# NRC Review of Kemmerer Unit 1 Construction Permit Application

# Implementation of LMP Safety Classification Process

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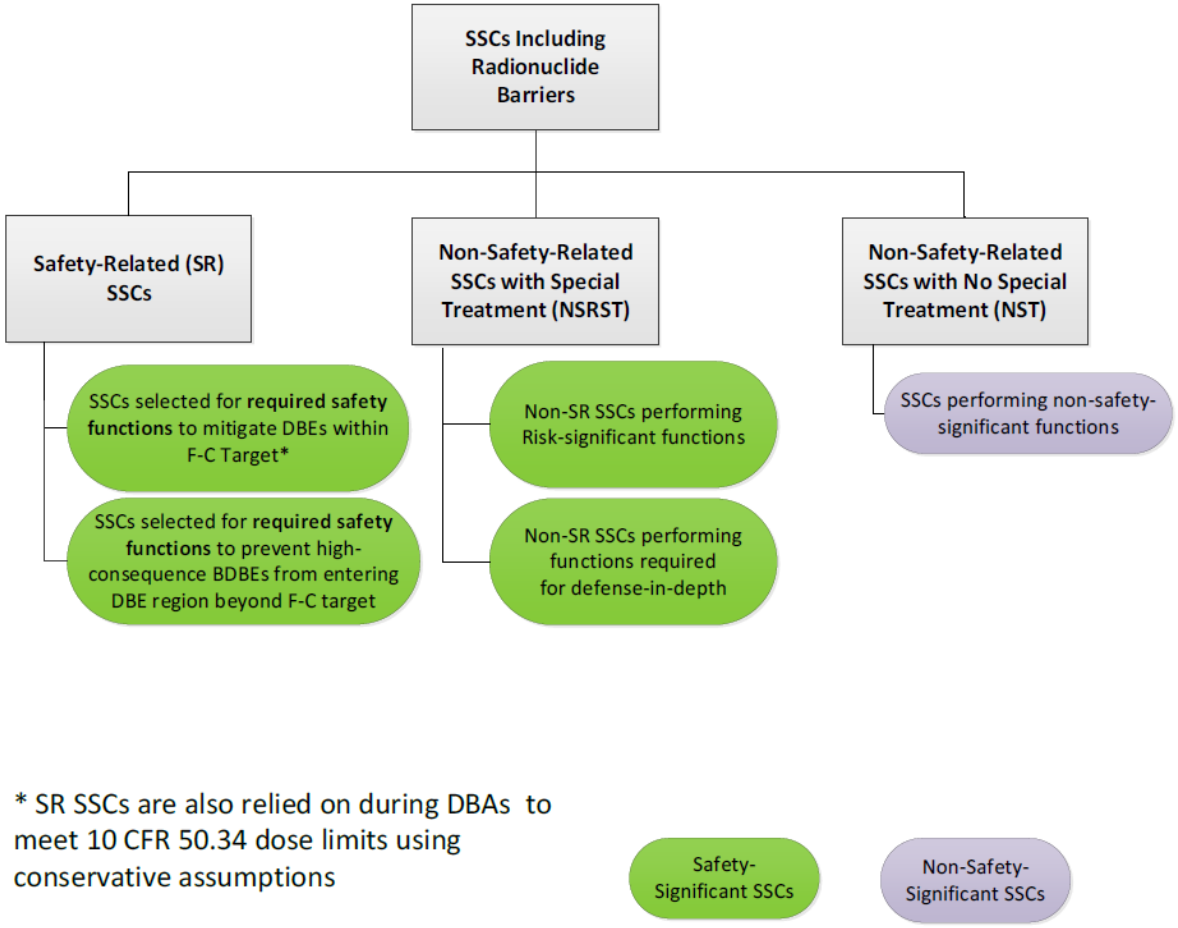
# Topics

- Overview of LMP safety classification process for structures, systems, and components (SSCs)
- Implementation of SSC safety classification process
  - Identification of risk-significant PRA safety functions (PSFs)
  - Preventative controls classification process
- SSC safety classification results
  - Control of heat generation
  - Control of heat removal
  - Radionuclide retention

# SSC Safety Classifications under LMP

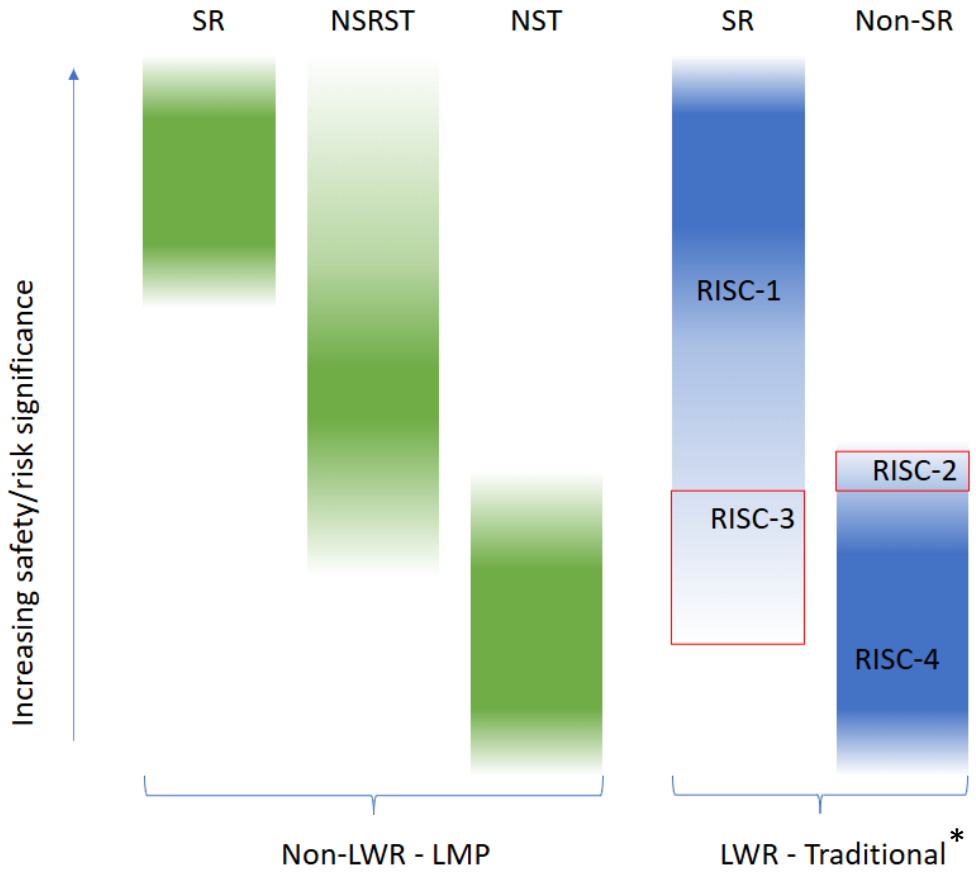



**NEI 18-04 Figure 4-3. LMP SSC Safety Categories and Safety Significant SSCs**

- All safety-related (SR) and non-safety-related with special treatment (NSRST) SSCs are safety-significant
- SSCs performing required safety functions (RSFs) are SR
  - RSF = SR function
- Risk-significant functions are identified through evaluations against the frequency-consequence (F-C) target and evaluations against the cumulative risk metrics
  - Can be SR or NSRST

