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MFN 06-373

Docket No. 52-010

October 6, 2006

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, D.C. 20555-0001

Subject: **Response to Portion of NRC Request for Additional Information Letter No. 59 Related to ESBWR Design Certification Application – Probabilistic Risk Assessment - RAI Numbers 19.1-22, 19.1-24, 19.1-25, 19.1-27, 19.1-28, 19.1-29, 19.1-30, 19.1-32, 19.1-33, 19.1-34, 19.1-36, 19.1-38, 19.1-40, and 19.1-41**

Enclosure 1 contains GE's response to the subject NRC RAI transmitted via the Reference 1 letter.

If you have any questions about the information provided here, please let me know.

Sincerely,

Kathy Sedney for

David H. Hinds
Manager, ESBWR

D068

Enclosure:

1. MFN 06-373 - Response to Portion of NRC Request for Additional Information Letter No. 59 Related to ESBWR Design Certification Application – Probabilistic Risk Assessment - RAI Numbers 19.1-22, 19.1-24, 19.1-25, 19.1-27, 19.1-28, 19.1-29, 19.1-30, 19.1-32, 19.1-33, 19.1-34, 19.1-36, 19.1-38, 19.1-40, and 19.1-41

Reference:

1. MFN 06-329, Letter from U. S. Nuclear Regulatory Commission to Mr. David H. Hinds, *Request for Additional Information Letter No. 59 Related to ESBWR Design Certification Application,* September 13, 2006

cc: AE Cubbage USNRC (with enclosures)
GB Stramback GE/San Jose (with enclosures)
DReF 0000-0059-2973

ENCLOSURE 1

MFN 06-373

Response to Portion of NRC Request for

Additional Information Letter No. 59

Related to ESBWR Design Certification Application

Probabilistic Risk Assessment

RAI Numbers 19.1-22, 19.1-24, 19.1-25, 19.1-27, 19.1-28, 19.1-29, 19.1-30, 19.1-32, 19.1-33, 19.1-34, 19.1-36, 19.1-38, 19.1-40, and 19.1-41

NRC RAI 19.1-22

NEDO-33201, Tables 4.5-5, Common Cause Failure (CCF), and 4.5-7, List of System Basic Events, are included in Section 4.5 without any discussion. It is not clear to the staff how some of the probabilities reported in these two tables were obtained. Examples are: (1) the basis for the probability of basic event C51-ACT-LO-CHASRNM (1.90E-02); (2) the reason some basic events with same code (e.g., VLU-FC) have different failure probabilities; and (3) the reason that some CCFs, involving software failure, mentioned in Section 5.3.5 (e.g., C74-DTM-CF-RTIFALL) are not included in Table 4.5-5.

(A) Provide complete lists of I&C basic and CCF events and discuss how the associated failure probabilities were calculated.

(B) Discuss how the potential for CCF (both hardware and software) was investigated. Include discussion on the following:

-The potential for software failure within subsystems and among cards;
-Sensor and transmitter miscalibration;
-Loss of cooling ventilation;
-Manufacturing and installation errors;
-Earthquake and fire;
-Setpoint drift or incorrect setpoint;
-Maintenance and test errors; and
-Electromagnetic interference

GE Response:

A list of I&C basic events is provided in Table 19.1-22-1. A list of I&C CCF events is provided in Table 19.1-22-2.

A discussion of how the basic event and common cause failure probabilities are calculated is found in NEDO-33201 Sections 5.2 and 5.3, respectively. This includes a discussion on how basic events with the same code (e.g., VLU-FC) have the same demand failure rate, but may have different test intervals, thus resulting in different failure probabilities.

The design of the I&C systems is not complete. Therefore, the lists provided in response to this RAI contain all of the I&C basic events and common cause failures representing all I&C components that are in the current PRA model. In addition, a discussion on the potential for hardware and software CCF will not be available until the I&C design is complete. When the design is complete, this information will be available in the updated PRA model.

Note that the mean failure rate in Table 19.1-22-1 for the type "ACT-LO" has been revised. The original failure rate was reported as 2.20E-6/hr, which was found to be in error. The actual failure rate is 1.20E-6/hr, per IEEE-Std-500. The erroneous data value was reported to the NRC in Table 19.1.0-5-1, which was provided in response to NRC RAI 19.1.0-5 (Reference MFN 06-20, January 23, 2006.) The erroneous data point has been corrected and will be reflected in a future revision to NEDO-33201. The effect of the data error on the CDF is insignificant because the erroneous value is slightly higher and thus, more conservative, than the original value.

No DCD changes will be made in response to this RAI.

