Table E6.4-7. HEP Model for Group #4 Scenario 1(d) for 51A-OpCTMdrop001-HFI-COD

Designator	Description	Probability
A	CTT is not sufficiently centered under port	0.002
B	Operator fails to notice CTT not sufficiently centered	0.05
C	Operator fails to notice lid tilt and continues lift	0.02
D	Operator "locks" lift button into position	0.05
E	Lid catches and jams in port	0.5
F	Load cell overload interlock fails	2.7E−5
G	Mechanical failure of hoist under overload causes lid drop	0.1

NOTE: CTT = cask transfer trolley; HEP = human error probability.

Source: Original

The Boolean expression for this scenario follows:

$$A \times B \times (C + D) \times E \times F \times G = 0.002 \times 0.05 \times (0.02 + 0.05) \times 0.5 \times 2.7E{-5} \times 0.1 < 1E{-8} \qquad \text{(Eq. E-6)}$$

E6.4.3.4.2.5 HFE Group #4 Scenario 1(e) for 51A-OpCTMdrop001-HFI-COD

1. Operator activates grapple disengagement switch prematurely
2. Load cell disengagement interlock fails
3. Lid or shield ring drops from grapple and strikes canister.

Operator Activates Grapple Disengagement Switch Prematurely—Once engaged with the lid/shield ring, the grapple remains engaged until the object is placed in its staging area. The operator could prematurely activate grapple disengagement for one of two reasons. Either the wrong control could be activated (for example, when closing the port slide gate) or a number of operational steps could be skipped and the operator could actuate the control.

This is a straightforward case of taking an action out of sequence. This can be represented by CREAM CFF E4, adjusted by the following CPCs with values not equal to 1.0:

- CFF E4: Action performed out of sequence (repetitions, jumps, and reversals). The baseline HEP is 0.003.

- CPC "Working Conditions": With regard to this potential unsafe action, the working conditions for the CTM operator are deemed to be advantageous. The CPC for an execution task with advantageous working conditions is 0.8.

- CPC "Adequacy of Training/Preparation": This routine action is well trained and performed often. The CPC for an execution task with adequate training and high experience is 0.8.

Applying these factors yields the following:

Operator activates grapple disengagement switch prematurely =

$$0.003 \times 0.8 \times 0.8 = 0.002$$

Load Cell Disengagement Interlock Fails—One of the load cell interlocks is designed to disable the grapple disengagement circuit if a load is sensed. This interlock would have to fail in order for the operator's action to trigger the disengagement mechanism.

This is a mechanical failure of the interlock. This event is quantified in Section E6.4.3.4.1.

Load cell disengagement interlock fails = 2.7E−5

Lid or Shield Ring Drops from Grapple and Strikes Canister—In order for the lid or shield ring to actually drop, the grapple disengagement mechanism would need to overcome the dead weight friction caused by the weight of the lid or shield ring. In the case of the canister, this is clearly expected to be true, but the lid and the shield ring both weigh much less than the canister; thus, it is not clear. However, there is still a chance that the grapple would not disengage or would not disengage while the lid or shield ring is over the open port.

There are a number of factors that affect the likelihood of this event. First, in order to strike the canister the disengagement must occur over the canister, including that the slide gates are open. Second, the design of the grapple is such that it may not have the force to disengage when it is loaded (this is certainly true when lifting a canister, but perhaps less so when lifting a lid or shield ring). Finally, the object has to fall in an orientation such that it strikes the canister. Taking this all into consideration, the HRA team judges that it is justifiable to assign a 10% chance that this event would occur.

Object drops from grapple and strikes canister = 0.1

HEP Calculation for Scenario 1(e)—The events in the HEP model for Scenario 1(e) are presented in Table E6.4-8.

Table E6.4-8. HEP Model for Group #4 Scenario 1(e) for 51A-OpCTMdrop001-HFI-COD

Designator	Description	Probability
A	Operator activates grapple disengagement switch prematurely	0.002
B	Load cell disengagement interlock fails	2.7E−5
C	Object drops from grapple and strikes canister	0.1

NOTE: HEP = human error probability.

Source: Original

The Boolean expression for this scenario follows:

$$A \times B \times C = 0.002 \times 2.7E{-5} \times 0.1 < 1E{-8} \qquad \text{(Eq. E-7)}$$

E6.4.3.4.2.6 HEP for HFE 51A-OpCTMdrop001-HFI-COD

The Boolean expression for the overall HFE (all scenarios) for lifting a lid off an HLW cask follows:

$$\text{51A-OpCTMdrop001-HFI-COD (lid lift)} = \text{HFE 1(a)} + \text{HFE 1(b)} + \text{HFE 1(c)} + \text{HFE 1(d)} + \text{HFE 1(e)} = (<1E{-}8) + 1E{-}7 + (<1E{-}8) + (<1E{-}8) + (<1E{-}8) = 2E{-}7 \quad \text{(Eq. E-8)}$$

The Boolean expression for the overall HFE (all scenarios) for lifting a shield ring off a naval canister follows:

$$\text{51A-OpCTMdrop001-HFI-COD (shield ring lift)} = \text{HFE 1(a)} + \text{HFE 1(b)} + \text{HFE 1(c)} + \text{HFE 1(e)} = (<1E{-}8) + 1E{-}7 + (<1E{-}8) + (<1E{-}8) = 2E{-}7 \quad \text{(Eq. E-9)}$$

The Boolean expression for the overall HFE (all scenarios) for placing an inner lid on a waste package follows:

$$\text{51A-OpCTMdrop001-HFI-COD (lid placement)} = \text{HFE 1(a)} + \text{HFE 1(b)} + \text{HFE 1(e)} = 2E{-}8 + 1E{-}7 + (<1E{-}8) = 2E{-}7 \quad \text{(Eq. E-10)}$$

HLW canisters have one lid lift and one inner lid placement as part of their processing. The Boolean expression for the overall HFE for HLW (a lid removal and a lid placement) follows:

$$\text{51A-OpCTMdrop001-HFI-COD (total)} = \text{51A-OpCTMdrop001-HFI-COD (lid lift)} + \text{51A-OpCTMdrop001-HFI-COD (lid placement)} = 2E{-}7 + 2E{-}7 = 4E{-}7 \quad \text{(Eq. E-11)}$$

Naval canisters have one shield ring lift and one inner lid placement as part of their processing. The Boolean expression for the overall HFE for naval waste (a shield ring removal and an inner lid placement) follows:

$$\text{51A-OpCTMdrop001-HFI-COD (total)} = \text{51A-OpCTMdrop001-HFI-COD (shield ring lift)} + \text{51A-OpCTMdrop001-HFI-COD (lid placement)} = 2E{-}7 + 2E{-}7 = 4E{-}7 \quad \text{(Eq. E-12)}$$

E6.4.3.4.3 Quantification of HFE Scenarios for 51A-OpCTMdrop002-HFI-COD: Operator Causes Drop of Canister during CTM Operations (Low-Level Drop)

E6.4.3.4.3.1 HFE Group #4 Scenario 2(a) for 51A-OpCTMdrop002-HFI-COD

1. Crew member improperly installs grapple
2. Primary grapple interlock gives false positive signal
3. Operator fails to notice bad connection between hoist and grapple through camera
4. Grapple/canister drops from hoist.

Crew Member Improperly Installs Grapple—Prior to a lift operation, a crew member prepares the CTM for the operation by installing the appropriate grapple for the type of canister to be processed. While it is possible that this operation does not need to be performed (it may be the same grapple as for the cask lid), it is uncertain how often this occurs, so this analysis considers that this action needs to be performed each time. The crew member can improperly secure the grapple to the hoist. This makes the grapple appear to be secured in place when it is not.

This is a straightforward matter of task execution. The task is simple and routine and can be represented by NARA GTT A5, adjusted by the following EPCs:

- GTT A5: Completely familiar, well-designed, highly practiced, routine task performed to the highest possible standards by highly motivated, highly trained, and experienced person, totally aware of implications of failure, with time to correct potential errors. The baseline HEP is 0.0001.

- EPC 3: Time pressure. The full affect EPC would be ×11, but this applies only in cases where there is barely enough time to complete a task, and rapid work is necessary. In this case, the time pressure is more abstract in that there is a desire to keep the process moving for production reasons, but not a compelling one. The APOA anchor for 0.1 is that the operator feels some time pressure, but there is sufficient time to carry out the task properly with checking. The crew member probably feels a little more time pressure, so the APOA is set at 0.2.

- EPC 8: Poor environment. This EPC is applied not so much that the environment is poor, but rather that it is simply not optimal. The full affect EPC would be ×8, but this applies when working on the plant, with suit and breathing apparatus, possible access problems, and for more than 45 minutes so that fatigue sets in. The APOA anchor for 0.1 is for work in the plant with suit and breathing apparatus, but none of the other environmental stressors. In this task no breathing apparatus is required, but it is somewhat physically demanding. Given the tradeoffs, the APOA is set at 0.1.

- EPC 13: Operator underload/boredom. The full affect EPC would be ×3, which applies to a routine task of low importance, carried out by a single individual for several hours. The APOA anchor for 0.1 is for low difficulty, low importance, single individual, for less than one hour. This appears reasonable for this task, so the APOA is set at 0.1.

Using the NARA HEP equation yields the following:

$$\text{Crew member improperly installs grapple} = 0.0001 \times [(11-1) \times 0.2 + 1] \times [(8-1) \times 0.1 + 1] \times [(3-1) \times 0.1 + 1] = 0.0006 \quad \text{(Eq. E-13)}$$

Preoperational Check Fails to Note Improper Installation—There are two crew members responsible for preparing the CTM for each operation. The second crew member checks the first crew member's installation of the grapple, which provides an opportunity for the error to be detected. The second crew member also has activities to perform, and so checking the first crew member is a secondary function. In addition, the existence of the grapple/hoist interlock provides an expectation that any error can be detected.

For the action being analyzed, the second crew member has helped initially with the connection of the grapple to line it up but then moves on to other things. At best, the second crew member performs a cursory check at the end of the job. Since the crew member was involved in the early stages, there is a bias that the job was done correctly. It is concluded that the level of dependence is high. The baseline HEP for the checking, for checking routine tasks without a checklist is best determined from THERP (Ref. E8.1.26), Table 20-22, item (2), which is 0.2. The HEP adjusted for high dependence is from THERP Table 20-21, item (4)(e)), which is 0.6.

$$\text{Preoperational check fails to note improper installation} = 0.6 \qquad \text{(Eq. E-14)}$$

Grapple Interlock Gives False Positive Signal—Before beginning the lifting process, the operator should confirm engagement by checking the primary grapple engagement interlock. The indicator could give a false positive signal. This could result from a failure in the indicator itself or as the result of a partial engagement that generates a positive signal by triggering the sensor even though only partial engagement has occurred. Since the indicator system has not yet been designed and the specific detection approach has not been defined, this cannot be ruled out.