# Comparison to Traditional Safety Classifications

- LMP shifts some SSCs that would have traditionally been SR into NSRST
- NSRST is a very broad band
- NSRST SSCs can be as risk significant as some SR SSCs
- NST items can have seismic interaction requirements, which is addressed separately from the SSC safety classification process
  - Resulting in NST items with what NEI 21-07 refers to as special safety functions




*RISC definitions in 10 CFR 50.69

# LMP SSC Safety Classifications Steps

| Task* | LBEs Evaluated | Evaluation | Criteria Compared Against | Values Used | Resulting SSC Classification and risk importance category |
|---|---|---|---|---|---|
| **7a.1** | DBEs and AOOs and BDBEs with uncertainty bands that extend into the DBE region | Remove individual functions and evaluate impact on individual LBEs | F-C target curve | Mean | SR RSF, risk-significant and safety-significant |
| **7a.2** | BDBEs with mean consequences that exceed 25 rem TEDE | Remove individual functions and evaluate impact on individual LBEs | F-C target curve | Mean | SR RSF, risk-significant and safety-significant |
| **7d** | DBAs | Conservative consequences evaluation in which only available SR SSCs perform their function | 10 CFR 50.34 dose limits | 95$^{th}$ percentile or greater | SR RSF, safety-significant |
| **7a.3** | All non-DBA LBEs | Remove individual functions and evaluate impact on individual LBEs | F-C target curve | 95$^{th}$ percentile | NSRST, risk-significant and safety-significant |
| **7b** | All non-DBA LBEs | Remove individual functions and evaluate total frequency of all associated LBEs | 1% of the cumulative risk metrics | Mean | NSRST, risk-significant and safety-significant |
| **7e** | All non-DBA LBEs | Perform defense-in-depth (DID) adequacy evaluation using the integrated decision-making process (IDP) and IDP panel (IDPP) | Table 5-2 and other DID concepts described in Section 5 of NEI 18-04 | N/A | NSRST, safety-significant |

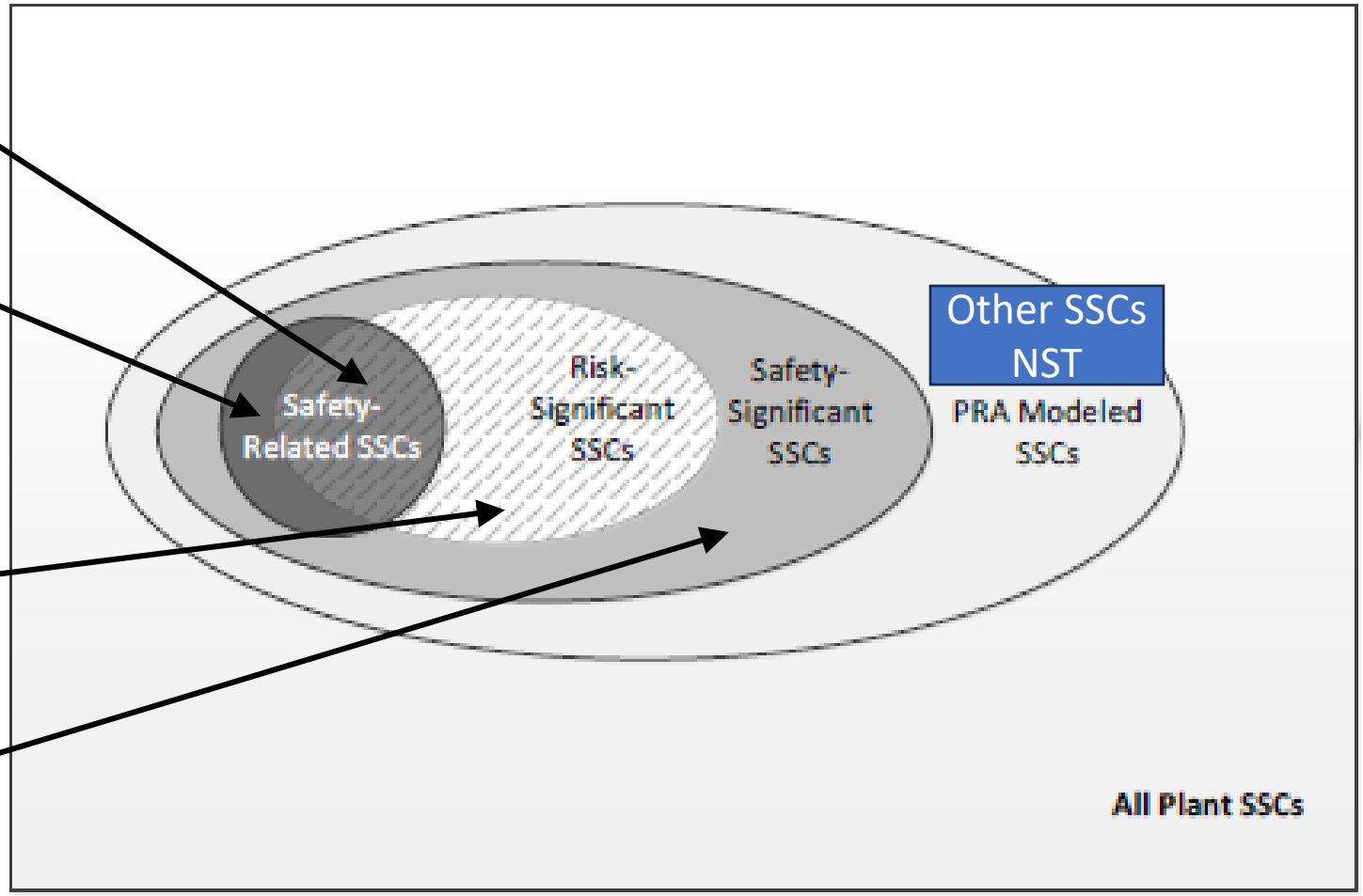
* From section 3.2.2 of NEI 18-04. Note, task 7c of determining risk significance is an assessment of the results determined in the 7a and 7b evaluations