Table 19.1-22-1 I&C Independent Failure Basic Event List

NAME(BE)	DESC	SOURCE(*)	DIST	Generic data	Tmission	Ttest	EF	P/lambda	d/h	Type	Lambda Standby (/hr)	Unavailability	Notes
B21-LT_-NO-DPSWRA	DPS WIDE RANGE LEVEL TRANSMITTER A (LEVEL 1&2) FAILS	Advanced Light Water	L	1.00E-06	24	0	10	1.00E-06	hr	LT_-NO		2.40E-05	
B21-LT_-NO-DPSWRB	DPS WIDE RANGE LEVEL TRANSMITTER B (LEVEL 1&2) FAILS	Advanced Light Water	L	1.00E-06	24	0	10	1.00E-06	hr	LT_-NO		2.40E-05	
B21-LT_-NO-DPSWRC	DPS WIDE RANGE LEVEL TRANSMITTER C (LEVEL 1&2) FAILS	Advanced Light Water	L	1.00E-06	24	0	10	1.00E-06	hr	LT_-NO		2.40E-05	
B21-LT_-NO-DPSWRD	DPS WIDE RANGE LEVEL TRANSMITTER D (LEVEL 1&2) FAILS	Advanced Light Water	L	1.00E-06	24	0	10	1.00E-06	hr	LT_-NO		2.40E-05	
B21-LT_-NO-N001A	WIDE RANGE LEVEL TRANSMITTER 1A (LEVEL 1&2) FAILS	Advanced Light Water	L	1.00E-06	24	0	10	1.00E-06	hr	LT_-NO		2.40E-05	
B21-LT_-NO-N001B	WIDE RANGE LEVEL TRANSMITTER 1B (LEVEL 1&2) FAILS	Advanced Light Water	L	1.00E-06	24	0	10	1.00E-06	hr	LT_-NO		2.40E-05	
B21-LT_-NO-N001C	WIDE RANGE LEVEL TRANSMITTER 1C (LEVEL 1&2) FAILS	Advanced Light Water	L	1.00E-06	24	0	10	1.00E-06	hr	LT_-NO		2.40E-05	
B21-LT_-NO-N001D	WIDE RANGE LEVEL TRANSMITTER 1D (LEVEL 1&2) FAILS	Advanced Light Water	L	1.00E-06	24	0	10	1.00E-06	hr	LT_-NO		2.40E-05	
B21-OR_-PG-01A	ORIFICE INSTR. LINE 1A FAILS TO REMAIN OPEN (PLUG)	NUREG/CR-2815	L	6.00E-07	24	0	3	6.00E-07	hr	OR_-PG		1.44E-05	
B21-OR_-PG-01B	ORIFICE INSTR. LINE 1B FAILS TO REMAIN OPEN (PLUG)	NUREG/CR-2815	L	6.00E-07	24	0	3	6.00E-07	hr	OR_-PG		1.44E-05	
B21-OR_-PG-01C	ORIFICE INSTR. LINE 1C FAILS TO REMAIN OPEN (PLUG)	NUREG/CR-2815	L	6.00E-07	24	0	3	6.00E-07	hr	OR_-PG		1.44E-05	
B21-OR_-PG-01D	ORIFICE INSTR. LINE 1D FAILS TO REMAIN OPEN (PLUG)	NUREG/CR-2815	L	6.00E-07	24	0	3	6.00E-07	hr	OR_-PG		1.44E-05	
C31-VLU-FC-RUNBACK	C31 SYSTEM VOTER LOGIC UNIT FAILS	GENERAL ELECTRIC	L	7.80E-05	0	0(1)	10	7.80E-05	d	VLU-FC		7.80E-05	
C51-ACT-LO-CHASRNM	SRNM CHANNEL A FAILS	IEEE-Std-500	L	1.20E-06	0	17520	10	1.20E-06	hr	ACT-LO		1.04E-02	The generic data has been changed in the new review of PRA
C51-ACT-LO-CHBSRNM	SRNM CHANNEL B FAILS	IEEE-Std-500	L	1.20E-06	0	17520	10	1.20E-06	hr	ACT-LO		1.04E-02	The generic data has been changed in the new review of PRA
C51-ACT-LO-CHCSRNM	SRNM CHANNEL C FAILS	IEEE-Std-500	L	1.20E-06	0	17520	10	1.20E-06	hr	ACT-LO		1.04E-02	The generic data has been changed in the new review of PRA
C51-ACT-LO-CHDSRNM	SRNM CHANNEL D FAILS	IEEE-Std-500	L	1.20E-06	0	17520	10	1.20E-06	hr	ACT-LO		1.04E-02	The generic data has been changed in the new review of PRA
C51-VLU-FC-1APRM	APRM DIV I 2/4 MODULE FAILS	GENERAL ELECTRIC	L	7.80E-05	0	0(1)	10	7.80E-05	d	VLU-FC		7.80E-05	
C51-VLU-FC-2APRM	APRM DIV II 2/4 MODULE FAILS	GENERAL ELECTRIC	L	7.80E-05	0	0(1)	10	7.80E-05	d	VLU-FC		7.80E-05	
C51-VLU-FC-3APRM	APRM DIV III 2/4 MODULE FAILS	GENERAL ELECTRIC	L	7.80E-05	0	0(1)	10	7.80E-05	d	VLU-FC		7.80E-05	
C51-VLU-FC-4APRM	APRM DIV IV 2/4 MODULE FAILS	GENERAL ELECTRIC	L	7.80E-05	0	0(1)	10	7.80E-05	d	VLU-FC		7.80E-05	
C62-BYP-FC-DIVBN1E	BYPASS UNIT DIV B(N1E) FAILS TO FUNCTION	IF-R-389/MIL-HDBK-217C	L	5.00E-06	60	0	10	5.00E-06	hr	BYP-FC		3.00E-04	
C62-BYP-FC-DIVCN1E	BYPASS UNIT DIV C (N1E) FAILS TO FUNCTION	IF-R-389/MIL-HDBK-217C	L	5.00E-06	60	0	10	5.00E-06	hr	BYP-FC		3.00E-04	
C62-VLU-FC-ESF1ADID	1ST DIV A ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C62-VLU-FC-ESF1BDID	1ST DIV B ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	

Table 19.1-22-1 I&C Independent Failure Basic Event List

NAME(BE)	DESC	SOURCE(*)	DIST	Generic data	Tmission	Ttest	EF	P/lambda	d/h	Type	Lambda Standby (/hr)	Unavailability	Notes
C62-VLU-FC-ESF1BN1E	1ST DIV B N1E ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C62-VLU-FC-ESF1CDID	1ST DIV C (DID) ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C62-VLU-FC-ESF1CN1E	1ST DIV C N1E ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C62-VLU-FC-ESF2ADID	2ND DIV A (DID) ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C62-VLU-FC-ESF2BDID	2ND DIV B (DID) ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C62-VLU-FC-ESF2BN1E	2ND DIV B (N1E) ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C62-VLU-FC-ESF2CDID	2ND DIV C(DID) ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C62-VLU-FC-ESF2CN1E	2ND DIV C (N1E) ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C72-BYP-FC-DPSDIV1	BYPASS UNIT DIV 1 FAILS TO FUNCTION	IF-R-389/MIL-HDBK-217C	L	5.00E-06	60	0	10	5.00E-06	hr	BYP-FC		3.00E-04	
C72-BYP-FC-DPSDIV2	BYPASS UNIT DIV 1 FAILS TO FUNCTION	IF-R-389/MIL-HDBK-217C	L	5.00E-06	60	0	10	5.00E-06	hr	BYP-FC		3.00E-04	
C72-BYP-FC-DPSDIV3	BYPASS UNIT DIVIII FAILS TO FUNCTION	IF-R-389/MIL-HDBK-217C	L	5.00E-06	60	0	10	5.00E-06	hr	BYP-FC		3.00E-04	
C72-BYP-FC-DPSDIV4	BYPASS UNIT DIVIV FAILS TO FUNCTION	IF-R-389/MIL-HDBK-217C	L	5.00E-06	60	0	10	5.00E-06	hr	BYP-FC		3.00E-04	
C72-DTM-FC-DPSDIV1	DTM OF DPS DIV. 1 FAILS TO TRIP	Engineering Criteria	L	6.00E-04	0	2160	10	6.00E-04	d	DTM-FC		6.00E-04	
C72-DTM-FC-DPSDIV2	DTM OF DPV DIV. 2 FAILS TO TRIP	Engineering Criteria	L	6.00E-04	0	2160	10	6.00E-04	d	DTM-FC		6.00E-04	
C72-DTM-FC-DPSDIV3	DTM OF DPS DIV. 3 FAILS TO TRIP	Engineering Criteria	L	6.00E-04	0	2160	10	6.00E-04	d	DTM-FC		6.00E-04	
C72-DTM-FC-DPSDIV4	DTM OF DPS DIV. 4 FAILS TO TRIP	Engineering Criteria	L	6.00E-04	0	2160	10	6.00E-04	d	DTM-FC		6.00E-04	
C72-VLU-FC-DPSESF11	1ST DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C72-VLU-FC-DPSESF12	1ST DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C72-VLU-FC-DPSESF13	1ST DIV III ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C72-VLU-FC-DPSESF14	1ST DIV IV ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C72-VLU-FC-DPSESF21	2ND DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C72-VLU-FC-DPSESF22	2ND DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C72-VLU-FC-DPSESF23	2ND DIV III ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C72-VLU-FC-DPSESF24	2ND DIV IV ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C74-BYP-FC-DIV1	BYPASS UNIT DIV 1 FAILS TO FUNCTION	IF-R-389/MIL-HDBK-217C	L	5.00E-06	60	0	10	5.00E-06	hr	BYP-FC		3.00E-04	
C74-BYP-FC-DIV2	BYPASS UNIT DIV 1 FAILS TO FUNCTION	IF-R-389/MIL-HDBK-217C	L	5.00E-06	60	0	10	5.00E-06	hr	BYP-FC		3.00E-04	