This is a mechanical failure of the interlock. This event is quantified in Section E6.4.3.4.1.

$$\text{Grapple interlock gives false positive signal} = 2.7\text{E}-5$$

Operator Fails to Notice Bad Connection between Hoist and Grapple through Camera—When the CTM operator is in the process of lifting the canister, the view through the camera shows the grapple and its connection to the hoist. The operator is not focused on that connection while lining up the grapple with the lifting device. However, as the lift begins, the operator is supposed to watch through the cameras. This gives the operator the opportunity to note that the grapple is not properly connected (for example, unexpected canister movement to one side or tilting of the grapple). This is an opportunity to question the stability of the connection and to lower the canister back down to recheck the connection. However, the operator does not expect any problems in this operation and tends to believe that any perceived problems are illusions caused by the distortions of viewing through a camera.

This action is best represented by the CREAM CFF O3, adjusted by the following CPCs with values not equal to 1.0:

- CFF O3: Observation not made. The baseline HEP is 0.003.
- CPC "Adequacy of Man–Machine Interface": For this particular observation, the use of a camera view (while the only practical means) is somewhere between tolerable and inappropriate. The CPC for an observation task with tolerable man–machine interface is 1.0, and for inappropriate is 5.0. With regard to being able to actually observe the condition of the grapple lock pin, the CPC is set as 4.0.
- CPC "Number of Simultaneous Goals": The operator is primarily focusing on properly aligning the bell and hoist, opening the ports, and grappling the lid. While it could be argued that this is not "more than capacity," it certainly relegates looking at the grapple/hoist connection to a secondary action. It is therefore deemed appropriate to apply the more than capacity CPC, which is 2.0.
- CPC "Adequacy of Training/Preparation": Training is adequate with high experience. The CPC for an observation task with adequate training and high experience is 0.8.

$$\text{Operator fails to notice bad connection between hoist and grapple through} = 0.003 \times 4 \times 2 \times 0.8 = 0.02$$

Grapple/Canister Drops from Hoist—Just because the lift is occurring with an improper grapple installation does not mean that the lid and grapple fall. The design safety margins built into these systems mean that it is possible that the lift and place can be completed successfully even with improper installation.

This event is quantified in Section E6.4.3.4.1.

$$\text{Grapple/canister drops from hoist} = 0.25$$

HEP Calculation for Scenario 2(a)—The events in the HEP model for Scenario 2(a) are presented in Table E6.4-9.

Table E6.4-9. HEP Model for HFE Group #4 Scenario 2(a) for 51A-OpCTMdrop002-HFI-COD

Designator	Description	Probability
A	Crew member improperly installs grapple	0.0006
B	Preoperational check fails to note improper installation	0.6
C	Grapple interlock gives false positive signal	2.7E−5
D	Operator fails to notice bad connection between hoist and grapple through camera	0.02
E	Grapple/canister drops from hoist	0.25

NOTE: HEP = human error probability.

Source: Original

The Boolean expression for this scenario follows:

$$A \times B \times C \times D \times E = 0.0006 \times 0.6 \times 2.7E{-5} \times 0.02 \times 0.25 < 1E{-8} \quad \text{(Eq. E-15)}$$

E6.4.3.4.3.2 HFE Group #4 Scenario 2(b) for 51A-OpCTMdrop002-HFI-COD

1. Operator fails to fully engage grapple
2. Grapple engagement interlock gives false positive signal
3. Operator fails to notice grapple not fully engaged through camera
4. Canister drops from grapple.

CTM Operator Fails to Fully Engage Grapple—The operator engages the grapple from the control panel. The grapple can be roughly positioned using the alignment guides for the CTM and the hoist height indicator on the control panel, but final alignment must be done visually using the view from the cameras provided on the grapple. Once the operator believes the grapple is aligned, the operator engages the grapple with the lift fixture and confirms through the camera. If the operator sees that the grapple has not properly engaged, then the operator disengages and repositions the grapple and tries again to engage.

In this task, the operator aligns the grapple visually using the camera view and then engages the grapple. If it is not aligned properly, it does not fully engage. This unsafe action can be best represented by the task execution error NARA GTT A1, adjusted by the following CPCs:

- NARA GTT A1: Carry out a simple manual task with feedback. Skill-based and therefore not necessarily with procedures. The baseline HEP is 0.005
- EPC 3: Time pressure. The full affect EPC would be ×11, but this applies only in cases where there is barely enough time to complete a task and rapid work is necessary. In this case, the time pressure is more abstract, in that there is a desire to keep the process moving for production reasons, but not a compelling one. The APOA anchor for 0.1 is that the operator feels some time pressure, but there is sufficient time to carry out the task properly with checking. The crew member probably feels a little more time pressure than that, so the APOA is set at 0.2.
- EPC 11: Poor, ambiguous or ill-matched system feedback. This EPC is applied to account for the need to observe the operation through cameras. The full affect EPC would be ×4. The full effect is applicable when legibility is poor or label is obscured, or where the layout of controls makes visual access and physical access difficult. The use of camera view is deemed to represent full effect. The APOA is set at 1.0.
- EPC 13: Operator underload/boredom. The full affect EPC would be ×3, which applies to a routine task of low importance, carried out by a single individual for several hours. The APOA anchor for 0.1 is for low difficulty, low importance, single individual, for less than one hour. This appears reasonable for this task, so the APOA is set at 0.1.

Using the NARA HEP equation yields the following:

$$\text{Operator fails to fully engage grapple} = 0.005 \times [(11-1) \times 0.2 + 1] \times [(4-1) \times 1.0 + 1] \times [(3-1) \times 0.1 + 1] = 0.07 \qquad \text{(Eq. E-16)}$$

Grapple Engagement Interlock Gives False Positive Signal—Before beginning the lifting process, the operator should confirm engagement by checking the grapple engagement interlock. The indicator could give a false positive signal. This could result from a failure in the indicator itself or as the result of a partial engagement that generates a positive signal by triggering the sensor even though only partial engagement has occurred. Since the indicator system has not yet been designed and the specific detection approach has not been defined, this cannot be ruled out.

This is a mechanical failure of the interlock. This event is quantified in Section E6.4.3.4.1.

$$\text{Grapple engagement interlock gives false positive signal} = 2.7\text{E}{-5}$$

CTM Operator Fails to Notice Grapple Not Fully Engaged through Camera—As the lift begins, the operator is supposed to watch through the cameras. This gives the operator the opportunity to note that the grapple is not properly engaged (for example, unexpected canister movement to one side or tilting of the grapple), which allows the operator the opportunity to question the stability of the connection and to lower the canister back down to recheck the connection. However, the operator does not expect any problems in this operation and tends to believe that any perceived problems are illusions caused by the distortions of viewing through a camera.

In this case, the operator's check is a self-check, again through the camera. The CTM operator believes that the correct action was performed initially, and this was confirmed by the false positive from the interlock, so this observation is deemed completely dependent on the prior actions. Using THERP (Ref. E8.1.26) Table 20-21 to assess dependency, item (5) for complete dependency:

Operator fails to notice grapple not fully engaged through camera = 1.0

Canister Drops from Grapple—Just because the lift is occurring with an improper grapple engagement does not mean that the canister falls. The safety margins built into these systems mean that it is possible that the lift and place can be completed successfully even with improper installation.

This event is quantified in Section E6.4.3.4.1.

Canister drops from grapple = 0.25

HEP Calculation for Scenario 2(b)—The events in the HEP model for Scenario 2(b) are presented in Table E6.4-10.

Table E6.4-10. HEP Model for HFE Group #4 Scenario 2(b) for 51A-OpCTMdrop002-HFI-COD

Designator	Description	Probability
A	Operator fails to fully engage grapple	0.07
B	Grapple engagement interlock gives false positive signal	2.7E−5
C	Operator fails to notice grapple not fully engaged through camera	1.0
D	Canister drops from grapple	0.25

NOTE: HEP = human error probability.

Source: Original

The Boolean expression for this scenario follows:

$$A \times B \times C \times D = 0.07 \times 2.7E{-5} \times 1.0 \times 0.25 = 5E{-7} \qquad \text{(Eq. E-17)}$$

E6.4.3.4.3.3 HFE Group #4 Scenario 2(c) for 51A-OpCTMdrop002-HFI-COD

1. CTT is not sufficiently centered under port
2. Operator fails to notice CTT not sufficiently centered
3. Operator fails to notice canister contacting ceiling and continues lift OR operator "locks" lift button into position
4. Load cell overload interlock fails
5. Mechanical failure of hoist under overload causes canister drop. (NOTE: This scenario only applies to naval canisters because the transportation cask lid was removed in the preparation area).

CTT Is Not Sufficiently Centered under Port—This unsafe action actually occurs prior to this operation, during movement of the CTT into the Cask Unloading Room. The CTT operator brings the unit into the Cask Unloading Room and locates it centered directly under the cask port by aligning it against end stops that properly locate it and by using markings on the floor. If the cask is not properly centered, it is possible that the naval canister could strike the ceiling around the cask port rather than rising smoothly through the cask port. This only applies to naval canisters because their cask lids are removed in the preparation area. For HLW any misalignment would be discovered during the lid lift by the CTM. In order for the naval canister to hit the unloading room ceiling during lift, the cask would have to be off-center by more at least a few feet.

The unsafe action results from stopping the CTT prematurely and leaving it at least a number of feet short of the proper location. This can be represented by CREAM CFF E1, adjusted by the following CPCs with values not equal to 1.0:

- CFF E1: Execution of wrong type performed (with regard to force, distance, speed, or direction). The baseline HEP is 0.003.

- CPC "Available Time": There is adequate time to perform this task. The only time pressure is the desire to keep the process moving, but the consequences are insignificant. The CPC for an execution task with adequate time is 0.5.

- CPC "Adequacy of Training/Preparation": This routine task is well trained and practiced and performed quite frequently. The CPC for an execution task with adequate training and high experience is 0.8.

The above parameters were the same as those applied to failure to properly center the CTT for a lid, where only being about a foot or two out of position could cause a problem. For the case of a canister, the miss must be by at least a few feet in order for the canister to strike the ceiling on the way up. The HRA team believes it is inappropriate to apply the same number to both unsafe actions, and deems it reasonable to further reduce the HEP for the unsafe action by a factor of two to account for this (a multiplier of 0.5).

Applying these factors yields the following:

$$\text{CTT is not sufficiently centered under port (dual-purpose canister/transportation cask)} = 0.003 \times 0.5 \times 0.8 \times 0.5 = 0.001$$

Operator Fails to Notice that CTT Is Not Sufficiently Centered—The CTM operator centers the CTM grapple over the cask lid lift fixture using a two-step process. First, the CTM operator does a rough alignment using the bridge and trolley position indicators and sets the bell and shield skirt in place. Then the operator opens the cask port and performs a fine alignment using a camera alignment system. The operator is not looking for perfect alignment but would expect it to be close. At this point, the operator would have the opportunity to question the amount of distance needed to move the hoist into position. Possible responses include: (1) the position is not off by much (2) the initial placement of the bell is in question and it is repositioned which may be easier to accomplish than asking another crew member to move the CTT), or (3) a belief that the position of the CTT is not off center by enough to make a difference.

