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Title: Layer of Protection Analysis for SIL Determination of the SCRAM System

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<p align="center">NCERC Los Alamos National Laboratory</p>	<p align="center">CALCULATION COVER SHEET</p>	<p>Calculation No: CEF-ENG-CAL-0465, Rev. 5</p>
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<p>PROJECT TITLE / NUMBER: National Criticality Experiments Research Center</p>	<p>CLIENT: Nuclear Engineering and Nonproliferation Division</p>
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<p>CALCULATION TITLE: Layer of Protection Analysis for SIL Determination of the SCRAM System</p>

<p>OBJECTIVE: The purpose of this calculation is to determine the Safety Integrity Level (SIL) required for the SCRAM System at the National Criticality Experiments Research Center (NCERC).</p>
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<p>DOCUMENTS AFFECTED: <i>CEF-ENG-0419, Safety Integrity Level (SIL) Verification of the Safety Instrumented System for the Critical Assembly Machine Installations at the Criticality Experiments Facility (CEF)</i></p>
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Revision Number	Affected Pages	Revision Description	Originator Name / Date	Checker Name / Date	Approver Name / Date
0		Initial Release	Cappiello 8/05		
1		Calculation for all scenarios	Robbins 11/18/05		
2		Format conclusions properly	Robbins	Hayes	Cappiello
3		Using latest PrHA PDSA dated Nov. 2006	Robbins	Hayes	Cappiello
4		Updated using latest DSA PrHA Eff. 03/19/12	Strelow 07/11/13	Hayes 07/11/13	Rhodes 07/11/13
5		Updated to Include Rev. 1, Change Notice 4	Strelow 03/19/15	Hayes 03/19/15	Rhodes 03/19/15

PROJECT NO.:	CALC NO.: CEF-ENG-CAL-0465	REVISION NO.: 5	SHEET No. 1/5
SUBJECT: LAYER OF PROTECTION ANALYSIS FOR THE SCRAM SYSTEM			
PREPARED BY: J. STRELOW	DATE: 19 MAR 2015	CHECKED BY: D. HAYES	DATE: 19 MAR 2015

Purpose

The purpose of this calculation is to determine the Safety Integrity Level (SIL) required for the SCRAM System at the National Criticality Experiments Research Center (NCERC).

System Description

The SCRAM System includes three Programmable Logic Controller (PLC) based subsystems. Each subsystem is designed to open a series of relays to initiate a SCRAM of the critical assembly machines. Each of these subsystems must be verified to meet their required Safety Integrity Level (SIL).

Subsystem #1: If it is determined that an abnormal condition exists, the worker can manually initiate a SCRAM by pushing an e-stop switch (manual pushbutton) located in the assembly bay or on the remote control console.

Subsystem #2: A SCRAM may be initiated by a worker opening the personnel access door to the assembly bay during operation.

Subsystem #3: A SCRAM may be initiated by a Log-N neutron channel sending a signal to the SCRAM system when CAM power reaches a preset value.

ISA 84.01 defines the 3 discrete Safety Integrity Levels (SIL) in terms of Probability of Failure on Demand (PFD). Shown below are these probabilities:

SIL 1 = 10^{-1} to 10^{-2}

SIL 2 = 10^{-2} to 10^{-3}

SIL 3 = 10^{-3} to 10^{-4}

Methodology

The methodology used to determine the Safety Integrity Level (SIL) is described in Chapter 8 of the LANL Engineering Standards Manual (Reference 1). In brief, the Documented Safety Analysis (DSA) (Reference 2) lists various accident scenarios in Appendix A and lists the uncontrolled frequency of each scenario. The DSA then credits one or more of the three SCRAM System subsystems as a preventive engineering control to reduce the frequency of that particular accident scenario.

This document uses Layer Of Protection Analysis (LOPA) to determine the required SIL for the SCRAM System. Two assumptions are made for these calculations. First, the uncontrolled frequency for the calculation is assumed to be the middle of the bin. That is, if the uncontrolled frequency is Bin II, the frequency is assumed to be 10^{-3} . Second, the required controlled frequency for the calculation is assumed to be "one half decade beyond the minimum". That is, if the required controlled frequency is Bin III, the frequency is assumed to be 5.0×10^{-5} .

Calculation

One or more of the three SCRAM System subsystems are identified as safety significant controls for several scenarios in the Process Hazard Analysis (PrHA) section of the DSA. The scenarios listed below are those that credit the SCRAM System for a reduction in frequency.