Table 19.1-22-1 I&C Independent Failure Basic Event List

NAME(BE)	DESC	SOURCE(*)	DIST	Generic data	Tmission	Ttest	EF	P/lambda	d/h	Type	Lambda Standby (/hr)	Unavailability	Notes
C74-BYP-FC-DIV3	BYPASS UNIT DIVIII FAILS TO FUNCTION	IF-R-389/MIL-HDBK-217C	L	5.00E-06	60	0	10	5.00E-06	hr	BYP-FC		3.00E-04	
C74-BYP-FC-DIV4	BYPASS UNIT DIVIV FAILS TO FUNCTION	IF-R-389/MIL-HDBK-217C	L	5.00E-06	60	0	10	5.00E-06	hr	BYP-FC		3.00E-04	
C74-BYP-FC-DIVADID	BYPASS UNIT DIV A (DID) FAILS TO FUNCTION	IF-R-389/MIL-HDBK-217C	L	5.00E-06	60	0	10	5.00E-06	hr	BYP-FC		3.00E-04	
C74-BYP-FC-DIVBDID	BYPASS UNIT DIV B (DID) FAILS TO FUNCTION	IF-R-389/MIL-HDBK-217C	L	5.00E-06	60	0	10	5.00E-06	hr	BYP-FC		3.00E-04	
C74-BYP-FC-DIVCDID	BYPASS UNIT DIV C(DID) FAILS TO FUNCTION	IF-R-389/MIL-HDBK-217C	L	5.00E-06	60	0	10	5.00E-06	hr	BYP-FC		3.00E-04	
C74-DTM-FC-DIV1	DTM OF SSLC DIV. 1 FAILS TO TRIP	Engineering Criteria	L	6.00E-04	0	2160	10	6.00E-04	d	DTM-FC		6.00E-04	
C74-DTM-FC-DIV2	DTM OF SSLC DIV. 2 FAILS TO TRIP	Engineering Criteria	L	6.00E-04	0	2160	10	6.00E-04	d	DTM-FC		6.00E-04	
C74-DTM-FC-DIV3	DTM OF SSLC DIV. 3 FAILS TO TRIP	Engineering Criteria	L	6.00E-04	0	2160	10	6.00E-04	d	DTM-FC		6.00E-04	
C74-DTM-FC-DIV4	DTM OF SSLC DIV. 4 FAILS TO TRIP	Engineering Criteria	L	6.00E-04	0	2160	10	6.00E-04	d	DTM-FC		6.00E-04	
C74-VLU-FC-ESF11	1ST DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C74-VLU-FC-ESF12	1ST DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C74-VLU-FC-ESF13	1ST DIV III ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C74-VLU-FC-ESF14	1ST DIV IV ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C74-VLU-FC-ESF21	2ND DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C74-VLU-FC-ESF22	2ND DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C74-VLU-FC-ESF23	2ND DIV III ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
C74-VLU-FC-ESF24	2ND DIV IV ESF VOTER LOGIC UNIT FAILS TO FUNCTION	GENERAL ELECTRIC	L	7.80E-05	0	17520	10	7.80E-05	d	VLU-FC	7.12E-08	6.24E-04	
H23-EMS-FC-DIV1	ESSENTIAL MULTIPLEXING SYSTEM DIV 1 FAILS TO FUNCTION	Engineering Criteria	L	1.00E-05	60	0	10	1.00E-05	hr	EMS-FC		6.00E-04	
H23-EMS-FC-DIV2	ESSENTIAL MULTIPLEXING SYSTEM DIV 2 FAILS TO FUNCTION	Engineering Criteria	L	1.00E-05	60	0	10	1.00E-05	hr	EMS-FC		6.00E-04	
H23-EMS-FC-DIV3	ESSENTIAL MULTIPLEXING SYSTEM DIV 3 FAILS TO FUNCTION	Engineering Criteria	L	1.00E-05	60	0	10	1.00E-05	hr	EMS-FC		6.00E-04	
H23-EMS-FC-DIV4	ESSENTIAL MULTIPLEXING SYSTEM DIV 4 FAILS TO FUNCTION	Engineering Criteria	L	1.00E-05	60	0	10	1.00E-05	hr	EMS-FC		6.00E-04	
H23-EMS-FC-DIVADID	ESSENTIAL MULTIPLEXING SYSTEM DIV A (DID) FAILS TO FUNCTION	Engineering Criteria	L	1.00E-05	60	0	10	1.00E-05	hr	EMS-FC		6.00E-04	
H23-EMS-FC-DIVBDID	ESSENTIAL MULTIPLEXING SYSTEM DIV B (DID) FAILS TO FUNCTION	Engineering Criteria	L	1.00E-05	60	0	10	1.00E-05	hr	EMS-FC		6.00E-04	
H23-EMS-FC-DIVBN1E	ESSENTIAL MULTIPLEXING SYSTEM DIV B (N1E) FAILS TO FUNCTION	Engineering Criteria	L	1.00E-05	60	0	10	1.00E-05	hr	EMS-FC		6.00E-04	
H23-EMS-FC-DIVCDID	ESSENTIAL MULTIPLEXING SYSTEM DIV C(DID) FAILS TO FUNCTION	Engineering Criteria	L	1.00E-05	60	0	10	1.00E-05	hr	EMS-FC		6.00E-04	
H23-EMS-FC-DIVCN1E	ESSENTIAL MULTIPLEXING SYSTEM DIV C (N1E) FAILS TO FUNCTION	Engineering Criteria	L	1.00E-05	60	0	10	1.00E-05	hr	EMS-FC		6.00E-04	

Table 19.1-22-1 I&C Independent Failure Basic Event List

NAME(BE)	DESC	SOURCE(*)	DIST	Generic data	Tmission	Ttest	EF	P/lambda	d/h	Type	Lambda Standby (/hr)	Unavailability	Notes
H23-EMS-FC-DPSDIV1	ESSENTIAL MULTIPLEXING SYSTEM DPS DIV 1 FAILS TO FUNCTION	Engineering Criteria	L	1.00E-05	60	0	10	1.00E-05	hr	EMS-FC		6.00E-04	
H23-EMS-FC-DPSDIV2	ESSENTIAL MULTIPLEXING SYSTEM DPS DIV 2 FAILS TO FUNCTION	Engineering Criteria	L	1.00E-05	60	0	10	1.00E-05	hr	EMS-FC		6.00E-04	
H23-EMS-FC-DPSDIV3	ESSENTIAL MULTIPLEXING SYSTEM DPS DIV 3 FAILS TO FUNCTION	Engineering Criteria	L	1.00E-05	60	0	10	1.00E-05	hr	EMS-FC		6.00E-04	
H23-EMS-FC-DPSDIV4	ESSENTIAL MULTIPLEXING SYSTEM DPS DIV 4 FAILS TO FUNCTION	Engineering Criteria	L	1.00E-05	60	0	10	1.00E-05	hr	EMS-FC		6.00E-04	
H23-RMU-FC-1ADS	RMU 001 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-2ADS	RMU 002 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-DIV1	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-DIV2	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-DIV3	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-DIV4	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-DPS1ADS	RMU 001 FOR MANUAL DPS ACTUATION IN CONTROL ROOM FAILS	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-DPS2ADS	RMU 002 FOR MANUAL DPS ACTUATION IN CONTROL ROOM FAILS	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-DPSDIV1	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-DPSDIV2	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-DPSDIV3	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-DPSDIV4	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-DPSESF11	1ST DIV II ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-DPSESF12	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-DPSESF13	1ST DIV III ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-DPSESF14	1ST DIV IV ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-DPSESF21	2ND DIV 1 ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-DPSESF22	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-DPSESF23	2ND DIVIII ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-DPSESF24	2ND DIVIII ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-ESF11	1ST DIV II ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-ESF12	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	