7a.1 and 7a.2 SSCs
SR, safety-significant, and risk-significant

7d SSCs
SR and safety-significant but not risk-significant

7a.3 and 7b SSCs
NSRST, safety-significant, and risk-significant

7e SSCs
NSRST and safety-significant but not risk-significant

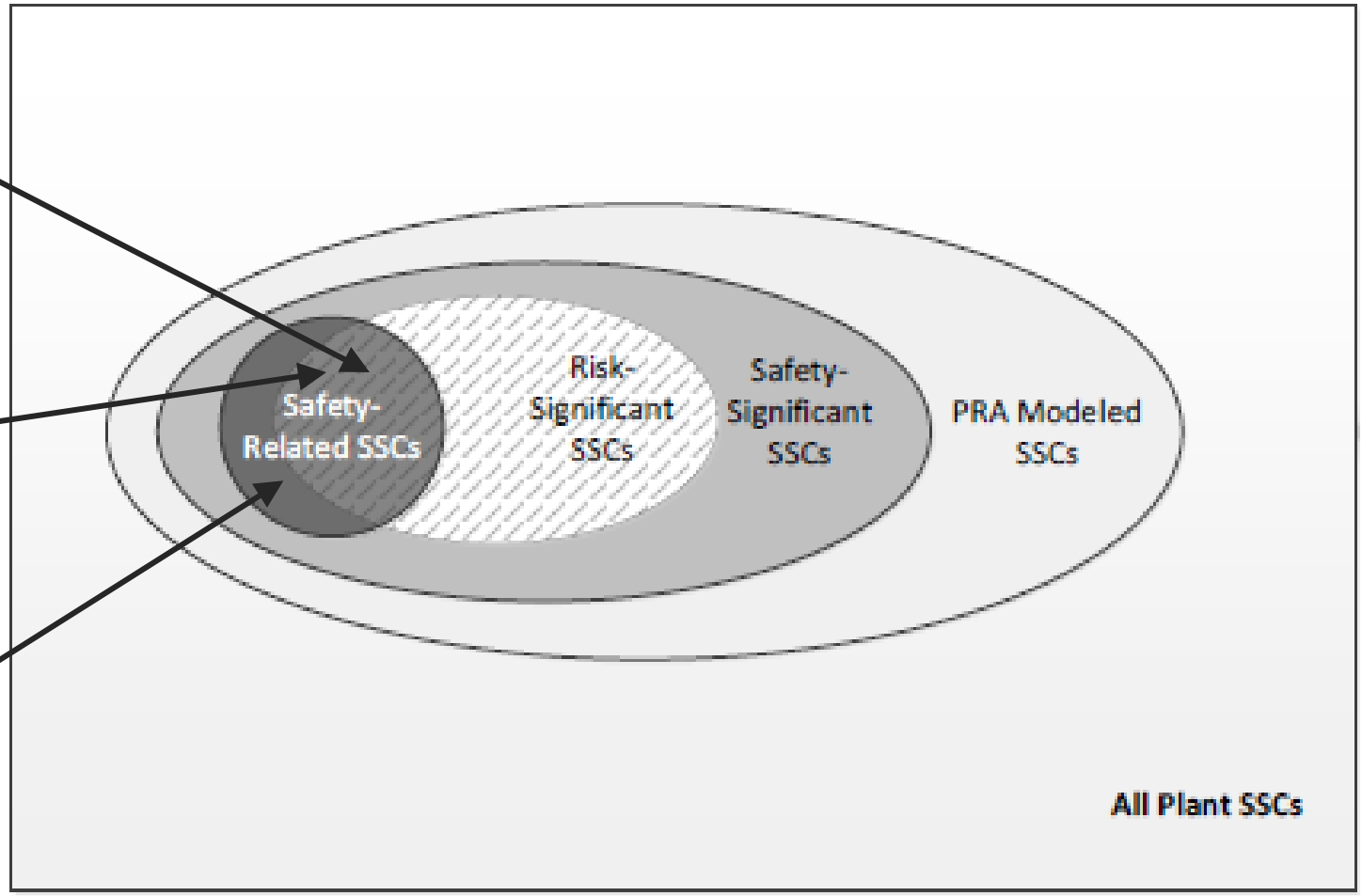



**NEI 18-04 Figure 4-2. Definition of Risk-Significant and Safety-Significant SSCs**

SSCs ***selected by the designer*** to perform the RSFs needed to mitigate the consequences of DBEs to within the F-C Target using realistic assumptions