In this task, the CTM operator roughly centers the CTM over the cask port, lowers the shield, and opens the port and CTM gates. The operator needs to more accurately locate the grapple over the lid by moving the hoist within the bell. At this point, the operator has an opportunity to judge if the amount of movement required to align the grapple is too much for the lid to clear the edges of the port during the lift. In this case, it is not so much that the operator has failed in an observation of the relative locations of the grapple and the lid, or that the canister is not perfectly centered, but rather that the operator's decision is that it doesn't matter (it's "close enough") is incorrect. This can be represented by CREAM CFF I2, adjusted by the following CPCs with values not equal to 1.0:

- CFF I2: Decision error (either not making a decision or making a wrong or incomplete decision). The baseline HEP is 0.01.
- CPC "Available Time": With regard to the general level of time pressure for the task and the situation type, it would be easy to believe that there is adequate time since the consequences of taking more time are (from a safety perspective) insignificant. However, from a production perspective, this would be a significant setback since the CTM operator would have to get the CTT crew back to move the CTT, a time-consuming process. This time pressure could bias the operator towards a decision that "it's close enough." The CPC for an interpretation task with continuously inadequate available time is 5.0.

Applying these factors yields the following:

Operator fails to notice that CTT not sufficiently centered =
$0.01 \times 5 = 0.05$

Operator Fails to Notice Canister Contacting Ceiling and Continues Lift—The CTM operator is able to see the naval canister through the camera display. When the naval canister strikes the ceiling, it stops as the hoist continues to try to rise. The operator has an opportunity to notice the stopped CTM before it stops the lift. The prior unsafe action of failing to notice that the cask is too far off center could lead the operator to be somewhat more careful and observant during the lift than if it had been closer to center (e.g., like the extra care a driver might show while pulling into a narrower than normal parking space).

If the operator is looking at the camera view during the lift, there is an opportunity to observe the canister contacting the ceiling of the Cask Unloading Room and stopping rather than rising straight through. The most likely failure is not looking at the screen at the time this occurs, which can be represented by CREAM CFF O3, adjusted by the following CPCs with values not equal to 1.0:

- CFF O3: Observation not made (omission). The baseline HEP is 0.003.

- CPC "Adequacy of Man–Machine Interface": There are two vulnerabilities in the man–machine interface for this observation. First, there is no alarm or indicator to alert the operator. Second, the camera view is not perfect. These are inherent to this type of operation, but would make it more likely that the operator would not be looking at the screen at the time. Thus, the man–machine interface could be considered inappropriate with regard to success of this observation (as it was for scenario 1(e)). However, the fact that the magnitude of the CTT offset required to cause a problem is so much greater in this case argues for a somewhat lesser adjustment. That is, the man–machine interface is somewhat better with regard to this failure, and it is more likely that the operator is looking and sees the contact. The CPC for an observation task with inappropriate man-machine interface is 5.0. The HRA team has determined that a CPC of 3.0 is more appropriate in this case.

Applying these factors yields the following:

Operator fails to notice canister contacting ceiling and continues lift =
$0.003 \times 3 = 0.01$

Operator "Locks" Lift Button into Position—Another way that the lift would go too long is if the operator were to use some inventive means to lock the "button" in place. The CTM lifts are a tedious task and require holding the button in place for long periods of time. There is no locking feature associated with the ASD that would keep the button in place; however, it is not inconceivable that, after many lifts have been done without ASD failure, an operator would develop a creative technique to accomplish this. Since the operator develops trust in the ASD and the other system interlocks, the action would not be perceived as unsafe but rather as a clever way to free time to get ready for subsequent steps or perform other duties. Again, the operator might be less likely to do this if there are doubts about the positioning of the cask.

The quantification of this event is discussed in detail under Scenario 1(c). In this scenario, it is judged that there is no bias dependency towards this failure that results from prior failures in the scenario. Therefore, the value used for the non-bias case (0.05) could be applied here. However, similar to the previous discussion, the HRA team believes that the magnitude of the CTT offset required to cause a problem actually creates a bias in the operator against taking any shortcuts (as opposed to no bias), so that a further reduction of 0.5 should be applied.

Operator "locks" lift button into place = $0.05 \times 0.5 = 0.03$

Load Cell Overload Interlock Fails—The load cell has an interlock that shuts off the hoist if it senses that the load exceeds the approved load for the hoist. The hoist straining to lift the naval canister in contact with the ceiling would be one such condition. Since this would shut the hoist down prior to exceeding the ultimate capacity of the system, it would have to fail in order to cause a drop.

This is a mechanical failure of the interlock. This event is quantified in Section E6.4.3.4.1.

Load cell interlock fails = 2.7E−5

Mechanical Failure of Hoist under Overload Causes Canister Drop—There are three potential failure modes that could cause the canister to detach from the hoist. The cable could fail, the grapple could break free from the lower block, or the lifting fixture could break free from the grapple or canister. However, just because the hoist keeps pulling does not mean that the naval canister falls (the hoist motor could overload and fail before the naval canister becomes detached from the hoist).

This event is quantified in Section E6.4.3.4.1.

Mechanical failure of hoist under overload causes canister drop = 0.25

HEP Calculation for Scenario 2(c)—The events in the HEP model for Scenario 2(c) are presented in Table E6.4-11.

Table E6.4-11. HEP Model for HFE Group #4 Scenario 2(c) for 51A-OpCTMdrop002-HFI-COD

Designator	Description	Probability
A	CTT is not sufficiently centered under port	0.001
B	Operator fails to notice CTT not sufficiently centered	0.05
C	Operator fails to notice canister contacting ceiling and continues lift	0.01
D	Operator “locks” lift button into position	0.03
E	Load cell overload interlock fails	2.7E−5
F	Mechanical failure of hoist under overload causes canister drop	0.25

NOTE: CTT = cask transfer trolley; HEP = human error probability.

Source: Original

The Boolean expression for this scenario follows:

$$A \times B \times (C + D) \times E \times F = 0.001 \times 0.05 \times (0.01 + 0.03) \times 2.7E{-5} \times 0.25 < 1E{-8} \quad \text{(Eq. E-18)}$$

E6.4.3.4.3.4 HFE Group # 4 Scenario 2(d) for 51A-OpCTMdrop002-HFI-COD

1. Crew member fails to fully withdraw lift fixture bolts
2. Operator fails to notice canister is rising with lift fixture and shield ring
3. Canister drops from lift fixture.

Crew Member Fails to Fully Withdraw Lift Fixture Bolts—The lift fixture for the naval canister is attached to both the canister and the shield ring. The lift fixture roughly looks like two concentric circles. The center circle has three bolts which attach the fixture to the canister, and the outer circle has several bolts which attach the fixture to the shield ring. A crew member is in the Canister Transfer Room, standing over the waste package port gate using long reach tools to unbolt the fixture from the canister. The crew member loosens the bolts until there is no resistance and there is confidence that the bolt is completely loose. The crew member does not remove the bolts from the fixture. This crew member is highly trained and performs bolt removal daily.

The crew member uses a long-reach tool to loosen the bolts. Since the bolts are not actually removed and the threads cannot be seen, the bolts are loosened until each one rotates freely. This unsafe action can be represented by NARA GTT A1, adjusted by the following CPCs:

- GTT A1: Carry out a simple manual task with feedback. Skill-based and therefore not necessarily with procedures. The baseline HEP is 0.005

- EPC 3: Time pressure. The full affect EPC would be ×11, but this applies only in cases where there is barely enough time to complete a task and rapid work is necessary. In this case, the time pressure is more abstract, in that there is a desire to complete the task and get to an area of lower radiation levels and also to keep the process moving for production reasons, but these are not compelling time pressure. The APOA anchor for 0.1 is that the operator feels some time pressure, but there is sufficient time to carry out the task properly with checking. The APOA anchor for 0.5 is that the operator must work at a fast pace with reduced time for checking. In this case, it is not that the operator must work at a fast pace, but rather that the operator wants to work quickly. Overall, it is reasonable to set APOA at 0.3.

- EPC 11: Poor, ambiguous or ill-matched system feedback. While the operator can be said to have feedback (the feel of a bolt moving freely). This EPC is applied to account for the operator only having this indirect feedback. The full affect EPC would be ×4. The full effect is applicable when legibility is poor or label is obscured, or where the layout of controls makes visual access and physical access difficult. The presence of indirect feedback only is deemed to represent full effect. The APOA is set at 1.0.

- EPC 13: Operator under-load/boredom. The full affect EPC would be ×3, which applies to a routine task of low importance, carried out by a single individual for several hours. The APOA anchor for 0.1 is for low difficulty, low importance, single individual, for less than one hour. This appears reasonable for this task, so the APOA is set at 0.1.

- EPC 14: A conflict between immediate and long term objectives. This EPC looks further at the issue of the operator wishing to get to a lower radiation area versus the need to complete the tasks. The full affect EPC is 2.5, which applies to a conflict between two very significant and important tasks, one of which has greater time urgency. The APOA anchor for 0.1 is for an operator having an immediate personal need, but there is an obvious safety task requiring completion. This appears reasonable for this task, so the APOA is set at 0.1.

- EPC 16: No obvious way of keeping track of progress during an activity. This addresses that there are no job aids that can track the loosening of the bolts; the crew member has to remember which ones are finished. The full affect EPC is 2. The APOA anchor for 0.1 is for a task of 5 to 9 steps. This task is three steps (three bolts). It appears reasonable to set the APOA at 0.05.

Using the NARA HEP equation yields the following:

$$\text{Crew member fails to fully withdraw lift fixture bolts} = 0.005 \times [(11-1) \times 0.3 + 1] \times [(4-1) \times 1.0 + 1] \times [(3-1) \times 0.1 + 1] \times [(2.5-1) \times 0.1 + 1] \times [(2-1) \times 0.05 + 1] = 0.2 \quad \text{(Eq. E-19)}$$

Operator Fails to Notice Canister is Rising with Lift Fixture and Shield Ring—When the CTM operator is in the process of lifting the shield ring, the view through the camera shows the canister and its connection to the hoist. The operator is focused on that connection, due to specific training to ensure that the canister is free from the grapple/hoist. As the lift begins, the operator watches through the cameras, this is an opportunity to note that the canister is beginning to lift. This is also an opportunity to stop and ask the other crew member to return and finish unbolting. However, the operator does not be expecting there to be any problems in this operation and tends to believe that any perceived problems are illusions caused by the distortions of viewing through a camera. In addition to a camera view, there is also a view of the loadcell meter which indicates that the load on the hoist, which is also checked when beginning a lift.

In this case, the CTM operator fails to observe the lifting of the lift device and shield ring, and does not see (through the camera) or otherwise detect (by observing the output of the load cell on the control panel) that the canister is rising. This can be represented by CREAM CFF O3, adjusted by the following CPCs with value not equal to 1.0:

- CFF O3: Observation not made. (Omission. Overlooking a signal or a measurement). The baseline HEP is 0.003.