PROJECT NO.:	CALC No.: CEF-ENG-CAL-0465	REVISION No.: 5	SHEET No. 3/5
SUBJECT: LAYER OF PROTECTION ANALYSIS FOR THE SCRAM SYSTEM			
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The 9 accident scenarios above that credit the SCRAM System fit into the 3 categories shown below:

Category	Initial Freq	Final Freq	P.E. Control Credited	Accident Scenarios Fitting this Category
1	I	II	Manual SCRAM Buttons Door Interlock	REA-11, REA-20 REB -06
2	I	II	Log-N Channels	REA-14, REB-03, REB-04
3	II	II	Door Interlock	REA-13, REA-21, REB-08

For the purposes of the calculations, there is a single Independent Protection Layer defined as follows:

Independent Protection Layer 1 (IPL-1) is the SCRAM System consisting of the SCRAM Safety System (SSS) and the Safety Shutdown Mechanism (SSM). The SSS includes the following initiating subsystems that may individually or in combination activate the SSM for the critical assemblies within the cell.

- Manual SCRAM buttons
- Door interlock
- Log-N channel input

Below, a Layer Of Protection Analysis (LOPA) is performed for Category 1 and Category 2 accident scenarios. Category 3 accident scenario does not involve a reduction in frequency, so a LOPA is not required.

PROJECT No.:	CALC No.: CEF-ENG-CAL-0465	REVISION No.: 5	SHEET No. 4/5
SUBJECT: LAYER OF PROTECTION ANALYSIS FOR THE SCRAM SYSTEM			
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For accident scenarios fitting category 1:

Unmitigated Hazardous Event	Independent Protection Layer 1 (manual SCRAM buttons)	Unacceptable Consequence Likelihood
	IPL-1 Fails	Likelihood
	PFD_{IPL-1}	Frequency Bin II $<5.0 \times 10^{-3}$ events/year
REA-11, REA-20, REB-06 Frequency Bin I 10^{-1} events/year		
	Independent Protection Layer Operates	No Impact

$10^{-1} * PFD_{IPL-1} < 5.0 * 10^{-3}$
Therefore: $PFD_{IPL-1} < 5.0 * 10^{-2}$

Unmitigated Hazardous Event	Independent Protection Layer 1 (door interlock)	Unacceptable Consequence Likelihood
	IPL-1 Fails	Likelihood
	PFD_{IPL-1}	Frequency Bin II $<5.0 \times 10^{-3}$ events/year
REA-11, REA-20, REB-06 Frequency Bin I 10^{-1} events/year		
	Independent Protection Layer Operates	No Impact

$10^{-1} * PFD_{IPL-1} < 5.0 * 10^{-3}$
Therefore: $PFD_{IPL-1} < 5.0 * 10^{-2}$

PROJECT NO.:	CALC No.: CEF-ENG-CAL-0465	REVISION No.: 5	SHEET No. 5/5
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For accident scenarios fitting category 2:

Unmitigated Hazardous Event	Independent Protection Layer 1 (Log-N channels)	Unacceptable Consequence Likelihood
	IPL-1 Fails	Likelihood
	PFD _{IPL-1}	Frequency Bin II <5.0x10 ⁻³ events/year
REA-14, REB-03, REB-04 Frequency Bin I 10 ⁻¹ events/year		
	Independent Protection Layer Operates	No Impact

$$10^{-1} * PFD_{IPL-1} < 5.0 * 10^{-3}$$

$$\text{Therefore: } PFD_{IPL-1} < 5.0 * 10^{-2}$$

Conclusion

For category 1 accident scenario: $PFD_{IPL-1} < 5.0 * 10^{-2}$ (initiated by manual SCRAM buttons OR door interlock)

For category 2 accident scenario: $PFD_{IPL-1} < 5.0 * 10^{-2}$ (initiated by Log-N Channels)

For category 3 accident scenario there is no reduction in frequency

In all categories above, the PFD required is $< 5.0 * 10^{-2}$. The Safety Integrity Level (SIL) for a PFD of $< 5.0 * 10^{-2}$ is SIL 1 = 10^{-1} to 10^{-2} .

References:

1. STD-342-100, *LANL Engineering Standards Manual*, Chapter 8, Attachment A, Attachment 1, Rev. 2, 9/29/14.
2. LLNL-MI-407120, *Device Assembly Facility Documented Safety Analysis Addendum for Criticality Experiments Facility Operations*, Revision 1 – Input for NSTec, Change Notice 4, Eff. 08/20/14.