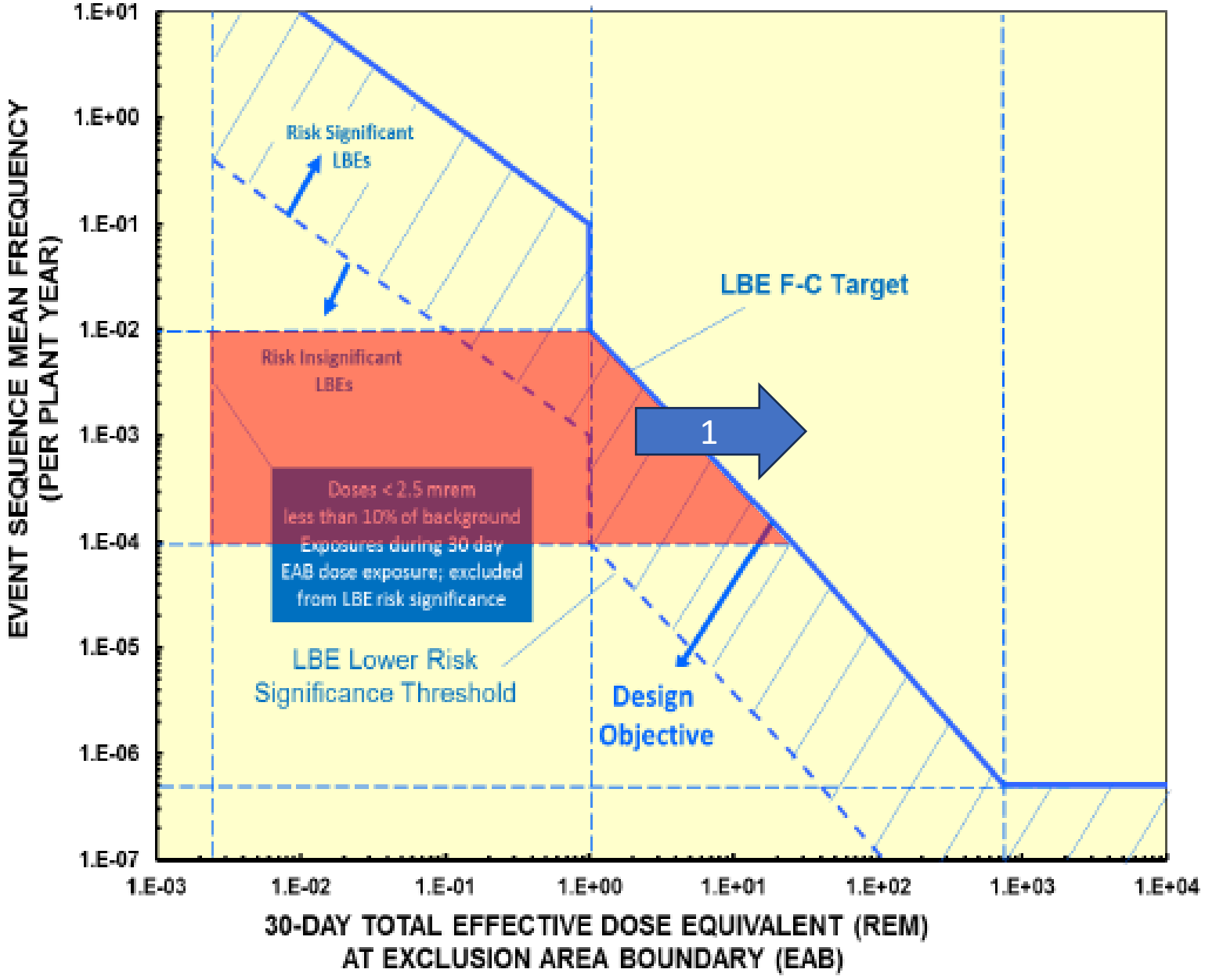
SSCs ***selected by the designer*** to perform the RSFs needed to prevent BDBEs with consequences greater than 10 CFR 50.34 limits from increasing into the DBE region

SSCs required to prevent 95$^{th}$ percentile dose consequences from exceeding limits in 10 CFR 50.34 in DBA analysis




**NEI 18-04 Figure 4-2. Definition of Risk-Significant and Safety-Significant SSCs**

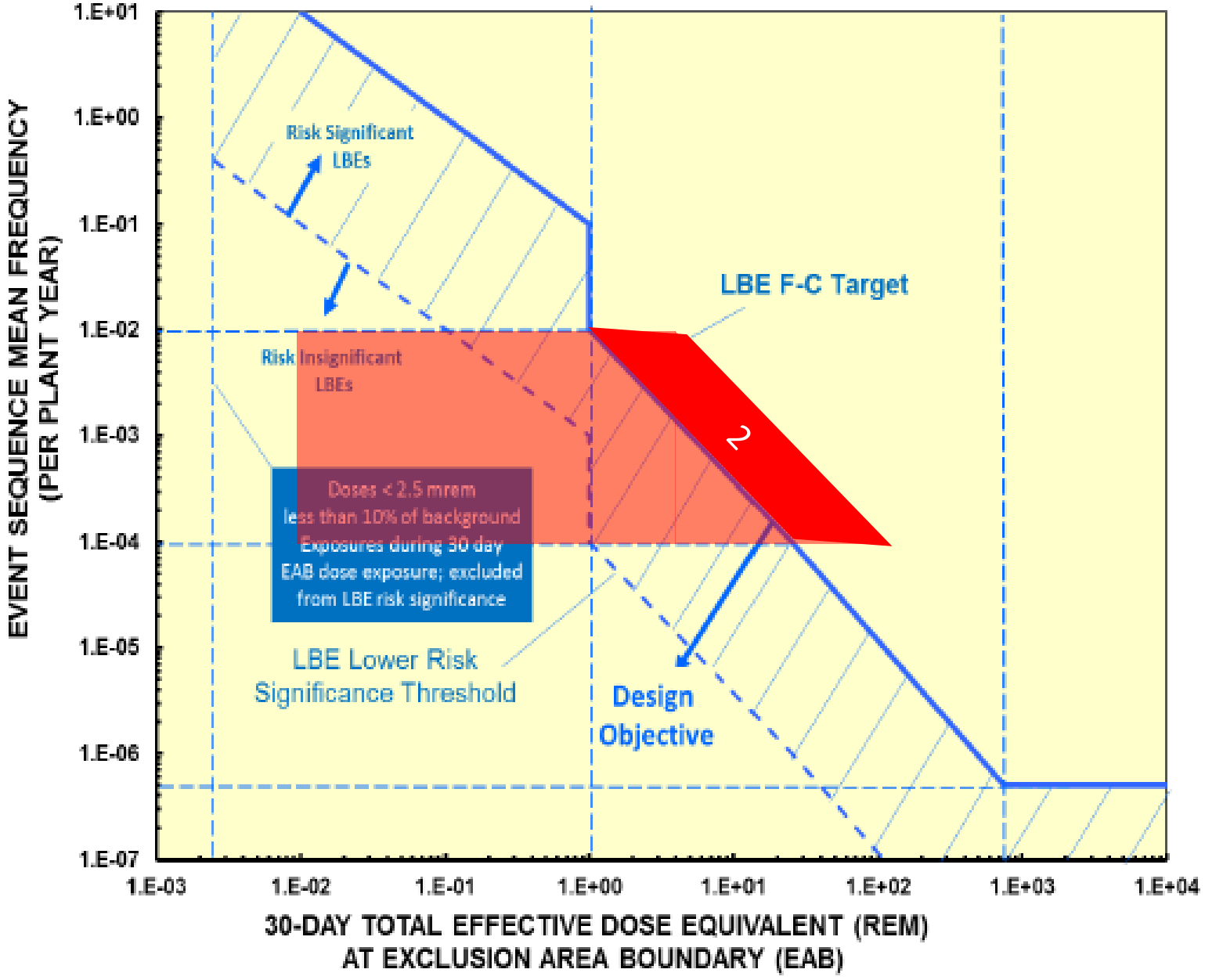
7a.1 SSCs ***selected by the designer*** to perform the RSFs needed to mitigate the consequences of DBEs to within the F-C Target using realistic assumptions




1. DBEs and AOOs or BDBEs with frequency bands extending into the DBE region are evaluated without certain mitigative safety functions.