- CPC "Adequacy of Training/Preparation": This routine task is well trained and practiced. The CPC value for an observation task with adequate training and high experience is 0.8.

Applying these factor yields the following:

$$\text{Operator fails to notice canister is rising with lift fixture and shield ring} = 0.003 \times 0.8 = 0.003$$

Canister Drops from Lift Fixture—Just because the lift is occurring with partial engagement of one or more bolts does not mean that the canister falls. The safety margins built into these systems mean that it is possible that the canister can lift with the fixture and shield ring and be discovered later in the operation, allowing the operator to put it back down undamaged.

This event is quantified in Section E6.4.3.4.1.

Canister drops from lift fixture = 0.25

HEP Calculation for Scenario 2(d)—The events in the HEP model for Scenario 2(d) are presented in Table E6.4-12.

Table E6.4-12. HEP Model for HFE Group #4 Scenario 2(d) for 51A-OpCTMdrop002-HFI-COD

Designator	Description	Probability
A	Crew member fails to fully withdraw lift fixture bolts	0.2
B	Operator fails to notice canister is rising with lift fixture and shield ring	0.003
C	Canister drops from lift fixture	0.25

NOTE: HEP = human error probability.

Source: Original

The Boolean expression for this scenario follows:

$$A \times B \times C = 0.2 \times 0.003 \times 0.25 = 2E{-}4 \qquad \text{(Eq. E-20)}$$

E6.4.3.4.3.5 HEP for HFE 51A-OpCTMdrop002-HFI-COD

The Boolean expression for the overall HFE (all scenarios) for moving a naval canister follows:

$$\text{51A-OpCTMdrop002-HFI-COD (Naval Canister)} = \text{HFE 2(a)} + \text{HFE 2(b)} + \text{HFE 2(c)} + \text{HFE 2(d)} = (<1E{-}8) + 5E{-}7 + (<1E{-}8) + 2E{-}4 = 2E{-}4 \qquad \text{(Eq. E-21)}$$

The Boolean expression for the overall HFE (all scenarios) for moving an HLW canister follows:

$$\text{51A-OpCTMdrop002-HFI-COD (HLW)} = \text{HFE 2(a)} + \text{HFE 2(b)} = (<1E{-}8) + 5E{-}7 = 5E{-}7 \qquad \text{(Eq. E-22)}$$

E6.4.3.4.4 Quantification of HFE Scenarios for 51A-OpCTMImpact1-HFI-COD: Operator Moves the CTM while Canister or Object Is Below or Between Levels

E6.4.3.4.4.1 HFE Group #5 Scenario 3(a) for 51A-OpCTMImpact1-HFI-COD

1. Operator leaves CTM in lid lift mode (HLW only).
2. Operator fails to notice that lift stops too soon.
3. Operator fails to close port slide gate OR fails to notice that it does not fully close.
4. Operator fails to close CTM slide gate OR fails to notice it does not fully close.
5. CTM slide gate interlock fails.

Operator Leaves CTM in Lid Lift Mode (HLW only)—The operator is supposed to set the ASD to canister lift mode prior to lifting the canister. It should be in lid lift mode because the lid was lifted right before the canister. Failing to reset for a canister lift would result in the canister stopping part way through the port.

Setting the CTM system to the appropriate lift mode prior to performing a lift is fundamental to the operation, not simply a step in a procedure that can be missed. The initial action to set the mode is quite simple, so the only realistic way that the operator can leave the ASD in lid lift mode is to completely fail to take any actions to set the CTM system for a lift. This failure can be represented by NARA GTT B3, adjusted by the following EPCs.

- GTT B3: Set system status as part of routine operations using strict administratively controlled procedures. The baseline HEP is 0.0007.

This operation is performed under optimal conditions. It is early in the operation, and the operator is active, so it is too early in the task for boredom to set in. The baseline HEP is used without adjustment.

Operator leaves CTM in lid lift mode = 0.0007

Operator Fails to Notice that Lift Stops too Soon—Lifting the canister takes on the order of ten minutes, whereas lifting the lid takes only on the order of three minutes. Since the operator has to hold the lift button in or the lift stops, there is an opportunity to notice that the hoist has stopped sooner than expected. On the control panel the operator would have the camera view and also the hoist position indication, either of which can confirm that the canister has not been fully lifted. Failure to do so would result in continuing the operations with the canister between floors.

The operator is supposed to hold the lift button until the lift automatically stops. The operator has performed this operation many times in the past and has an instinctive feel for how long the lift takes. A canister lift should take around three times as long as a lid lift. If the operator feels it has not taken long enough, the camera and the indicators on the control panel can provide confirmation that the lift was prematurely terminated. Failing to recognize the short lift (and thus an implied failure to question the result of the action) could be an observation error (CREAM CFF O2, wrong identification made, or O3, observation not made). But the more conservative and more applicable approach is represented by the interpretation error CREAM CFF I1, adjusted by the following CPCs with values not equal to 1.0:

- CFF I1: Faulty diagnosis (either a wrong diagnosis or an incomplete diagnosis). The baseline HEP is 0.2.

- CPC "Working Conditions": The operator has optimal working conditions in the control room. The CPC for an interpretation task with advantageous working conditions is 0.8.

- CPC "Available Time": The operator clearly has adequate time before beginning the next steps in the process to realize that the amount of time spent in the lift is not reasonable for a canister lift. The CPC for an interpretation task with adequate available time is 0.5.

- CPC "Adequacy of Training/Preparation": Training is adequate with high experience. The CPC for an observation task with adequate training and high experience is 0.8.

Applying these factors yields the following:

Operator fails to notice lift is taking too long = $0.2 \times 0.8 \times 0.5 \times 0.8 = 0.07$

Operator Fails to Close Port Slide Gate—The operator is supposed to close the port slide gate as soon as the lift is completed. This gives the operator an opportunity to determine that the canister is not fully withdrawn. The operator would fail to notice this if either the operator skipped this step or if the operator performed the action and failed to notice that the gate had not closed all the way (e.g., because it is blocked from doing so by the canister). In the latter case, the slide gate open/close indicator lights are in an incorrect state (either both on or both off, depending on design).

The operator is supposed to close the port slide gate prior as a part of the lift and transfer process. This is an EOO that can most closely be represented by CREAM CFF E5, adjusted by the following CPCs with values not equal to 1.0:

- CFF E5: Action missed, not performed (omission), including the omission of the last actions in a series. The baseline HEP is 0.03.
- CPC "Available Time": There is adequate time available. The CPC for an execution task with adequate time is 0.5.
- CPC "Adequacy of Training/Preparation": Training is adequate with high experience. The CPC for an execution task with adequate training and high experience is 0.8.

Applying these factors yields the following:

$$\text{Operator fails to close port slide gate} = 0.03 \times 0.5 \times 0.8 = 0.01$$

Operator Fails to Notice that Port Slide Gate Does Not Fully Close—The action of closing the port slide gate is simple. In this scenario, the gate does not close all the way because the canister is in the way. The operator has visible feedback on the failure of the gate to close because the "open" (or "green") light on the control panel stays on and the "closed" (or "red") light also comes on and stays on. Both lights on at the same time signifies that the port is neither fully open nor fully closed. The problem can be easily confirmed by looking at the camera or checking the status of the light curtain at the bottom of the bell. This unsafe action can be represented by NARA GTT C1, adjusted by the following EPCs.

- GTT C1: Simple response to a range of alarms/indications providing clear indication of situation (simple diagnosis required). The baseline HEP is 0.0004.
- EPC 3: Time pressure. The full affect EPC would be ×11, but this applies only in cases where there is barely enough time to complete a task, and rapid work is necessary. In this case, the time pressure is more abstract in that there is a desire to keep the process moving for production reasons, but not a compelling one. The APOA anchor for 0.1 is that the operator feels some time pressure, but there is sufficient time to carry out the task properly with checking. This appears reasonable for this task, so the APOA is set at 0.1.
- EPC 13: Operator underload/boredom. The full affect EPC would be ×3, which applies to a routine task of low importance, carried out by a single individual for several hours. The APOA anchor for 0.1 is for low difficulty, low importance, single individual, for less than one hour. This appears reasonable for this task, so the APOA is set at 0.1.

Using the NARA HEP equation yields the following:

Operator fails to notice that port slide gate does not fully close
$= 0.0004 \times [(11-1) \times 0.1 + 1] \times [(3-1) \times 0.1 + 1] = 0.001$ (Eq. E-22a)

Operator Fails to Close CTM Slide Gate—The operator is supposed to close the CTM slide gate as soon as the port slide gate is closed. This gives the operator another opportunity to determine that the canister is not fully withdrawn. The operator would fail to notice this if either the operator skipped this step or if the operator performed the action and failed to notice that the gate had not closed all the way (e.g., because it is blocked from doing so by the hoist cables or load cell). In the latter case, the slide gate open/close indicator lights would be an incorrect state (either both on or both off, depending on design).

The baseline HEP for failure to close this gate would be the same as for the similar unsafe action for the port slide gate.

Operator fails to close CTM slide gate (independent) = 0.01

However, this would only apply in the case where the earlier unsafe action was failure to notice that the port slide gate had failed to close. In the case where the earlier unsafe action was failure to close the port slide gate, there is a dependence on the failure to perform a similar task next in the sequence. It is judged that the dependence between these two actions is high. Using item (4)(a) from THERP (Ref. E8.1.26) Table 20-21, the HEP follows:

Operator fails to close CTM slide gate (given failure to close the port slide gate) = 0.5

Operator Fails to Notice CTM Slide Gate Does Not Fully Close—The baseline HEP for failure to notice that this gate did not fully close would be the same as for the similar unsafe action for the port slide gate.

Operator fails to notice CTM slide gate does not fully close (independent) = 0.001

However, this would only apply in the case where the earlier unsafe action was failure to close the port slide gate. In the case where the earlier unsafe action was failure to notice that the port slide gate did not fully close, there is a dependence on the failure to perform a similar task next in the sequence. It is judged that the dependence between these two actions is high. Using item (4)(a) from THERP (Ref. E8.1.26) Table 20-21, the HEP follows:

Operator fails to notice CTM slide gate does not fully close (given failure notice that port slide gate did not fully close) = 0.5

CTM Slide Gate Interlock Fails—The CTM slide gate interlock prevents CTM movement with the slide gate open (the shield skirt cannot be raised). If the interlock itself fails, the operator can move the CTM with the canister between levels.

This is a mechanical failure of the interlock. This event is quantified in Section E6.4.3.4.1.

CTM slide gate interlock fails = 2.7E−5

HEP Calculation for Scenario 3(a)—The events in the HEP model for Scenario 3(a) are presented in Table E6.4-13.