Table 19.1-22-1 I&C Independent Failure Basic Event List														
NAME(BE)	DESC	SOURCE(*)	DIST	Generic data	Tmission	Ttest	EF	P/lambda	d/h	Type	Lambda Standby (/hr)	Unavailability	Notes
H23-RMU-FC-ESF13	1ST DIV III ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-ESF14	1ST DIV IV ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-ESF1ADID	1ST DIV A (DID) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-ESF1BDID	1ST DIV B (DID) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-ESF1BN1E	1ST DIV B (N1E) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-ESF1CDID	1ST DIV C (DID) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-ESF1CN1E	1ST DIV C (N1E) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-ESF21	2ND DIV 1 ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-ESF22	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-ESF23	2ND DIVIII ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-ESF24	2ND DIVIII ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-ESF2ADID	2ND DIV A (DID) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-ESF2BDID	2ND DIV B (DID) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-ESF2BN1E	2ND DIV B (N1E) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-ESF2CDID	2ND DIV C DID ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	
H23-RMU-FC-ESF2CN1E	2ND DIV C (N1E) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION	NUMAC Field Data, B. Simon	L	5.00E-06	60	0	10	5.00E-06	hr	RMU-FC		3.00E-04	

(*) The generic sources were revised following RAI 19.1.0-5.
(1) Immediate detection of failure

Table 19.1-22-2 I&C CCF List

Basic Event	Population m	Component Type-Failure Mode	Independent Failure Mode	Independent Failure Rate	Error factor EF	(d=demand, hr=hour)	CCF factor fcc	CCF model	CCF (alpha factors) Source	Mission Time Tm (Hours)	Test period Tp (Hours)	Standby Failure Rate	Unavailability	Description of the basic event
B21-LT_-CF-DPSWR	4	LT_-CF	NO	1.00E-06	10	hr	5.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	24			1.20E-07	CCF OF DPS WR LEVEL TRANSMITTERS
B21-LT_-CF-N001A/B/C/D	4	LT_-CF	NO	1.00E-06	10	hr	5.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	24			1.20E-07	CCF OF DIVERSIFIED LEVEL 1 & 2 TRANSM. 10A/B/C/D
C51-ACT-CF-1PRM	4	ACT-CF	FC	6.80E-06	10	hr	5.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)		17520		2.98E-04	CCF APRM NEUTRON CHANNELS
C51-ACT-CF-APRMSTUCK	4	ACT-CF	NO	1.80E-06	10	hr	5.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	24			2.16E-07	CCF APRM DETECTORS STUCK AT POWER LEVEL
C51-ACT-CF-SRNM	4	ACT-CF	FC	6.80E-06	10	hr	5.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)		17520		2.98E-04	CCF OF SRNM CORE FLUX CHANNELS
C51-VLU-CF-1PRM	4	VLU-CF	FC	7.80E-05	10	d	1.20E-02	GS	generic alphas (NUREG/CR-5801 p. 36)		0[1]		9.36E-07	PRNM DIV I 2/4 MODULES FAILS
C51-VLU-CF-2PRM	4	VLU-CF	FC	7.80E-05	10	d	1.20E-02	GS	generic alphas (NUREG/CR-5801 p. 36)		0[1]		9.36E-07	PRNM DIV II 2/4 MODULES FAILS
C51-VLU-CF-APRM	4	VLU-CF	FC	7.80E-05	10	d	1.20E-02	GS	generic alphas (NUREG/CR-5801 p. 36)		0[1]		9.36E-07	CCF 2/4 MODULES APRM
C62-BYP-CF-N1EALL	2	BYP-CF	FC	5.00E-06	10	hr	5.00E-02	GO	generic alphas (NUREG/CR-5801 p. 36)	60			1.50E-05	CCF OF BYPASS UNITS (N1E)
C62-VLU-CF-DIDALL	2	VLU-CF	FC	7.80E-05	10	d	5.00E-02	GS	generic alphas (NUREG/CR-5801 p. 36)		17520	7.12E-08	3.12E-05	CCF OF VOTER LOGIC UNITS
C62-VLU-CF-N1EALL	2	VLU-CF	FC	7.80E-05	10	d	5.00E-02	GS	generic alphas (NUREG/CR-5801 p. 36)		17520	7.12E-08	3.12E-05	CCF OF VOTER LOGIC UNITS
C72-BYP-CF-DPSALL	4	BYP-CF	FC	5.00E-06	10	hr	5.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	60			1.50E-06	CCF OF BYPASS UNITS
C72-DTM-CF-DPSALL	4	DTM-CF	FC	6.00E-04	10	d	3.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)		2160		1.18E-05[2]	CCF 3/4 DTM OF DPS DIV 1/2/3/4
C72-VLU-CF-DPSALL	2	VLU-CF	FC	7.80E-05	10	d	5.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)		17520	7.12E-08	3.12E-06	CCF OF VOTER LOGIC UNITS
C74-BYP-CF-ALL	4	BYP-CF	FC	5.00E-06	10	hr	5.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	60			1.50E-06	CCF OF BYPASS UNITS
C74-BYP-CF-DIDALL	4	BYP-CF	FC	5.00E-06	10	hr	3.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	60			9.00E-07	CCF OF BYPASS UNITS (DID)
C74-DTM-CF-ALL	4	DTM-CF	FC	6.00E-04	10	d	3.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)		2160		1.18E-05[2]	CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-VLU-CF-ALL	2	VLU-CF	FC	7.80E-05	10	d	5.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)		17520	7.12E-08	3.12E-06	CCF OF VOTER LOGIC UNITS
C74-VLU-CF-ATWS	2	VLU-CF	FC	7.80E-05	10	d	5.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)		17520	7.12E-08	3.12E-06	CCF 3/4 VOTING LOGIC UNIT ATWS DIVISSIONS
H23-EMS-CF-ALL	4	EMS-CF	FC	1.00E-05	10	hr	3.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	60			1.80E-06	CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4
H23-EMS-CF-DIDALL	4	EMS-CF	FC	1.00E-05	10	hr	3.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	60			1.80E-06	CCF OF ALL DIVISION OF THE EMS
H23-EMS-CF-DPSALL	4	EMS-CF	FC	1.00E-05	10	hr	3.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	60			1.80E-06	CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4
H23-EMS-CF-N1EALL	4	EMS-CF	FC	1.00E-05	10	hr	3.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	60			1.80E-06	CCF OF ALL DIVISION OF THE EMS
H23-RMU-CF-ALL	4	RMU-CF	FC	5.00E-06	10	hr	3.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	60			9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE
H23-RMU-CF-DIDALL	4	RMU-CF	FC	5.00E-06	10	hr	3.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	60			9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS (DID)
H23-RMU-CF-DPSALL	4	RMU-CF	FC	5.00E-06	10	hr	3.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	60			9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE
H23-RMU-CF-N1EALL	4	RMU-CF	FC	5.00E-06	10	hr	3.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	60			9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS (NO 1E) TO OPERATE