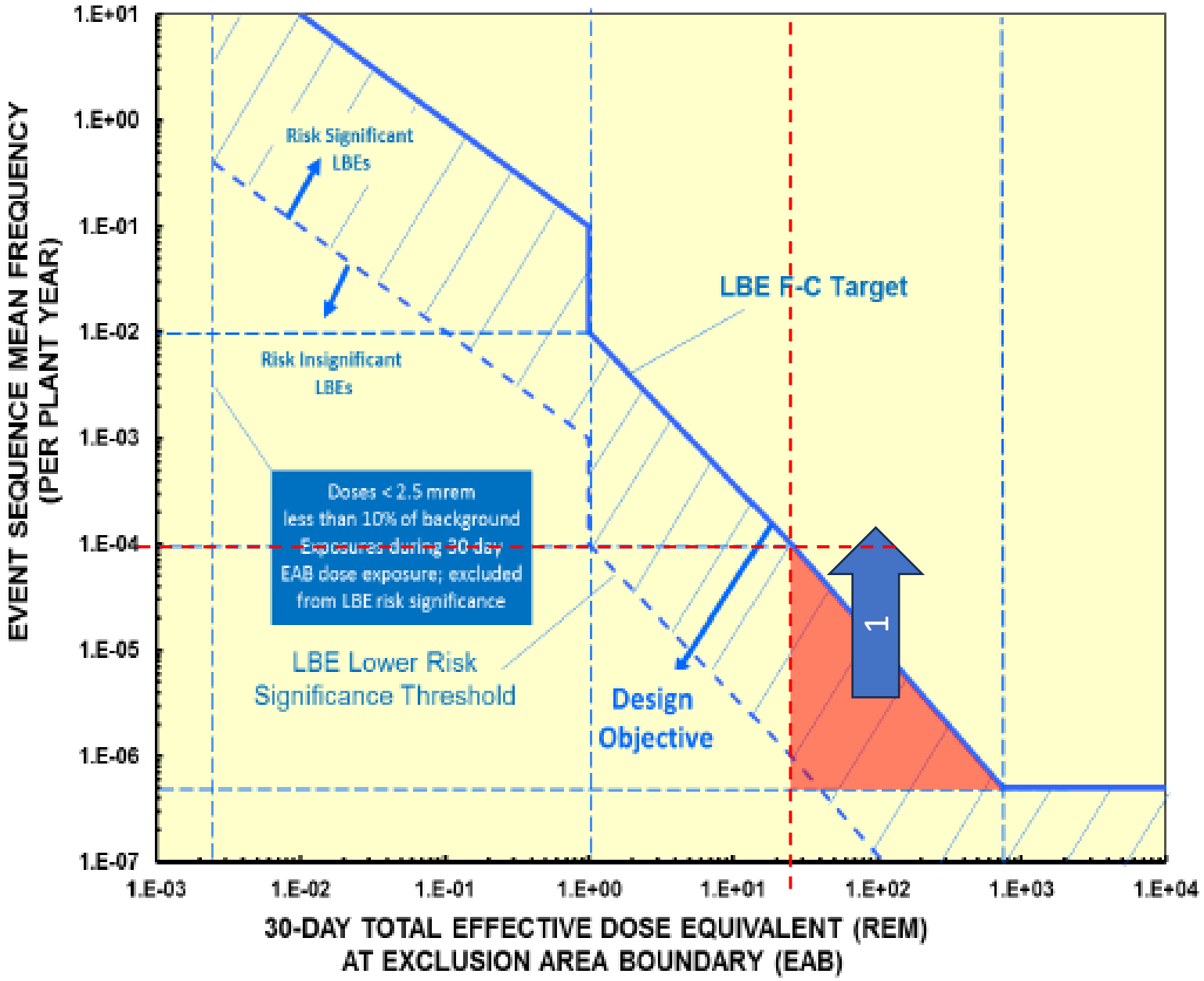
***This will move scenario results to higher consequence***

7a.1 SSCs ***selected by the designer*** to perform the RSFs needed to mitigate the consequences of DBEs to within the F-C Target using realistic assumptions




1. DBEs and AOOs or BDBEs with frequency bands extending into the DBE region are evaluated without certain mitigative safety functions.
2. If **mean** results exceed the F-C Target, then it is an RSF and the SSCs **selected by the designer** to perform that function are SR.

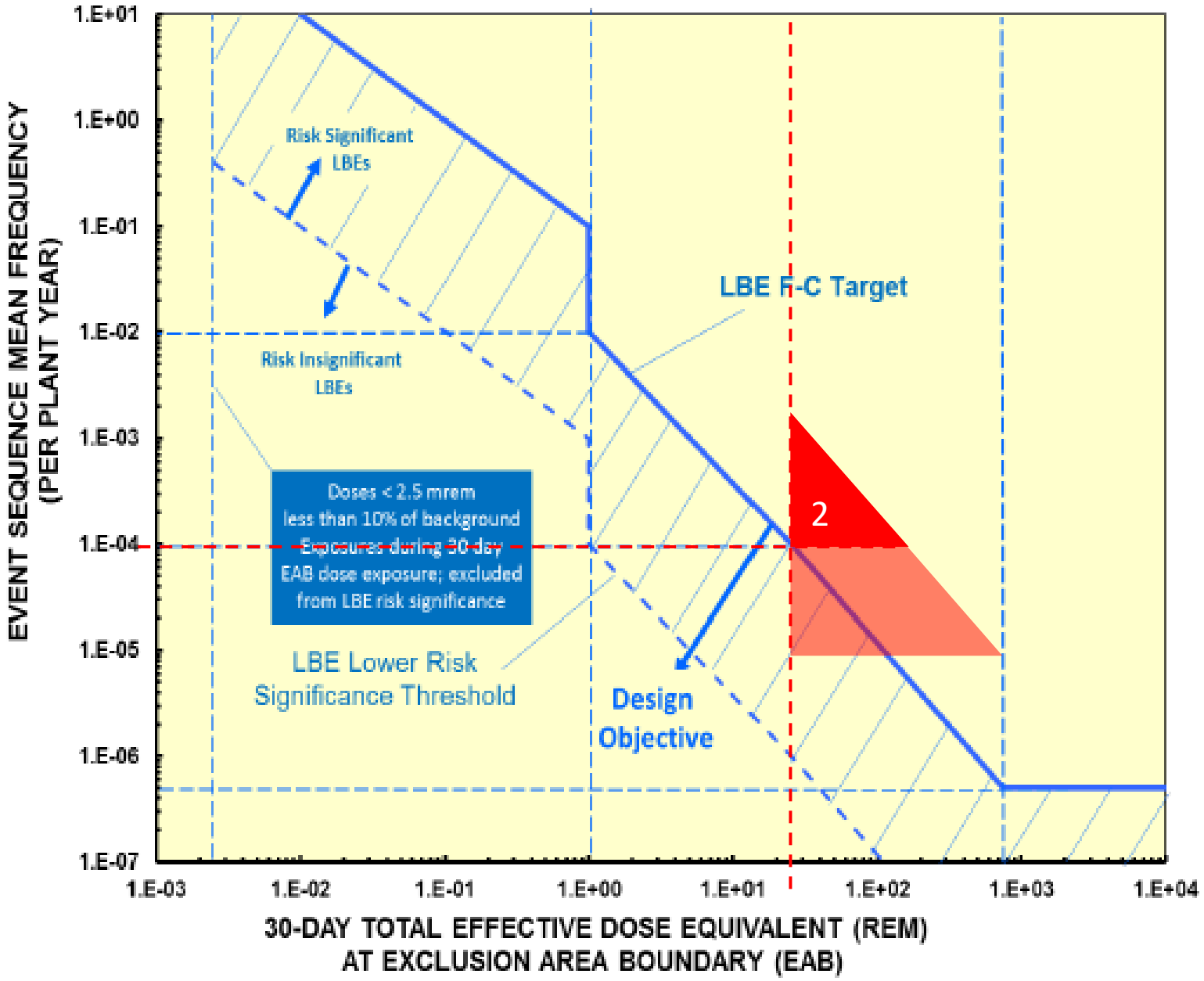
# 7a.2 SSCs ***selected by the designer*** to perform the RSFs needed to prevent BDBEs with consequences greater than 10 CFR 50.34 limits from increasing into the DBE region