Table E6.4-13. HEP Model for HFE Group #5 Scenario 3(a) for 51A-OpCTMImpact1-HFI-COD

Designator	Description	Probability
A	Operator leaves CTM in lid lift mode	0.0007
B	Operator fails to notice that lift stops too soon	0.07
C	Operator fails to close port slide gate	0.01
D	Operator fails to notice that port slide gate does not fully close	0.001
E1	Operator fails to close CTM slide gate (independent)	0.01
E2	Operator fails to close CTM slide gate (given failure to close the port slide gate)	0.5
F1	Operator fails to notice CTM slide gate does not fully close (independent)	0.001
F2	Operator fails to notice CTM slide gate does not fully close (given failure to notice that port slide gate did not fully close)	0.5
G	CTM slide gate interlock fails	2.7E−05

NOTE: CTM = canister transfer machine; HEP = human error probability.

Source: Original

The Boolean expression for this scenario follows:

$$A \times B \times \{[C \times (E2 + F1)] + [D \times (E1 + F2)]\} \times G =$$
$$0.0007 \times 0.07 \times \{[0.01 \times (0.5 + 0.001)] + [0.001 \times (0.01 + 0.5)]\} \times 2.7E{-}05 =$$
$$0.0007 \times 0.07 \times 0.006 \times 2.7E{-}05 = (<1E{-}8) \qquad \text{(Eq. E-22b)}$$

E6.4.3.4.4.2 HFE Group #5 Scenario 3(b) for 51A-OpCTMImpact1-HFI-COD

1. Operator places CTM in lid lift mode (naval canister).
2. Operator fails to notice that lift stops too soon.
3. Operator fails to close port slide gate OR fails to notice that it does not fully close.
4. Operator fails to close CTM slide gate OR fails to notice it does not fully close.
5. CTM slide gate interlock fails.

Operator Inadvertently Places CTM in Lid Lift Mode (naval)—The operator is supposed to set the ASD to canister lift mode prior to lifting the canister. For naval operations, the ASD is in maintenance (or manual) lift mode because this is the default positioning. Failing to reset for canister lift would result in the canister stopping part way through the port.

The CTM operator is supposed to set the CTM system to the appropriate lift mode prior to performing a lift. This is fundamental to the operation, not simply a step in a procedure that can be missed. For the situation involving the naval canister, the ASD has been in maintenance mode as a default condition; therefore, the operator must inadvertently set the ASD to lid lift mode rather than canister lift mode. There are only two modes to choose from: lid lift and canister lift. The ASD control is a screen where the operator can scroll between the choices to pick the appropriate lift mode. The act of selecting the wrong mode from these two can be best represented by the task execution error NARA GTT A1, adjusted by the following CPCs:

- NARA GTT A1: Carry out a simple single manual action with feedback. Skill-based and therefore not necessarily with procedures. The baseline HEP is 0.005.

- This operation is performed under optimal conditions. It is early in the operation, and the operator is active, so it is too early in the task for boredom to set in. The ASD control system requests confirmation from the operator (e.g., "You have selected canister lift. Confirm Y/N"). The baseline HEP is used without adjustment.

Operator inadvertently places CTM in lid lift mode (naval) = 0.005.

Operator Fails to Notice that Lift Stops too Soon—Lifting the canister takes on the order of ten minutes, whereas lifting the lid takes only on the order of three minutes. Since the operator has to hold the lift button in or the lift stops, the operator has an opportunity to notice that the hoist has stopped sooner than expected. In front on the control panel there is a camera view and also the hoist position indication, either of which can confirm the suspicion that the canister has not been fully lifted. Failure to do so would result in a continuation of the operations with the canister between floors.

The operator is supposed to hold the lift button until the lift automatically stops. The operator has performed this operation many times in the past, and has an instinctive feel for how long the lift takes. A canister lift should take around three times as long as a lid lift. If the operator feels it has not taken long enough, the operator need only look at the camera and the indicators on the control panel. Failing to recognize the short lift (and thus an implied failure to question the result of the action) can be represented by CREAM CFF I1, adjusted by the following CPCs with values not equal to 1.0:

- CFF I3: Faulty diagnosis (either a wrong diagnosis or an incomplete diagnosis). The baseline HEP is 0.2.

- CPC "Working Conditions": The operator has optimal working conditions in the control room. The CPC for an interpretation task with advantageous working conditions is 0.8.

- CPC "Available Time": The operator clearly has adequate time before beginning the next steps in the process to realize that the amount of time spent in the lift is not reasonable for a canister lift. The CPC for an interpretation task with adequate available time is 0.5.

- CPC "Adequacy of Training/Preparation": Training is adequate with high experience. The CPC for an observation task with adequate training and high experience is 0.8.

Applying these factors yields the following:

Operator fails to notice lift is taking too long = $0.2 \times 0.8 \times 0.5 \times 0.8 = 0.07$

Operator Fails to Close Port Slide—The operator is supposed to close the port slide gate as soon as the lift is completed as a part of the lift and transfer process. This gives the operator an opportunity to determine that the canister is not fully withdrawn. The operator would fail to notice this if either the operator skipped this step or if the operator performed the action and failed to notice that the gate had not closed all the way (e.g., because it is blocked from doing so by the canister). In the latter case, the slide gate open/close indicator lights would be in an incorrect state (either both on or both off, depending on design).

This is an EOO that can most closely be represented by CREAM CFF E5, adjusted by the following CPCs with values not equal to 1.0:

- CFF E5: Action missed, not performed (omission), including the omission of the last actions in a series. The baseline HEP is 0.03.
- CPC "Available Time": There is adequate time available. The CPC for an execution task with adequate time is 0.5.
- CPC "Adequacy of Training/Preparation": Training is adequate with high experience. The CPC for an execution task with adequate training and high experience is 0.8.

Applying these factors yields the following:

Operator fails to close port slide gate = $0.03 \times 0.5 \times 0.8 = 0.01$

Operator Fails to Notice that Port Slide Gate Does Not Fully Close—The action of closing the port slide gate is simple. In this scenario, the gate does not close all the way because the canister is in the way. The operator has visible feedback on the failure of the gate to close because the "open" (or "green") light on the control panel stays on and the "closed" (or "red") light also comes on and stays on. Both lights on at the same sign signify that the port is neither fully open nor fully closed. The problem can be easily confirmed by looking at the camera or checking the status of the light curtain at the bottom of the bell. This unsafe action can be represented by NARA GTT C1, adjusted for the following EPCs:

- GTT C1: Simple response to a range of alarms/indications providing clear indication of situation (simple diagnosis required). The baseline HEP is 0.0004.
- EPC 3: Time pressure. The full affect EPC would be ×11, but this applies only in cases where there is barely enough time to complete a task, and rapid work is necessary. In this case, the time pressure is more abstract, in that there is a desire to keep the process moving for production reasons, but not a compelling one. The APOA anchor for 0.1 is that the operator feels some time pressure, but there is sufficient time to carry out the task properly with checking. This appears reasonable for this task, so the APOA is set at 0.1.
- EPC 13: Operator underload/boredom. The full affect EPC would be ×3, which applies to a routine task of low importance, carried out by a single individual for several hours. The APOA anchor for 0.1 is for low difficulty, low importance, single individual, for less than one hour. This appears reasonable for this task, so the APOA is set at 0.1.

Using the NARA HEP equation yields the following:

$$\text{Operator fails to notice that port slide gate does not fully close} = 0.0004 \times [(11-1) \times 0.1 + 1] \times [(3-1) \times 0.1 + 1] = 0.001 \qquad \text{(Eq. E-22c)}$$

Operator Fails to Close CTM Slide Gate—The operator is supposed to close the CTM slide gate as soon as the port slide gate is closed. This gives the operator another opportunity to determine that the canister is not fully withdrawn. This failure would go unnoticed if the operator either skipped this step or performed the action and failed to notice that the gate had not closed all the way (e.g., because it is blocked from doing so by the hoist cables or load cell). In the latter case, the slide gate open/close indicator lights would be an incorrect state (either both on or both off, depending on design).

The baseline HEP for failure to close this gate would be the same as for the similar unsafe action for the port slide gate.

Operator fails to close CTM slide gate (independent) = 0.01

However, this would only apply in the case where the earlier unsafe action was failure to notice that the port slide gate had failed to close. In the case where the earlier unsafe action was failure to close the port slide gate, there is a dependence on the failure to perform a similar task next in the sequence. It is judged that the dependence between these two actions is high. Using item (4)(a) from THERP (Ref. E8.1.26) Table 20-21, the HEP follows:

Operator fails to close CTM slide gate (given failure to close the port slide gate) = 0.5

Operator Fails to Notice CTM Slide Gate Does Not Fully Close—The baseline HEP for failure to notice this gate did not fully close would be the same as for the similar unsafe action for the port slide gate.

Operator fails to notice CTM slide gate does not fully close (independent) = 0.001

However, this would only apply in the case where the earlier unsafe action was failure to close the port slide gate. In the case where the earlier unsafe action was failure to notice that the port slide gate did not fully close, there is a dependence on the failure to perform a similar task next in the sequence. It is judged that the dependence between these two actions is high. Using item (4)(a) from THERP (Ref. E8.1.26) Table 20-21, the HEP follows:

Operator fails to notice CTM slide gate does not fully close
(given failure notice that port slide gate did not fully close) = 0.5

CTM Slide Gate Interlock Fails—The CTM slide gate interlock prevents CTM movement with the slide gate open (i.e., the shield skirt cannot be raised). If the interlock itself fails, the operator can move the CTM with the canister between levels.

This is a mechanical failure of the interlock. This event is quantified in Section E6.4.3.4.1.

CTM slide gate interlock fails = 2.7E−5

HEP Calculation for Scenario 3(b)—The events in the HEP model for Scenario 3(b) are presented in Table E6.4-14.

Table E6.4-14. HEP Model for HFE Group #5 Scenario 3(b) for 51A-OpCTMImpact1-HFI-COD

Designator	Description	Probability
A	Operator inadvertently places CTM in lid lift mode	0.005
B	Operator fails to notice that lift stops too soon	0.07
C	Operator fails to close port slide gate	0.01
D	Operator fails to notice that port slide gate does not fully close	0.001
E1	Operator fails to close CTM slide gate (independent)	0.01
E2	Operator fails to close CTM slide gate (given failure to close the port slide gate)	0.5
F1	Operator fails to notice CTM slide gate does not fully close (independent)	0.001
F2	Operator fails to notice CTM slide gate does not fully close (given failure to notice that port slide gate did not fully close)	0.5
G	CTM slide gate interlock fails	2.7E−05

NOTE: CTM = canister transfer machine; HEP = human error probability.

Source: Original

The Boolean expression for this scenario follows:

$$A \times B \times \{[C \times (E2 + F1)] + [D \times (E1 + F2)]\} \times G = 0.005 \times 0.07 \times \{[0.01 \times (0.5 + 0.001)] + [0.001 \times (0.01 + 0.5)]\} \times 2.7E{-}05 = 0.005 \times 0.07 \times 0.006 \times 2.7E{-}05 = (<1E{-}8) \quad \text{(Eq. E-22d)}$$

E6.4.3.4.4.3 HFE Group #5 Scenario 3(c) for 51A-OpCTMImpact1-HFI-COD

1. Operator puts CTM in maintenance mode (HLW).
2. Operator terminates lift prior to automatic stop.
3. Operator fails to close port slide gate OR fails to notice that it does not fully close.
4. Operator fails to close CTM slide gate OR fails to notice it does not fully close.
5. CTM slide gate interlock fails.