(1) Immediate detection of failure
(2) A contribution of 1E-05 is added to the CCF estimation to considerer software CCF contribution

Table 19.1-22-2 I&C CCF List

Basic Event	Population m	Component Type-Failure Mode	Independent Failure Mode	Independent Failure Rate	Error factor EF	(d=demand, hr=hour)	CCF factor fcc	CCF model	CCF (alpha factors) Source	Mission Time Tm (Hours)	Test period Tp (Hours)	Standby Failure Rate	Unavailability	Description of the basic event
B21-LT_-CF-DPSWR	4	LT_-CF	NO	1.00E-06	10	hr	5.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	24			1.20E-07	CCF OF DPS WR LEVEL TRANSMITTERS
B21-LT_-CF-N001A/B/C/D	4	LT_-CF	NO	1.00E-06	10	hr	5.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	24			1.20E-07	CCF OF DIVERSIFIED LEVEL 1 & 2 TRANSM. 10A/B/C/D
C51-ACT-CF-1PRM	4	ACT-CF	FC	6.80E-06	10	hr	5.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)		17520		2.98E-04	CCF APRM NEUTRON CHANNELS
C51-ACT-CF-APRMSTUCK	4	ACT-CF	NO	1.80E-06	10	hr	5.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	24			2.16E-07	CCF APRM DETECTORS STUCK AT POWER LEVEL
C51-ACT-CF-SRNM	4	ACT-CF	FC	6.80E-06	10	hr	5.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)		17520		2.98E-04	CCF OF SRNM CORE FLUX CHANNELS
C51-VLU-CF-1PRM	4	VLU-CF	FC	7.80E-05	10	d	1.20E-02	GS	generic alphas (NUREG/CR-5801 p. 36)		0(1)		9.36E-07	PRNM DIV I 2/4 MODULES FAILS
C51-VLU-CF-2PRM	4	VLU-CF	FC	7.80E-05	10	d	1.20E-02	GS	generic alphas (NUREG/CR-5801 p. 36)		0(1)		9.36E-07	PRNM DIV II 2/4 MODULES FAILS
C51-VLU-CF-APRM	4	VLU-CF	FC	7.80E-05	10	d	1.20E-02	GS	generic alphas (NUREG/CR-5801 p. 36)		0(1)		9.36E-07	CCF 2/4 MODULES APRM
C62-BYP-CF-N1EALL	2	BYP-CF	FC	5.00E-06	10	hr	5.00E-02	GO	generic alphas (NUREG/CR-5801 p. 36)	60			1.50E-05	CCF OF BYPASS UNITS (N1E)
C62-VLU-CF-DIDALL	2	VLU-CF	FC	7.80E-05	10	d	5.00E-02	GS	generic alphas (NUREG/CR-5801 p. 36)		17520	7.12E-08	3.12E-05	CCF OF VOTER LOGIC UNITS
C62-VLU-CF-N1EALL	2	VLU-CF	FC	7.80E-05	10	d	5.00E-02	GS	generic alphas (NUREG/CR-5801 p. 36)		17520	7.12E-08	3.12E-05	CCF OF VOTER LOGIC UNITS
C72-BYP-CF-DPSALL	4	BYP-CF	FC	5.00E-06	10	hr	5.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	60			1.50E-06	CCF OF BYPASS UNITS
C72-DTM-CF-DPSALL	4	DTM-CF	FC	6.00E-04	10	d	3.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)		2160		1.18E-05(2)	CCF 3/4 DTM OF DPS DIV 1/2/3/4
C72-VLU-CF-DPSALL	2	VLU-CF	FC	7.80E-05	10	d	5.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)		17520	7.12E-08	3.12E-06	CCF OF VOTER LOGIC UNITS
C74-BYP-CF-ALL	4	BYP-CF	FC	5.00E-06	10	hr	5.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	60			1.50E-06	CCF OF BYPASS UNITS
C74-BYP-CF-DIDALL	4	BYP-CF	FC	5.00E-06	10	hr	3.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	60			9.00E-07	CCF OF BYPASS UNITS (DID)
C74-DTM-CF-ALL	4	DTM-CF	FC	6.00E-04	10	d	3.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)		2160		1.18E-05(2)	CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-VLU-CF-ALL	2	VLU-CF	FC	7.80E-05	10	d	5.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)		17520	7.12E-08	3.12E-06	CCF OF VOTER LOGIC UNITS
C74-VLU-CF-ATWS	2	VLU-CF	FC	7.80E-05	10	d	5.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)		17520	7.12E-08	3.12E-06	CCF 3/4 VOTING LOGIC UNIT ATWS DIVISSIONS
H23-EMS-CF-ALL	4	EMS-CF	FC	1.00E-05	10	hr	3.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	60			1.80E-06	CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4
H23-EMS-CF-DIDALL	4	EMS-CF	FC	1.00E-05	10	hr	3.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	60			1.80E-06	CCF OF ALL DIVISION OF THE EMS
H23-EMS-CF-DPSALL	4	EMS-CF	FC	1.00E-05	10	hr	3.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	60			1.80E-06	CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4
H23-EMS-CF-N1EALL	4	EMS-CF	FC	1.00E-05	10	hr	3.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	60			1.80E-06	CCF OF ALL DIVISION OF THE EMS
H23-RMU-CF-ALL	4	RMU-CF	FC	5.00E-06	10	hr	3.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	60			9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE
H23-RMU-CF-DIDALL	4	RMU-CF	FC	5.00E-06	10	hr	3.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	60			9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS (DID)
H23-RMU-CF-DPSALL	4	RMU-CF	FC	5.00E-06	10	hr	3.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	60			9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE
H23-RMU-CF-N1EALL	4	RMU-CF	FC	5.00E-06	10	hr	3.00E-03	GS	generic alphas (NUREG/CR-5801 p. 36)	60			9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS (NO 1E) TO OPERATE

(1) Immediate detection of failure
(2) A contribution of 1E-05 is added to the CCF estimation to considerer software CCF contribution

NRC RAI 19.1-24

Explain or clarify assumptions in quantifying the frequency of initiating event categories.