1. BDBEs with consequences above 10 CFR 50.34 limits (i.e., 25 rem) are evaluated without certain safety functions.

   By their nature of impacting frequency, these will be preventative functions or functions that both prevent and mitigate.

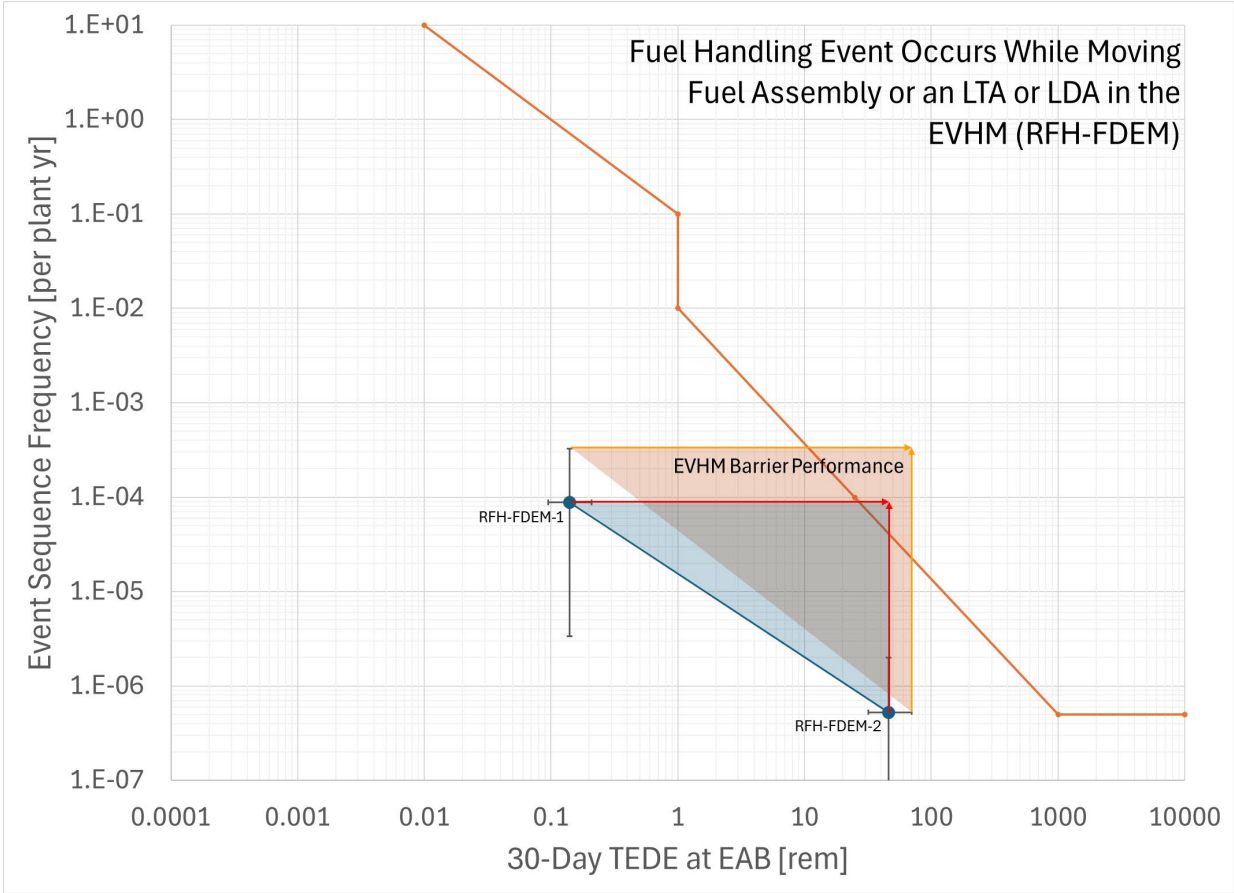
7a.2 SSCs ***selected by the designer*** to perform the RSFs needed to prevent BDBEs with consequences greater than 10 CFR 50.34 limits from increasing into the DBE region




1. BDBEs with consequences above 10 CFR 50.34 limits (i.e., 25 rem) are evaluated without certain safety functions.
2. If frequency increases to >$10^{-4}$, then it is an RSF and the SSCs **selected by the designer** to perform that function are SR.