Operator Puts CTM in Maintenance Mode (HLW)—The operator is supposed to set the ASD to canister lift mode prior to lifting the canister. It should be in lid lift mode because the lid was lifted right before the first canister. Placing it in the maintenance mode instead of the canister lift mode removes the ASD height control set point and also defeats the CTM slide gate interlock (since maintenance mode would allow CTM movement with the slide gate open). In order to place it into maintenance mode, the operator is required to enter a password.

In this case, the operator commits the unsafe action of placing the CTM in maintenance mode. This is not easy to do; if the operator inadvertently selects this mode, the operator is asked to confirm the selection and is also required to enter a password, which is not required for the selection of canister mode. This can be represented by NARA GTT A5, adjusted for the following EPCs:

- GTT A5: Completely familiar, well-designed, highly practiced routine task performed to highest possible standards by highly motivated, highly trained, and experienced personnel, totally aware of implications of failure, with time to correct potential errors. The baseline HEP is 0.0001.

- EPC 6: A means of suppressing or overriding information or features that are too easily accessible. In this case, while a warning is given and a password is required, the operator still can still override the feature and enter manual mode. The full affect is ×9. The APOA anchor for 0.5 is for something overridden on a regular basis. The APOA anchor for 0.1 is for something overridden once in a while. Other considerations for a reduction from full affect are a good interface design and good safety culture. Since maintenance mode is required on a regular basis, but there are other mitigating factors, it appears reasonable for this task that the APOA be set at 0.3.

Using the NARA HEP equation yields the following:

$$\text{Operator puts CTM in maintenance mode} = 0.0001 \times [(9-1) \times 0.3 + 1] = 0.0004 \qquad \text{(Eq. E-22e)}$$

Operator Terminates Lift Prior to Automatic Stop—The operator is supposed to hold the lift button until the lift automatically stops. This happens even in the maintenance mode since the interlocks that prevent two-blocking are still active, and the CTM transfer sequence can still be completed successfully. However, if the operator terminates the lift prematurely, the canister could still be between floors.

The unsafe action results from stopping the hoist prematurely and leaving the canister below or between the floors (i.e., a number of feet short of the proper location). This can be represented by CREAM CFF E1, adjusted by the following CPCs with values not equal to 1.0:

- CFF E1: Execution of wrong type performed (with regard to force, distance, speed, or direction). The baseline HEP is 0.003.

There are no CPCs that are deemed to have values not equal to 1.0 for this action.

Applying these factors yields the following:

$$\text{Operator terminates lift prior to automatic stop} = 0.003$$

Operator Fails to Close Port Slide Gate—The operator is supposed to close the port slide gate as soon as the lift is completed. This gives the operator an opportunity to determine that the canister is not fully withdrawn. The operator would fail to notice this if either the operator skipped this step or if the operator performed the action and failed to notice that the gate had not closed all the way (e.g., because it is blocked from doing so by the canister). In the latter case, the slide gate open/close indicator lights would be in an incorrect state (either both on or both off, depending on design).

This value is the same as for Scenario 3(a):

Operator fails to close port slide gate = 0.01

Operator Fails to Notice that Port Slide Gate Does Not Fully Close—This value is the same as for Scenario 3(a):

Operator fails to notice that port slide gate does not fully close = 0.001

Operator Fails to Close CTM Slide Gate—The operator is supposed to close the CTM slide gate as soon as the port slide gate is closed. This gives the operator another opportunity to determine that the canister is not fully withdrawn. The operator would fail to notice this if either the operator skipped this step or if the operator performed the action and failed to notice that the gate had not closed all the way (e.g., because it is blocked from doing so by the hoist cables or load cell). In the latter case, the slide gate open/close indicator lights would be an incorrect state (either both on or both off, depending on design).

This value is the same as for Scenario 3(a):

Operator fails to close CTM slide gate (independent) = 0.01
Operator fails to close CTM slide gate (given failure to
close the port slide gate) = 0.5

Operator Fails to Notice CTM Slide Gate Does Not Fully Close—This value is the same as for Scenario 3(a):

Operator fails to notice CTM slide gate does not fully close (independent) = 0.001
Operator fails to notice CTM slide gate does not fully close
(given failure notice that port slide gate did not fully close) = 0.5

CTM Slide Gate Interlock Fails

The CTM slide gate interlock prevents CTM movement with the slide gate open (the shield skirt cannot be raised). If the interlock itself fails, the operator can move the CTM with the canister between levels. Note: the maintenance mode does not bypass the shield skirt/slide gate interlock; this interlock cannot be bypassed.

This is a mechanical failure of the interlock. This event is quantified in Section 6.4.3.4.1.

CTM slide gate interlock fails = 2.7E−5

HEP Calculation for Scenario 3(c)—The events in the HEP model for Scenario 3(c) are presented in Table E6.4-15.

Table E6.4-15. HEP Model for HFE Group #5 Scenario 3(c) for 51A-OpCTMImpact1-HFI-COD

Designator	Description	Probability
A	Operator puts CTM in maintenance mode	0.0004
B	Operator terminates lift prior to automatic stop	0.003
C	Operator fails to close port slide gate	0.01
D	Operator fails to notice that port slide gate does not fully close	0.001
E1	Operator fails to close CTM slide gate (independent)	0.01
E2	Operator fails to close CTM slide gate (given failure to close the port slide gate)	0.5
F1	Operator fails to notice CTM slide gate does not fully close (independent)	0.001
F2	Operator fails to notice CTM slide gate does not fully close (given failure notice that port slide gate did not fully close)	0.5
G	CTM slide gate interlock fails	2.7E−05

NOTE: CTM = canister transfer machine; HEP = human error probability.

Source: Original

The Boolean expression for this scenario follows:

$$A \times B \times \{[C \times (E2 + F1)] + [D \times (E1 + F2)]\} \times G = 0.0004 \times 0.003 \times \{[0.01 \times (0.5 + 0.001)] + [0.001 \times (0.01 + 0.5)]\} \times 2.7E{-}05 = 0.0004 \times 0.003 \times .006 \times 2.7E{-}05 = 7E{-}09 \times 2.7E{-}05 = (<1E{-}08) \qquad \text{(Eq. E-22f)}$$

Truncating the human failure component, the HEP for this scenario becomes:

$$1E{-}5 \times 2.7E{-}5 = (<1E{-}08) \qquad \text{(Eq. E-22g)}$$

E6.4.3.4.4.4 HFE Group #5 Scenario 3(d) for 51A-OpCTMImpact1-HFI-COD

1. Operator leaves CTM in maintenance mode (naval).
2. Operator terminates lift prior to automatic stop.
3. Operator fails to close port slide gate OR fails to notice that it does not fully close.
4. Operator fails to close CTM slide gate OR fails to notice it does not fully close.
5. CTM slide gate interlock fails.

Operator Leaves CTM in Maintenance Mode (naval)—The operator is supposed to set the ASD to canister lift mode prior to lifting the canister. For naval operations, the ASD is in maintenance (or manual) lift mode because this is the default positioning. Leaving it in the maintenance mode instead of the canister lift mode removes the ASD height control set point and also defeats the CTM slide gate interlock (since maintenance mode allows CTM movement with the slide gate open).

In this case, this leaves the ASD in maintenance mode, which is the default position for naval operations. The initial action to set the mode is quite simple, so the only realistic way that the operator can leave the ASD in maintenance mode is to completely fail to take any actions to set the CTM system for a lift. This failure can be represented by NARA GTT B3, and adjusted by the following EPCs:

- GTT B3: Set system status as part of routine operations using strict administratively controlled procedures. The baseline HEP is 0.0007.

This operation is performed under optimal conditions. It is early in the operation, and the operator is active, so it is too early in the task for boredom to set in. The baseline HEP is used without adjustment.

Operator leaves CTM in maintenance mode = 0.0007

Operator Terminates Lift Prior to Automatic Stop—The operator is supposed to hold the lift button in until the lift automatically stops. This happens even in the maintenance mode since the interlocks that prevent two-blocking are still active, and the CTM transfer sequence can still be completed successfully. However, if the operator terminates the lift prematurely, the canister could still be between floors.

The unsafe action results from stopping the hoist prematurely and leaving the canister below or between the floors (i.e., a number of feet short of the proper location). This can be represented by CREAM CFF E1, adjusted by the following CPCs with values not equal to 1.0:

- CFF E1: Execution of wrong type performed (with regard to force, distance, speed, or direction). The baseline HEP is 0.003.

There are no CPCs that are deemed to have values not equal to 1.0 for this action.

Applying these factors yields the following:

Operator terminates lift prior to automatic stop = 0.003

Operator Fails to Close Port Slide Gate—The operator is supposed to close the port slide gate as soon as the lift is completed. This gives the operator the opportunity to determine that the canister is not fully withdrawn. This failure would go unnoticed if the operator either skipped this step or performed the action and failed to notice that the gate had not closed all the way (e.g., because it is blocked from doing so by the canister). In the latter case, the slide gate open/close indicator lights would be in an incorrect state (either both on or both off, depending on design).

This value is the same as for Scenario 3(a):

Operator fails to close port slide gate = 0.01

Operator Fails to Notice that Port Slide Gate Does Not Fully Close—This value is the same as for Scenario 3(a):

Operator fails to notice that port slide gate does not fully close = 0.001

Operator Fails to Close CTM Slide Gate—The operator is supposed to close the CTM slide gate as soon as the port slide gate is closed. This gives the operator another opportunity to determine that the canister is not fully withdrawn. This would go unnoticed if the operator either skipped this step or performed the action and failed to notice that the gate had not closed all the way (e.g., because it is blocked from doing so by the hoist cables or load cell). In the latter case, the slide gate open/close indicator lights would be an incorrect state (either both on or both off, depending on design).

This value is the same as for Scenario 3(a):

Operator fails to close CTM slide gate (independent) = 0.01

Operator fails to close CTM slide gate (given failure to close the port slide gate) = 0.5

Operator Fails to Notice CTM Slide Gate Does Not Fully Close—This value is the same as for Scenario 3(a):

Operator fails to notice CTM slide gate does not fully close (independent) = 0.001

Operator fails to notice CTM slide gate does not fully close
(given failure notice that port slide gate did not fully close) = 0.5

CTM Slide Gate Interlock Fails

The CTM slide gate interlock prevents CTM movement with the slide gate open (the shield skirt cannot be raised). If the interlock itself fails, the operator can move the CTM with the canister between levels. Note: the maintenance mode does not bypass the shield skirt/slide gate interlock; this interlock cannot be bypassed.

This is a mechanical failure of the interlock. This event is quantified in Section 6.4.3.4.1.

CTM slide gate interlock fails = 2.7E−5

HEP Calculation for Scenario 3(d)—The events in the HEP model for Scenario 3(d) are presented in Table E6.4-16.