(A) *NUREG/CR-5750 Event QG10, "Inadvertent Open/Close of one Safety/Relief Valve" is considered a contributor to both the frequency of general transients and IORV. Please explain.*

(B) *It is stated that the large, medium and small break frequencies inside containment were calculated by apportioning proportionally the associated NUREG/CR-5750 frequencies to each group of ESBWR lines. However, it appears that these frequencies, as reported in NEDO-33201, Tables 2.3-2 and 2.3-3, are underestimated (e.g., the total large break frequency is about 2E-5/yr instead of 3E-5/yr reported in NUREG/CR-5750). Please explain.*

(C) *The frequency of LOCAs outside containment resulting from main steam lines were obtained from NUREG/CR-4832 (specific to LaSalle Unit 2 Nuclear Power Plant). However, other sources (e.g., NUREG/CR-5750 and EPRI's Utility Requirements Document) report significantly higher frequencies for main steam line breaks. Please explain why the information in these additional sources was not taken into account in estimating the frequency of ESBWR main steam line breaks.*

(D) *The comparison of ESBWR PRA internal events initiating event frequencies to other studies, reported in NEDO-33201, Table 2.3-4, indicates a degree of variability that should be addressed with appropriate sensitivity studies. Please discuss.*

GE Response:

A) Although event QG10 was considered within both the General Transient and IORV initiating event categories, its frequency was determined to be a non-significant contributor to both frequencies. This is discussed in NEDO-33201 Section 2.3.1.

B) The mean values of LOCA frequencies used for the apportionment performed in NEDO-33201 Table 2.3-1 were obtained from Table J-2 of Appendix J of NUREG 5750. These frequencies are expressed in events per calendar year. The values indicated in NUREG 5750 Table 3-1 are in terms of events per critical year.

The most significant LOCA frequency with respect to CDF is the Medium Liquid LOCA, which contributes 0.76%. The difference between a frequency of 2E-5/yr and 3E-5/yr translates to an increase in CDF of approximately 1 E-10/yr, which is not significant. In a future revision to NEDO-33201 the LOCA frequencies will be expressed in terms of events per critical year.

C) The NUREG 5750 K1 group includes a small number of events that includes breaks, as well as leaks of small pipes that normally result in a less severe transient. Accordingly, it was decided that NUREG/CR-4832 input data was more appropriate for this event because it was obtained specifically for a BWR PRA analysis.

D) NEDO-33201 Table 2.3-4 shows that the variability observed between the ESBWR PRA and the other references is the normal variability usually observed among different PRAs. Additional sensitivity analyses taking into account this variability of initiating event values may be considered in future revisions of NEDO-33201.

No DCD changes will be made in response to this RAI.

NRC RAI 19.1-25

It is stated in NEDO-33201, Section 2.3.3.3 that vessel rupture is judged a negligible event and is not maintained as an initiator category for accident sequence quantification. However, an event tree for reactor vessel rupture is presented in Appendix A.3 (Figure A.3-20) and discussed in Section 3.3.3.5. Please clarify.

GE Response:

Vessel rupture is a transfer event tree, not an initiator on its own. Section 3.3.3.9 "Reactor Vessel Rupture" will be moved and incorporated into a new section 3.3.5 "Reactor Vessel Rupture after Initiation Events" in a future NEDO-33201 revision.

RAI # 19.1-27

The assumed mission time of 24 hours (NEDO-33201, Section 3.2.5) may be inadequate for some accident sequences where the reactor coolant system conditions are not stabilized in 24 hours or core damage is anticipated following 24 hours without further system or operator action. For each of these accident sequences which are not assumed to end in core damage, the systems and/or operator actions needed to prevent core damage, need to be identified and their failure characterized and addressed in the PRA. If it cannot be shown that the residual risk is not significant (e.g., through a bounding analysis), the mission time should be extended (to a point in time when it can be argued that the residual risk is not significant). This information is of particular interest in the focused PRA (where no credit is given to the non-safety-related "defense in-depth" systems to mitigate accidents) used in the regulatory treatment of non-safety systems (RTNSS) process.

(A) *Please discuss how these issues will be addressed and revise the PRA submittal accordingly.*
(B) *It is mentioned in NEDO-33201, Section 3.2.5, that two sensitivity studies related to this issue are in Section 11. One study investigating the impact of not including CD II events (i.e., events where the containment fails while the core is successfully cooled for at least 72 hours) in the baseline core damage frequency (CDF), and the other investigating the impact of extending the mission time to 72 hours. The staff could not find these sensitivity studies in Section 11. Please clarify.*

GE Response

(A) All sequences analyzed in the Level 1 part of the PRA have been finalized in a stable condition that can be maintained in the long term without extraordinary measures. Only the potential long-term failure of the containment has been identified as having a potential impact on this stable condition. NEDO-33201 Section 11.3.1 discusses this potential impact.

In NEDO-33201 section 11.3 "SENSITIVITY ANALYSES", in order to address the importance of various assumptions in the PRA, a set of sensitivity analyses were performed. NEDO-33201 Section 11.3 contains the results of those analyses. The sensitivity analyses performed were:

- Mission Time of the PRA
- Importance of Non-Safety Systems
- Truncation Value
- Human Reliability.
- Squib Valve Reliability.

(B) A global sensitivity analysis for both aspects is included under section NEDO-33201, 11.3.1 "Mission Time of the PRA", in which it is indicated that: "The purpose of this sensitivity analysis is to determine the contribution to CDF of Class II accident sequences using an extended mission time of 72 hours".

This analysis is performed using additional event trees, which are called Class II Core Cooling Vulnerability (CCV) event trees. NEDO-33201 Table 11-1 presents the results of the 72-hour mission time sensitivity analysis. The table includes all Class II sequences that result in a frequency above the truncation of $1.0x10^{-13}$ and presents the results of the Class II sequence quantification both before and after the CCV event trees. The results of this sensitivity analysis justify not including Class II accident sequences in the calculation of the Level 1 Internal Events CDF, due to their insignificant contribution.

NRC RAI 19.1-28

Discuss the basis, robustness and important assumptions associated with the following statements related to containment failure and core cooling following containment failure:

(A) *In all cases utilizing passive systems, the containment does not fail until at least 24 hours following the initiating event, and any subsequent core uncovery does not occur until 72 hours following the initiating event. For example, address bounding conditions used and other conservative assumptions made in the analysis which provide confidence about the robustness of these two numerical values.*

(B) *the containment failure does not affect continued indefinite core cooling when active water sources are used.*

GE Response

(A) The passive systems used include PCCS and GDCS. Their design is described in DCD Tier 2 Sections 6.2.2 and 6.3.2 respectively.

- The PCCS is a safety related system. Its function, as described in the DCD, is to remove decay heat rejected to the containment after a LOCA. It provides cooling for a minimum of 72 hours post-LOCA, with containment pressure never exceeding its design pressure limit.

- The GDCS is also a safety related system. Its function, as described in the DCD, is to provide emergency core cooling after any event that threatens the reactor coolant inventory. Once the reactor has been depressurized the GDCS is capable of injecting large volumes of water into the depressurized reactor pressure vessel to keep the core covered for at least 72 hours following a LOCA.

- PRA success criteria runs show that additional PCCS pool inventory is not required until 50-52 hours. Additional runs show that GDCS keeps the core covered for 52 hours after containment failure.

(B) The analysis of Containment Ultimate Strength, NEDO-33201 Rev 1 Appendix B.8, states the ultimate pressure capability of the containment structure is limited by the drywell head. The active water sources evaluated in NEDO-33201 Section 11 analysis of Class II sequences include CRD, FPS and FAPCS. It is not likely that these systems would be affected by containment failure at the drywell head due to the location of their main components. The CRD pumps are located in the lower levels of the Reactor Building and the FAPCS and FPS pumps are located outside of the Reactor Building.

