appropriate to the level of risk of the operations conducted therein. These analyses do provide guidance in planning experiments and a bounding set of accident consequences and will be used as the basis for the development of emergency planning options and actions for LACEF operations.

4. Summary

The use of an envelope approach to accident analysis is facilitated by the use of classes of operations and the use of bounding case consequence analysis. A simple fault tree analysis of operational modes helps resolve which operations are sensitive to human error and which are initiated by hardware of software failures. Where possible, these errors and failures are blocked by TSR LCOs

5. References

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FIGURE 1
Steady-State Mode Accident Fault Tree