Table E6.4-16. HEP Model for HFE Group #5 Scenario 3(d) for 51A-OpCTMImpact1-HFI-COD

Designator	Description	Probability
A	Operator leaves CTM in maintenance mode	0.0007
B	Operator terminates lift prior to automatic stop	0.003
C	Operator fails to close port slide gate	0.01
D	Operator fails to notice that port slide gate does not fully close	0.001
E1	Operator fails to close CTM slide gate (independent)	0.01
E2	Operator fails to close CTM slide gate (given failure to close the port slide gate)	0.5
F1	Operator fails to notice CTM slide gate does not fully close (independent)	0.001
F2	Operator fails to notice CTM slide gate does not fully close (given failure to notice that port slide gate did not fully close)	0.5
G	CTM slide gate interlock fails	2.7E−05

NOTE: CTM = canister transfer machine; HEP = human error probability.

Source: Original

The Boolean expression for this scenario follows:

$$A \times B \times \{[C \times (E2 + F1)] + [D \times (E1 + F2)]\} \times G =$$
$$0.0007 \times 0.003 \times \{[0.01 \times (0.5 + 0.001)] + [0.001 \times (0.01 + 0.5)]\} \times 2.7E{-}05 =$$
$$0.0004 \times 0.003 \times 0.006 \times 2.7E{-}05 = 7E{-}09 \times 2.7E{-}05 = (<1E{-}08) \qquad \text{(Eq. E-22h)}$$

Truncating the human failure component, the HEP for this scenario becomes:

$$1E{-}5 \times 2.7E{-}5 = (<1E{-}08) \qquad \text{(Eq. E-22i)}$$

E6.4.3.4.4.5 HEP for HFE 51A-OpCTMImpact1-HFI-COD

The Boolean expression for the overall HFE (all scenarios) follows:

$$\text{51A-OpCTMImpact1-HFI-COD} = \text{HFE 3(a)} + \text{HFE 3(b)} + \text{HFE 3(c)} +$$
$$\text{HFE 3(d)} = (<1E{-}8) + (<1E{-}8) + (<1E{-}8) + (<1E{-}08) = 4E{-}8 \qquad \text{(Eq. E-22j)}$$

NOTE: For lifting objects (in this case, the lid of the naval waste package), the only failure mode that is applicable is 3(d); therefore, 4E−8 conservatively models movement with the lid below the floor.

E6.4.4 Results of Detailed HRA for HFE Group #4

The final HEPs for the HFEs that required detailed analysis in HFE Group #4 are presented in Table E6.4-17 (with the original preliminary value shown in parentheses).

Table E6.4-17. Summary of HFE Detailed Analysis for HFE Group #4

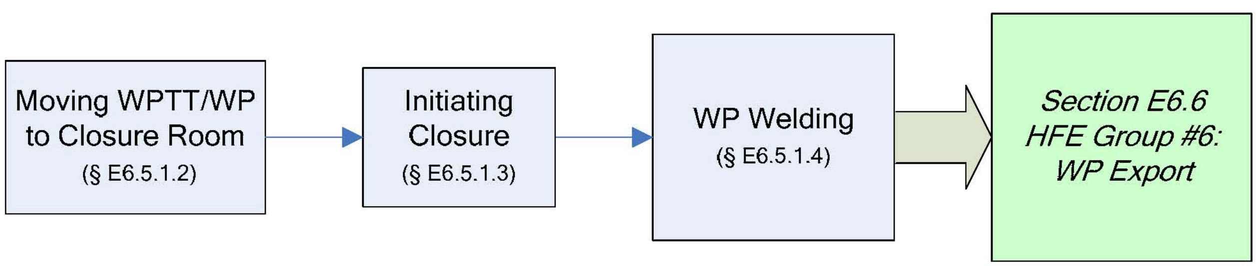
HFE	Application	Final Probability
51A-OpCTMdrop001-HFI-COD *Operator causes drop of object onto canister during CTM operations*	Applied to removing HLW lid and placing a waste package inner lid; does not apply to naval waste	4E−07 (2E−03)
	Applied to removing naval shield ring and placing a waste package inner lid; does not apply to HLW	4E−07 (2E−03)
51A-OpCTMdrop002-HFI-COD *Operator causes drop of canister during CTM operations (low-level drop)*	Applied to moving an HLW canister	5E−07 (2E−03)
	Applied to moving a naval canister	2E−04 (2E−03)

NOTE: CTM = canister transfer machine; HFE = human failure event; HLW = high-level radioactive waste; WP = waste package.

Source: Original

E6.5 ANALYSIS OF HUMAN FAILURE EVENT GROUP #5: WASTE PACKAGE ASSEMBLY AND CLOSURE

HFE group #5 corresponds to the operations and initiating events associated with the ESD and HAZOP evaluation nodes listed in Table E6.0-1, covering waste package assembly and closure. The operations covered in this HFE group are shown in Figure E6.5-1. Closure activities begin with the canister in the waste package, aligned with the waste package port with the port closed. The WPTT moves the loaded waste package from the Canister Transfer Room into position underneath the Waste Package Closure Room, where the waste package is closed in preparation for export to the drifts. Closure activities include verification of the waste package/waste form, as well as welding, inerting, and polishing the package. This operation ends with the waste package being ready to be moved to the Waste Package Loadout Room, where the waste package is transferred into the TEV.



NOTE: § = Section; HFE = human failure event; WP = waste package; WPTT = waste package transfer trolley.

Source: Original

Figure E6.5-1. Activities Associated with HFE Group #5

E6.5.1 Group #5 Base Case Scenario

E6.5.1.1 Initial Conditions and Design Considerations Affecting the Analysis

The following conditions and design considerations were considered in evaluating HFE group #5 activities:

1. The waste package is secured to the WPTT and is positioned in the Waste Package Loading Room.

2. The waste package has both the inner lid and the spread ring already in place.

3. The waste package port slide gate is closed. There is an interlock between the port slide gates and the Waste Package Loading Room shield doors; the port slide gate cannot be open while the shield doors to the Waste Package Loading Room are also open.

4. All waste package assembly and closure operations are performed remotely. Operators have an adequate view of all operations via camera.

The following personnel are involved in this set of operations:

- RHS operator
- Arm operators (two)
- WPTT operator
- Quality control person
- Level 2 and 3 NDE personnel
- Supervisor.

Section E5.1.2 provides a more detailed description of the duties performed by each of these personnel.

E6.5.1.2 Moving the WPTT with Loaded Waste Package under Waste Package Closure Room

The WPTT operator remotely controls the WPTT with the loaded waste package and moves it underneath the Waste Package Closure Room. The WPTT rides on rails, travels at one speed, and has preprogrammed paths to follow. Only a human can start the WPTT movement or make the WPTT stop. There is a shield door between the Waste Package Loading Room and the Waste Package Positioning Room (under the Waste Package Closure Room).

E6.5.1.3 Initiating Closure Process (Loaded Waste Package with HLW or Naval Waste)

The operator uses the camera and the bumpy bar code reader to read the bar code on the waste package to ensure that it is the correct package. At this time, the operator puts the waste package serial number into the tracking chart. This step is verified by quality control.

E6.5.1.4 Waste Package Welding

E6.5.1.4.1 Expanding Spread Ring for Seal Weld

Once the spread ring position is verified, the RHS operator uses the RHS and camera to engage the spread ring expander tool. The RHS operator uses the expander tool to expand the spread ring.

E6.5.1.4.2 Sealing Weld Spread Ring to Inner Vessel and Inner Lid and Performing NDE

The welding team is composed of two arm operators, an RHS operator, a quality control person, and a level 2 and 3 NDE person(s). Each arm operator is responsible for welding half the circumference of the spread ring. The RHS operator is in charge of changing the end effectors as needed for the process (e.g., normal welding, grinding out the weld, dressing the weld). The arm operators use the robotic arm to do the actual welding, and the level 2 and 3 NDE personnel supervises, visually inspects, and verifies the weld. For this weld, there is a constant stainless steel weld wire spool feed. The level 2 and 3 NDE personnel must sign off this step.

E6.5.1.4.3 Inerting Waste Package and Performing Leak Test at Spread Ring and Purge Port Plug

All operations in this step are performed remotely. The RHS operator remotely retrieves the purge port tool and places it on top of the purge port. Once the tool is properly positioned, the operator initiates the tool and allows the helium to flow until sufficient time has passed and the pressure gage gives the proper reading. The RHS operator then sends the signals for the tool to stop helium flow, closes the cap, performs leak detection, and then checks the indicators to ensure that there are no leaks before continuing. Quality control verifies this step.

E6.5.1.4.4 Retrieval and Placement of Purge Port Cap

The RHS operator retrieves the purge port cap from its staging area, scans it with the bumpy bar code reader, documents the serial number, and places it onto the purge port. Quality control verifies this step.

E6.5.1.4.5 Welding Purge Port Cap and Performing NDE

The RHS operator installs the end effector on the robotic arm. The weld material is the same stainless steel used to weld the spread ring. The arm operator welds the cap in place, while the level 2 and 3 NDE person(s) visually inspects the process. Once welded, the RHS operator switches out the end effector for a dressing end effector, and the arm operator dresses the weld while the level 2 and 3 NDE person(s) visually inspects. A level 2 and 3 NDE must sign off this step.

E6.5.1.4.6 Retrieval and Placement of Outer Lid on the Waste Package from the Waste Package Closure Room

The RHS operator uses the camera and bumpy bar code reader to read the bar code on the waste package outer lid. At this time, the operator puts the waste package serial number into the tracking chart. This step is verified by quality control. Once the outer lid is documented, the operator retrieves the lid, engages the lid grapple, moves the lid to the proper position, and then disengages the grapple.

E6.5.1.4.7 Welding Outer Lid to Outer Barrier and Performing NDE

In preparation for this step, the RHS operator switches out the stainless steel weld feed spool for Alloy 22. This step is nearly identical to welding the inner lid (Section E6.5.1.4.2). The difference is that the end effector used has an ultrasonic testing/eddy-current testing (UT/ET) attachment that follows and tests the weld. The weld and UT/ET are verified by a level 2 and 3 NDE.

E6.5.1.4.8 Performing Stress Mitigation and NDE on Outer Lid

The RHS operator places the stress mitigation tool on the outer lid, and the operator and the level 2 and 3 NDE person(s) visually inspect the polish using a camera. Once the stress mitigation tool is done, the RHS operator removes the tool and places a UT/ET end effector on the robotic arm; the arm operator commences ultrasonic testing. The sealed waste package is verified again by a level 2 and 3 NDE.

E6.5.2 HFE Descriptions and Preliminary Analysis

This section defines and screens the HFEs that are identified for the base case scenario, that can affect the probability of initiating events occurring, and that could lead to undesired consequences. Descriptions and preliminary analysis for the HFEs of concern during waste package assembly and closure are summarized in Table E6.5-1. The analysis presented here includes the assignment of preliminary HEPs in accordance with the methodology described in Section E3.2 and Appendix E.III of this analysis. Section E4.2 provides details on the use of expert judgment in this preliminary analysis.