As described in DCD Table 9.5-2, the FPS is supplied by a minimum storage of 1,100,000 gallons. This is compared to the decay heat from 72 hours to 7 days below.

The calculation of Revised ESBWR Core Decay Heat (GE-NE-0000-0035-8721-R0-DRAFT A) has the following values for Integrated Shutdown Power (+2σ):

3 days = 1.656E+03 seconds
7 days (6.00E+05 seconds) = 2.967E+03 seconds

Decay Heat from 3 to 7 days = (2.967E+03s – 1.656E+03s) * 4.5E9 Watts
= 5.8995E+12 Joules = 5.592E+09 Btu

Assuming the FPS water starts as 100F water and boils at atmospheric pressure, the enthalpy change is:

$$1150.5\text{Btu/lb}_{\text{steam at 14.7psia}} - 68\text{Btu/lb}_{\text{water at 100F}} = 1082.5\text{Btu/lb.}$$

The amount of required water is equal to:

5.592E+09Btu / 1082.5Btu/lb = 5.1658E+06 lb

5.1658E+06 lb * 0.0161 Ft^3/lb * 7.48 gal/ Ft^3 = 622,100 gallons

Therefore, the supply of water to the FPS system will support core cooling for 7 days.

This response does not identify any change to the DCD or NEDO-33201.

NRC RAI 19.1-29

It is stated that following a loss of feedwater event, the initial water level drop is much more severe than in a general transient. In order to avoid actuation of the Automatic Depressurization System (ADS), adequate supply of water inventory within a few minutes is required. The success criterion for this function (top event U2CISHORT) is stated as follows: "The inventory requirement only requires operation of the CRD [control rod drive] and IC condensate return lines for approximately 15 minutes to achieve success." Similar statements are made in the description of the loss of preferred power event tree. Please address the following:

(A) Specify how many CRD pumps and how many IC loops are required for success and explain why only the IC condensate return lines, as opposed to IC loops, are required for success.

(B) Provide the basis for the assumed 15 minutes time requirement (10 minutes for loss of preferred power) and explain how was this time modeled in the PRA (e.g., impact on the probability of avoiding ADS actuation).

(C) How is this criterion changed in the focused PRA (where no credit is given to the non-safety-related "defense-in-depth" systems to mitigate accidents) used in the RTNSS process?

(D) Clarify the heading descriptions for top events related to IC and CRD following success and failure of top event U2CISHORT and state the associated success criteria

GE Response:

(A) As indicated in NEDO-33201 Table 3.2-1, the success criteria for the "U2CISHORT" function are "2 of 2 CRD pumps for 15 minutes and 3 of 4 IC condensate return lines open". The success criterion of the IC only includes the condensate return lines, because its function in this event is to supply water to restore vessel level, not to remove residual heat.

It is also stated in NEDO-33201, Section 3.3.1.3, "Loss of Feedwater Transient" that, "The design basis for the loss of feedwater event is such that if 3 of 4 isolation condensers actuate and both CRD pumps start in high pressure injection mode upon receipt of Level 2 signal, water level will be restored above Level 1.5 before the timer sequence expires."

(B) The basis for the assumed 15 minutes time requirement is a decision point in the event trees that delineates whether automatic ADS initiation will occur. ADS will automatically initiate if level is below Level 1.5 for 15 minutes continuous. Therefore, if level is restored above Level 1.5 within 15 minutes, this actuation signal for ADS is no longer valid. The 10 minutes requirement for loss of preferred power accounts for a delay in CRD injection until the diesel generators are started and loaded. This is a deterministic success criterion that is not factored into a probability of avoiding ADS actuation. The CRD and ICS functions are accounted for in the events following event U2CISHORT.

(C) The event trees used in the focused PRA are modified to ensure CRD failure. Therefore, no credit is taken from CRD in the focused PRA.

(D) The U1C heading is similar to the U1CF "heading" described in the Section 3.3.1.1, but with the Feedwater system unavailable.

The "I" heading is the same as the one described in the NEDO-33201 Section 3.3.1.1.

In relation to the success criteria for both, NEDO-33201 Table 3.2-1 indicates that for the "I" function it is "3 of 4 IC and all PCCS pool connections", and for the "U1C" function, it is "1 of 2 CRD pumps".

No DCD changes will be made in response to this RAI.

Note: A design change is currently being developed for the ESBWR that will significantly reduce the probability of having an automatic depressurization following a loss of feedwater or loss of preferred power event. Additional volume of water is being added to the ICS standby inventory so that no CRD pumps are necessary to avoid the ADS signal. This design change, when incorporated, will make the LOPP and LOFW event tree structures very much like the General Transient structure.

NRC RAI 19.1-30

Regarding the loss of feedwater (LOFW) event, it is stated that "If the water level drops below 1.5 but the ADS does not successfully actuate, ICS [isolation condenser system]remains available for core cooling. Additionally, if the ICS fails too, CRD and FAPCS [fuel and auxiliary pool cooling] in LPCI [low pressure coolant injection] mode (given depressurization using the SRVs only) could still provide core cooling." This statement seems to imply that failure of ADS actuation, as designed to occur, is actually a "success." If under these conditions the ICS can provide core cooling why does the design provide for an ADS logic actuation? Furthermore, if the accident can be mitigated without using ADS, what would prevent the operator from trying to inhibit automatic ADS actuation to avoid blowdown and its economic consequences? Please discuss.

GE Response:

A design change is currently being developed for the ESBWR that will significantly reduce the probability of having an automatic depressurization following a loss of feedwater or loss of preferred power event. Additional volume of water is being added to the ICS standby inventory so that no CRD pumps are necessary to avoid the ADS signal. This design change, when incorporated, will make the LOPP and LOFW event tree structures very much like the General Transient structure. Therefore, the concerns about ADS actuation and trying to inhibit ADS will no longer be relevant.

NRC RAI 19.1-32

In events where water level drops abruptly, such as loss of feedwater and loss of preferred power (loss of offsite power) transients, active high-pressure makeup is needed to prevent reaching the ADS actuation setpoint (see event U2CIDHORT). As modeled in the event trees, it takes the single failure of a non-safety-related system, such as a CRD pump or a diesel generator, to reach the ADS actuation setpoint. This implies that the blowdown frequency of ESBWR may be relatively high, especially in the focused PRA, given the frequencies of events such as loss of feedwater (about 1E-1 events/year) and loss of preferred power (about 5E-2/year) are not remote.

Please provide the total expected frequency of blowdown as modeled in both the baseline and focused PRAs. This information is needed to assess the relative importance of active "defense in-depth" systems to mitigate accidents and determine whether any requirements are needed to ensure availability and reliability commensurate with their importance.

GE Response:

A design change is currently being developed for the ESBWR that will significantly reduce the probability of having an automatic depressurization following a loss of feedwater or loss of preferred power event. Additional volume of water is being added to the ICS standby inventory so that no CRD pumps are necessary to avoid the ADS signal. This design change, when incorporated, will make the LOPP and LOFW event tree structures very much like the General Transient structure. Therefore, the probability of an ADS actuation will be significantly reduced, and the relative importance of active systems to mitigate blowdown events will no longer be relevant.