# Example from Kemmerer Unit 1

- Fuel handling events in ex-vessel handling machine (EVHM)
- RFH-FDEM initiating event family
  - RFH-FDEM-1 is evaluated as a BDBE with a 95$^{th}$ percentile frequency in the DBE region
  - RFH-FDEM-2 is evaluated as a high consequence BDBE
  - Both evaluations identify the EVHM barrier performance as an RSF
- SSCs selected to perform this function are SR, risk-significant, and safety-significant



# Implementation of LMP Classification Steps

| Task* | LBEs Evaluated | Evaluation | Criteria Compared Against | Values Used | Resulting SSC Classification and risk importance category |
|---|---|---|---|---|---|
| 7a.1 | DBEs and AOOs and BDBEs with uncertainty bands that extend into the DBE region | Remove individual functions and evaluate impact on individual LBEs | F-C target curve | Mean | SR RSF, risk-significant and safety-significant |
| 7a.2 | BDBEs with mean consequences that exceed 25 rem TEDE | Remove individual functions and evaluate impact on individual LBEs | F-C target curve | Mean | SR RSF, risk-significant and safety-significant |
| 7d | DBAs | Conservative consequences evaluation in which only available SR SSCs perform their function | 10 CFR 50.34 dose limits | 95$^{th}$ percentile or greater | SR RSF, safety-significant |
| 7a.3 | All non-DBA LBEs | Remove individual functions and evaluate impact on individual LBEs | F-C target curve | 95$^{th}$ percentile | NSRST, risk-significant and safety-significant |
| 7b | All non-DBA LBEs | Remove individual functions and evaluate total frequency of all associated LBEs | 1% of the cumulative risk metrics | Mean | NSRST, risk-significant and safety-significant |
| 7e | All non-DBA LBEs | Perform DID adequacy evaluation using the IDP and IDPP | Table 5-2 and other DID concepts described in Section 5 of NEI 18-04 | N/A | NSRST, safety-significant |

* From section 3.2.2 of NEI 18-04. Note, task 7c of determining risk significance is an assessment of the results determined in the 7a and 7b evaluations

# Identification of Risk-Significant PSFs

- LMP has four steps that result in the identification of risk-significant PSFs, of these USO performed two more conservatively and one was inadvertently not performed
  - Use of the 95$^{th}$ instead of mean for identification of risk-significant RSFs was conservative and may have resulted in a few NSRST SSCs being SR
  - The step that was inadvertently not performed was partially offset by an additional step in the USO DID process that evaluated LBEs against the F-C target using the mean values
    - Resulted in most risk-significant NSRST SSCs being classified NSRST for DID
- USO is ensuring this step for identify risk-significant NSRST functions is performed appropriately moving forward

# Preventative Controls Classification Process

- Some preventative controls were not evaluated for safety classification because of the way they were modeled in the PRA
  - Included interlocks on fuel handling movements, special treatments to cranes to reduce the frequency of initiating events, and criticality safety controls
- Interlocks and other preventative controls with failure on demand information will be moved to allow application of the safety classification process
- Other preventative controls are being addressed through a new step in the DID evaluation process that was reviewed at a preliminary level, but will be reviewed in detail at the OL stage

# Safety-Significant SSCs for Controlling Heat Generation

- Chapter 5 lists two high level SR functions
  - Individual scram functions are provided in the reactor protection system (RPS) design description in PSAR section 7.6
  - These are all subfunctions of the gravity driven scram PSF
- ASTs employ different ways of detecting events and initiating a trip, providing diversity and DID
- Where the frequency or consequence of the event is low, a single NSRST may be enough to keep LBEs in F-C target

| Primary Control (SR) | Secondary Control (NSRST) |
|---|---|
| Gravity driven scram | Driveline scram follow |
| Scram on loss of power | Manual reactor scram, alternative shunt trip (AST) on low primary sodium outlet pressure |
| Scram on high neutron flux | AST on high core exit temperature |
| Scram on high positive neutron flux rate | AST on high core exit temperature |
| Scram on high negative neutron flux rate | Manual reactor scram |
| Scram on low power, high neutron flux | Manual reactor scram |
| | Automatic seismic trip |
| Scram on high hot pool temp | AST on high core exit temperature |
| Scram on high cold pool temp | |
| Scram on high primary sodium level | AST on low intermediate heat transport system (IHT) level |
| Scram on high power-to-flow ratio | AST on low primary sodium outlet pressure |
| Scram on loss of primary sodium flow | |
| Scram on low primary sodium level | |
| | AST on high IHT level |

# Safety-Significant SSCs for Controlling Heat Removal

- Natural circulation in the primary system is required for successful operation of RAC and IAC passive mode
- PSP coastdown is required in the event of PSP trip for smooth transition to natural circulation and to prevent exceeding SARRDLs
- Where the frequency or consequence of the event is low, a single control (SR or NSRST) may be sufficient

| Primary Control (SR) | Secondary Control (NSRST) |
|---|---|
| Natural circulation in primary system | |
| Primary sodium pump (PSP) coastdown | |
| Reactor air cooling system (RAC) operation | Intermediate air cooling system (IAC) passive mode operation |
| PSP trip on high primary sodium temperature | PSP trip automatic backup |
| | Manual PSP trip |
| Intermediate sodium pump (ISP) trip on high primary sodium temperature | ISP trip automatic backup |
| | Manual ISP trip |
| ISP trip on high primary sodium level | ISP trip on low IHT level |
| Sodium processing system (SPS) pump trip on low primary sodium level | Manual SPS pump trip |
| Passive heat removal in fuel handling equipment and failed fuel canister | |

# Safety-Significant SSCs for Radionuclide Retention

- For events with the largest material-at-risk or MAR (e.g., fuel releases during operation), one SR barrier (in addition to the SR fuel cladding) does not provide sufficient mitigation and an NSRST barrier is also needed.

| Material-at-risk (MAR) | Primary Barrier | Secondary Barrier | Tertiary Barrier | Licensing Basis Event (LBE) |
|---|---|---|---|---|
| **Fuel Inventory (during operation)** | Fuel Cladding (SR) | RES boundary (SR)<br>SCG Isolation (SR) | Head Access Area (HAA) barrier (NSRST) | LFF-SAO-BL (DBE), DHP-LOOP-3 (BDBE), DHP-LOOP-4 (BDBE) |
| | | | HAA barrier (NSRST), degraded performance | LFF-SAO-1 (BDBE), LFF-SAO-CN (DBA), RFH-FDIV-CN (DBA) |
| | | RES boundary (SR) at degraded performance, SCG isolation (SR) | HAA barrier (NSRST) | LFF-SAO-2 (BDBE)* |

* Consequence from LFF-SAO-1 used for this event

# Safety-Significant SSCs for Radionuclide Retention

- For fuel release after shutdown, one SR barrier (in addition to the SR fuel cladding) is generally sufficient unless the frequency of the initiating event plus SR barrier failure is high enough that an LBE involving the SR barrier failure is included. In this case, an NSRST barrier is needed to provide mitigation when the SR barrier fails.

| Material-at-risk (MAR) | Primary Barrier | Secondary Barrier | Tertiary Barrier | Licensing Basis Event (LBE) |
|---|---|---|---|---|
| **Fuel Inventory (shortly after shutdown)** | Fuel Cladding (SR) | RES boundary (SR), SCG isolation (SR), ex-vessel handling machine (EVHM) cask barrier (SR) | | RFH-FDIV-1 (DBE), RFH-FDIV-3 (DBE) |
| | | RES boundary (SR) at degraded performance, SCG isolation (SR) | Reactor building (RXB), degraded performance (NST) | RFH-FDIV-2 (BDBE), RFH-FDIV-4 (BDBE) |
| | | EVHM cask barrier (SR) | | RFH-LMCA-1 (BDBE), RFH-FDEM-1 (BDBE) |
| | | EVHM cask barrier (SR) at degraded performance | | RFH-LMCA-2 (BDBE), RFH-FDEM-2 (BDBE) |
| | | PRC cell barrier (SR) | | RFH-OERC-BL (AOO), RFH-FDRC-1 (BDBE) |

* Consequence from LFF-SAO-1 used for this event

# Safety-Significant SSCs for Radionuclide Retention

- For releases from auxiliary systems, the MAR is generally low enough that only one NSRST barrier is needed (in addition to the process barrier) to reach acceptable risk.

| Material-at-risk (MAR) | Primary Barrier | Secondary Barrier | Tertiary Barrier | Licensing Basis Event (LBE) |
|---|---|---|---|---|
| SPS Inventory | Primary SPS barrier (NSRST) | HAA barrier (NSRST), degraded | | RRS-SPLX-CN (DBA) |
| | | HAA barrier (NSRST)* | RXB superstructure (NST), 2-hour exhaust time | RRS-SPLX-BL (DBE) |
| | | SPS cell barrier (NSRST) | RAB substructure (NSRST, not for radionuclide retention), 2-hour exhaust time | RRS-SPLA-BL (DBE) |
| | | SPS cell barrier (NSRST), degraded | | RRS-SPLA-CN (DBA) |
| SCG Inventory | Primary SCG barrier (NSRST) | SCG cell barrier (NSRST) | | No associated LBEs |
| | | SCG cell barrier (NSRST) or vapor trap cell barrier (NSRST), degraded | | RRS-CGR-CN (DBA) |
| | | Vapor trap cell barrier (NSRST) | | SUD-CGR-2 (BDBE) |
| | | | NHV isolation (NSRST) and filtration (NST) | RRS-CGR-1 (DBE) |
| | | HAA barrier (NSRST) | | RRS-CGR-BL (DBE) |
| | | | NHV filtration (NST) | SUD-CGR-1 (BDBE) |

* SPS piping has an additional barrier for fire protection surrounding the piping in the HAA that is not credited in the LBE analyses.

# Safety-Significant SSCs for Radionuclide Retention

- The gaseous radwaste processing system (RWG) inventory and tritium MAR are low enough that no mitigation is needed to reach acceptable risk when the process barrier fails.

| Material-at-risk (MAR) | Primary Barrier | Secondary Barrier | Licensing Basis Event (LBE) |
|---|---|---|---|
| **RWG Inventory** | Gaseous radwaste barrier (NSRST) | Holdup tank vault (NST) | RRS-RWG-1 (DBE) |
| | | Vent Stack Filtration (NST) | RRS-RWG-2 (DBE) |
| | | | RRS-RWG-CN (DBA) |
| **SPS Tritium Inventory** | Intermediate cold trap SPS barrier (NSRST) | | RRS-ISPL-BL (DBE), RRS-ISPL-CN (DBA) |

# Summary

- The initial set of SR and NSRST functions identified in the PSAR are reasonable based on the preliminary design
- Additional steps, including assessment of risk significance for NSRST functions, are necessary prior to the operating license application (OLA)
- The SSC safety classification process being implemented by USO is thorough and systematic, providing reasonable assurance that the final safety analysis provided in the OLA will be sufficient to ensure safety

# Acronyms

- ACRS – Advisory Committee on Reactor Safeguards
- ANS – American Nuclear Society
- AOO – Anticipated Operational Occurrence
- ASME – American Society of Mechanical Engineers
- AST – Alternative Shutdown Trip
- BDBE – Beyond Design Basis Event
- CDA – Core Disruptive Accident
- CFR – Code of Federal Regulations
- CP – Construction Permit
- CPA – Construction Permit Application
- DBA – Design Basis Accident
- DBE – Design Basis Event
- DBHL – Design Basis Hazard Level
- DID – Defense In Depth
- EAB – Exclusion Area Boundary
- EVHM – Ex-vessel Handling Machine
- F-C – Frequency-Consequence
- HAA – Head Access Area
- IDP – Integrated Decision-making Process
- IDPP – Integrated Decision-making Process Panel
- IAC – Intermediate Air-cooling System
- ISP – Intermediate Sodium Pump
- IE – Initiating Event
- IHT – Intermediate Heat Transport System
- KU1 – Kemmerer Unit 1
- LBE – Licensing Basis Event
- LDA – Lead Demonstration Assembly
- LMP - Licensing Modernization Project
- LPZ – Low Population Zone
- LTA – Lead Test Assembly
- LWR – Light Water Reactor
- MAR – Material At Risk
- NEI – Nuclear Energy Institute
- NHV – Nuclear Island Heating, Ventilation, and Air-cooling System
- NRC – Nuclear Regulatory Commission
- NRR – Office of Nuclear Reactor Regulation
- NSRST – Non-safety-related with Special Treatment
- NST – No Special Treatment
- OL – Operating License
- OLA – Operating License Application
- PRA – Probabilistic Risk Assessment
- PRC – Pin Removal Cell
- PRISM – Power Reactor Innovative Small Module
- PSAR – Preliminary Safety Analysis Report
- PSID - Preliminary Safety Information Document
- PSF – PRA Safety Functions
- PSP – Primary Sodium Pump
- QHO – Quantitative Health Objective
- RAC – Reactor Air Cooling System
- RES – Reactor Enclosure System
- RG – Regulatory Guide
- RPS – Reactor Protection System
- RSF – Required Safety Functions
- RXB – Reactor Building
- SARRDL - Specified Acceptable Radionuclide Release Design Limits
- SCG – Sodium Cover Gas
- SE – Safety Evaluation
- SFR – Sodium Fast Reactor
- SPS – Sodium Purification System
- SR – Safety Related
- SRDC – Safety Related Design Criteria
- SSC – Structures, Systems, and Components
- TEDE – Total Effective Dose Equivalent
- TICAP - technology inclusive content of application
- TREAT – Transient Reactor Test Facility
- USO – US SFR Owner