RAI # 19.1-33

If no high pressure injection system is available, following a transient or small LOCA initiating event, it is necessary to depressurize (partially) by opening SRVs to permit effective injection using the FAPCS or the Fire Protection System (FPS) pump. In Chapter 3 of the PRA (page 3.3-4) it is stated that the success criterion for this function is the manual opening of at least five of eight SRVs. However, in page 4.1-3 (where the ADS is discussed) it is stated that 10 of the 18 SRVs have the capability of actuating in the ADS mode. Please clarify why the above mentioned success criteria refers to only eight SRVs.

GE Response

That part of the text on page 3.3-4 of the NEDO-33201 Chapter 3 related to the XS5 function is misleading and will be revised. As is indicated in Table 3.2-1, the success criteria for the "XS5 function is "5 of 10 SRVs open". In the same table it is stated that the success criteria is "4 of 8 DPVs" open for the ADS function. The ESBWR design has 18 SRV valves but only 10 are pneumatically operated.

RAI # 19.1-34

In the loss of feedwater and loss of preferred power event trees, it is assumed that core cooling can be achieved using the IC following the actuation of up to three DPVs. Please provide the basis for this assumption and discuss whether there is any pressure interval associated with ADS configuration where neither IC nor gravity driven cooling system (GDCS) can provide effective core cooling.

GE Response

The failure of the total ADS function could lead to the use of the IC system for residual high removal. Accordingly, another heading seems to be required to determine whether the IC can be successful. However, the failure of the ADS function is dominated by the common cause failure of all the valves to open. If a new heading was included in the event tree after the ADS function and before the IC function [that takes into account the failure to open of all the ADS valves], that new failure path would have no cutest and is not necessary.

A design change is currently being developed for the ESBWR that will significantly reduce the probability of having an automatic depressurization following either a loss of feedwater or loss of preferred power event. Additional volume of water is being added to the ICS standby inventory so that no CRD pumps are necessary to avoid the ADS signal. This design change will be incorporated in a future revision of NEDO 33201 and will make the LOPP and LOFW event tree structures very much like the General Transient structure.

NRC RAI 19.1-36

The top two sequences of the Small Liquid LOCA event trees (NEDO-33201, Figures A.3-18 and A.3-19) are both shown as no core damage, whether Isolation Condenser succeeds or not. Please clarify

GE Response:

The SL-002 sequence in the Small Liquid LOCA event trees, Figures A.3-18 and A.3-19 in NEDO-33201 Rev 1, is a leftover from previous model revisions and will be corrected in a future NEDO-33201 revision.

NRC RAI 19.1-38

Provide information on the modeling of several top events, such as the overpressure protection function (event tree headings M and MA), the SRV re-closure in ATWS (event tree heading PA), the containment venting function (event T11-SYS-FF-OPEN), and the high pressure injection (event UCF) in ATWS.

(A) The staff could not find events B21-SYS-FF-18/18SRV (1 of 18 SRVs must open), B21-SYS-FF-10/18SRV (9 of 18 SRVs must open), and B21-SYS-FF-1/9OPEN (all SRVs must re-close) in NEDO-33021, Table 4.1-8 (List of system top events for ADS) or the assumed probabilities for these events. Similar information on the modeling of the containment vent function failure is needed.

(B) In Table 5.4-1 (Special Events), event T11-SYS-FF-OPEN is described as "all overpressure protection valves fail to open" and a probability of 5.69E-2 was assumed based on "Bounding Value, Engineering Judgment." Please explain.

(C) Information on the modeling of the high pressure injection (event UCF) in ATWS is needed. Please clarify what top fault tree(s) were used for UCF since some ATWS events involve feedwater (FDW) run-back.

GE Response:

(A) The events B21-SYS-FF-18/18SRV (1 of 18 SRVs must open), B21-SYS-FF-10/18SRV (9 of 18 SRVs must open), and B21-SYS-FF-1/9OPEN (all SRVs must re-close) are Special Events as indicated in NEDO-33201 Rev 1 Section 5.4, Table 5.4-1. Furthermore, as indicated in NEDO-33201 Rev 1 Figures A3-1 to A3-25, these events correspond to the following event tree headings:

M	B21-SYS-FF-18/18SRV
MA	B21-SYS-FF-10/18SRV
PA	B21-SYS-FF-1/9OPEN

The first two events correspond to mechanical failures in the development of the **safety function** of the SRVs, while the third one corresponds to the mechanical closure of the SRVs (due to the spring). They are not included in Section 4.1 of NEDO-33201 Rev 1 because only models related to the **relief function** are included in it. The assumed probabilities for these events are provided in NEDO-33201 Section 5.4, Table 5.4-1.

(B) The event T11-SYS-FF-OPEN (all overpressure protection valves fail to open) is related to the event tree heading WC, as indicated in NEDO-33201 Figures A3-1 to A3-25, and corresponds to the mechanical failure of the containment overpressure protection valves. Its value has been judged based on the actions involved in the manual containment venting process required.

(C) According to the ATWS event trees, the high-pressure injection (UCF event tree heading) is used after the success of the event tree heading SL (discharge of both Standby Liquid Control trains). In this case, the feedwater runback signal has been generated. Therefore, in the ATWS event trees the event tree heading UCF will be changed to UC in a future NEDO-33201 revision.

NRC RAI 19.1-40

In the ATWS event tree drawings, the top event for the decay heat removal function using the reactor water cleanup/shutdown cooling (RWCU/SDC) system, is shown as GG31TOP. However, this top event is not listed in Table 4.4-8 (List of system top events for RWCU/SDC). Please clarify how the operator failure to inhibit RWCU/SDC isolation signals, developed by ATWS logic, and bypass the filters was modeled in the PRA.

GE Response:

The top event of the reactor water cleanup/shutdown cooling (RWCU/SDC) system (GG31TOP) is included in NEDO-33201 Rev. 1, Table 4.8-8 (list of system top events for RWCU/SDC). However, the table entry was misspelled and it appears as G31TOP.

For ATWS Events, the RWCU/SDC (event tree heading WHA) is always used after the success of the event tree heading SL (discharge of both Standby Liquid Control trains). These ATWS scenarios imply the closure and block closing of RWCU/SDC containment isolation valves G31-F002/3/7/8 A and B due to SLCS signal initiation. This signal cannot be inhibited by the operator but can be overridden to align the system in SDC mode.

In the RWCU/SDC fault tree model (GG31TOP) this override capability has been taken into account using a different human action to align the system in case of SLCS actuation. This alignment requires bypassing the demineralizers and opening valves G31-F002/3/7/8 A and B.

Table 4.8-8 in NEDO-33201 Rev. 1 will be updated to correct the typographical error. No changes to the DCD have been identified.

NRC RAI 19.1-41

It is not clear what small LOCA categories are included in the "ATWS after Small LOCA above Core" event. Please clarify how "small LOCA above core" relates to level position (i.e., RPV Level 3).

GE Response:

NEDO-33201 Rev 1 Section 3.3.2.6, "ATWS from Small LOCA above Reactor Core", represents the group of small liquid LOCA between TAF and Level 3, and the Small Steam LOCA in which the core can always be maintained cooled from internal injection systems.