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Table E6.5-1. HFE Group #5 Descriptions and Preliminary Analysis

HFE ID	HFE Description	Applicable ESD	Preliminary Value	Justification
51A-OpWPCollide1-HFI-NOD	*Operator Causes Low-Speed Collision of WPTT During Transfer to Closure Area:* As the WPTT is moved from the Waste Package Loading Room to the Waste Package Closure Room, the operator can cause the WPTT to collide into an SSC. The WPTT cannot physically go faster than 2.5 mph, and all collisions of the WPTT are low-speed.	8	3E−03	The WPTT is on rails, but an operator can cause a collision of the WPTT with an object in its path or into an SSC. The WPTT speed is physically limited by motor design; therefore, all collisions of the WPTT would be low-speed collisions. This failure is nearly identical to collision of the railcar while entering the facility (51A-OpRCCollide1-HFI-NOD; Section E6.1, HFE Group #1) and was assigned the same probability. This preliminary value is conservative because the path that the WPTT travels is expected to have fewer obstructions (e.g., doors, potential objects in the path) to collide with.
51A-OpTiltDown01-HFI-NOD	*Operator Initiates Premature Tilt -down during Transfer to Closure Area*: The operator can inadvertently initiate tilt-down of the waste package during transfer to the Waste Package Closure Room. If the waste package is near a facility structure, then this action could result in a collision of the waste package.	8	1.0	The operator can cause the WPTT to prematurely tilt down. The WPTT operator may be in the process of driving the WPTT to the Positioning Room. Tilt-down only occurs during waste package loadout in the Waste Package Loadout Room, and the controller for the WPTT tilt-down is distinct from other WPTT controls. In order to accomplish this failure, an interlock must also fail. This interlock, between the tilt-down mechanism and the docking station, has no bypass. As was previously discussed, the HRA team has assigned all unsafe actions that are combined with interlocks an HEP of 1.0.
WPTT derailment	*Operator Causes Derailment of WPTT*: The WPTT travels on rail from the Waste Package Loading Room to the Waste Package Positioning Room. During this transfer the operator can cause the WPTT to derail by running over a large object left on the rail or through other such mechanisms.	8	N/A[a]	In this step, the WPTT moves on rail from outside the Waste Package Loading Room to the closing position in the Waste Package Positioning Room below the Waste Package Closure Room. During this travel, there is a probability that the WPTT can derail, leading to a tipover of the WPTT. This HFE was not explicitly quantified because the probability of derailment due to human failure is incorporated in the historical data used to provide a general failure probability for derailment. Documentation for this failure can be found in Attachment C.
51A-OPWPInnerLid-HFI-NOD	*Operator Causes Direct Exposure During WP Loading*: If the CTM operator fails to close the port gate before lifting the shield skirt after placing a canister in a waste package, and a worker violates the procedural control by entering the Transfer Room during canister transfer activities, that worker is exposed. Also, if the CTM operators fail to install the WP inner lid and a person violates the procedural controls and enters the WP closure area when the WPTT is transferred into the room, that person gets a direct exposure. This HFE results in a potential direct exposure in the CTM transfer room and/or in the WP Closure Room. In this case, to prevent double counting, this failure event was only modeled only in ESD 12B (Direct exposure during waste package closure), not ESD 12A (Direct exposure during CTM activities) and 12B.	12	1E−04	Closure of the port gate is a simple action that is performed multiple times in a day. This action is performed every time the CTM is moved without deviation, and the operator is trained on the consequences associated with this failure. Similarly, installation of a WP is a very simple operation, is performed regularly, and the operator is trained on the consequences associated with this failure. In addition to these failures, a completely independent failure, involving violation of a strict procedural control by inappropriately entering a radiation controlled area, by a person of a separate "team" must also occur. This HFE was considered extremely unlikely and assigned a preliminary value of 0.0001.
Improper waste package closure	*Operator Damages Canister during Welding*: The waste package inner and outer lids are welded closed as part of waste package closure activities. This task is a remote operation with a high level of automation; however, it may be possible for an operator to improperly weld the canister such that the canister becomes damaged. Note: Improper welding may also have postclosure implications. However, HFEs that have no safety consequences over the preclosure period but that may have consequences postclosure are out of the scope of this analysis and are addressed in the postclosure safety assessment.	9	N/A	The analysts could not identify any human actions that would contribute to canister damage during welding. Latent conditions due to bad welds may have postclosure consequences, but they are out of the scope of this analysis and are addressed in the postclosure safety assessment.
Drop of object	*Operator Drops Object on Canister with RHS:* The waste package inner and outer lids are welded closed as part of waste package closure activities. The RHS is used to move objects over the canister, including the outer lid, as part of this task. The operator could drop an object onto the canister during these lifts.	9	N/A[a]	In this step the operator uses the RHS to move several objects over the waste package and canister. The outer lid is moved over the waste package. Other objects, such as spools of welding material, may also be moved over the waste package during this operation; however, the inner and outer lids are the only objects that are heavy enough to potentially damage the waste package or canister. These HFEs were not explicitly quantified because the probability of a crane drop due to human failure is incorporated in the historical data used to provide general failure probabilities for drops involving various crane and rigging types. Documentation for this failure can be found in Attachment C.

NOTE: [a] HRA preliminary value replaced by use of historic data; Attachment C provides additional information on Active Component Reliability Data.

CTM = canister transfer machine; ESD = event sequence diagram; HFE = human failure event; HRA = human reliability analysis; ID = identification; IHF = Initial Handling Facility; N/A = not applicable; RHS = remote handling system; SSC = structure, system, or component; TEV = transport and emplacement vehicle; WPTT = waste package transfer trolley.

Source: Original

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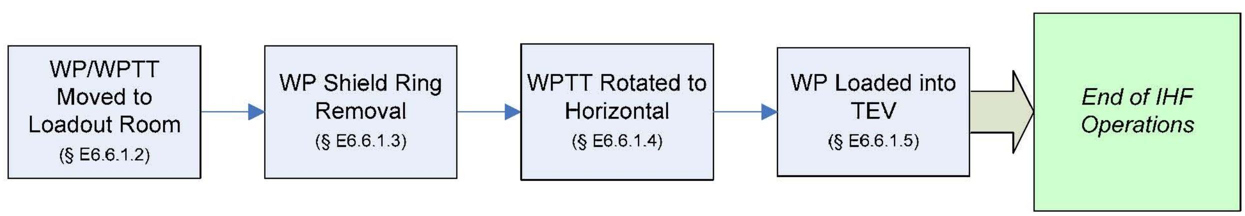
E6.5.3 Detailed Analysis

There are no HFEs in this group that require detailed analysis; the preliminary values in the facility model do not result in any Category 1 or Category 2 event sequences that fail to comply with the 10 CFR 63.111 performance objectives; therefore, the preliminary values were sufficient to demonstrate compliance with 10 CFR Part 63 (Ref. E8.2.1).

E6.6 ANALYSIS OF HUMAN FAILURE EVENT GROUP #6: WASTE PACKAGE EXPORT

HFE group #6 corresponds to the operations and initiating events associated with the ESD and HAZOP evaluation nodes listed in Table E6.0-1, covering waste package export. The operations covered in this HFE group are shown in Figure E6.6 1. The activities covered in HFE group #6 begin with the sealed waste package ready for emplacement, sitting vertically in the WPTT in the Waste Package Closure Room. They proceed through moving the WPTT to the Waste Package Loadout Room, removal of the waste package shield ring, translation of the WPTT enclosure to a horizontal position, and transfer of the waste package to the TEV. The operation ends when the TEV is loaded, ready for export.



NOTE: § = Section; IHF = Initial Handling Facility; TEV = transport and emplacement vehicle; WP = waste package; WPTT = waste package transfer trolley.

Source: Original

Figure E6.6-1. Activities Associated with HFE Group #6

E6.6.1 Group #6 Base Case Scenario

E6.6.1.1 Initial Conditions and Design Considerations Affecting the Analysis

The following conditions and design considerations were considered in evaluating HFE group #6 activities:

1. The waste package is secured to the WPTT and positioned under the Waste Package Closure Room.

2. The waste package is sealed, inspected, and has a shield ring resting on top.

3. The TEV is staged in the loadout area, ready to be loaded–shield door open and bottom plate lowered.

4. There is an interlock between the shield door and the personnel access doors–if there is a loaded waste package in the Closure Room (load cell), the shield door does not

open (and thus the WPTT cannot move into the Loadout Room) until the personnel access doors are closed and locked.

The following personnel are involved in this set of operations:

- WPTT Operator
- Crane Operator
- Signaling Crew member
- Verification Crew member
- Radiation Protection Worker
- Supervisor
- TEV Operator.

Section E5.1.2 provides a more detailed description of the duties performed by each of these personnel.

E6.6.1.2 Loaded and Sealed Waste Package Movement to Waste Package Loadout Room and WPTT Docking Station Engagement

This operation is performed remotely. The WPTT operator opens the closure area shield door and moves the WPTT (on rail) to the docking station in the Waste Package Loadout Room. Once the WPTT has cleared the door, the WPTT operator closes the closure area shield door. When in the proper position by the docking station, the WPTT engages the docking station by moving an arm down. Engagement is automatic. The WPTT operator checks the indicator to ensure proper engagement before continuing.

E6.6.1.3 Waste Package Shield Ring Removal and Movement of Shield Ring to Waste Package Shield Ring Stand

At this point, the crane operator, with the aid of a signaling and a verification crew member, removes the waste package shield ring from the WPTT. It is to be determined if this operation is performed remotely or locally; this analysis describes a local operation as it is believed to be the case with greater potential for error. Here, the operator installs a lifting device (sling or hooks which connect to eye holes) on the waste package shield ring. Once the fixture is secure, the operator moves several yards away from the WPTT and signals the crane operator to lift the ring and place it on the stand. Once the shield ring is on the stand, all crew members must leave the area and close the shield door. A pre-designated person, such as the radiation protection worker, is responsible for ensuring (via a checklist) that all personnel have left the Waste Package Loadout Room and for relaying that information to the WPTT operator in the IHF Control Room.

E6.6.1.4 WPTT Horizontal Rotation

The following steps are performed remotely. The WPTT operator confirms that the Waste Package Loadout Room is empty and signals the WPTT to downend the waste package.

E6.6.1.5 Waste Package Inspection and Loading into TEV

The WPTT operator signals the transfer carriage to move the waste package under the TEV. As the waste package is moving under the TEV, the WPTT and TEV operators visually (via camera) inspect the waste package for damage; these are independent checks because the WPTT and TEV operators are in different control rooms; the WPTT operator is in the facility while the TEV operator is in the Central Control Center. Once the waste package is under the TEV, the TEV operator signals the TEV to pick up the waste package, lift the bottom shield plate, and close the shield door.

E6.6.2 HFE Descriptions and Preliminary Analysis

This section defines and screens the HFEs that are identified for the base case scenario, can affect the probability of initiating events occurring, and that could lead to undesired consequences. Descriptions and preliminary analysis for the HFEs of concern during waste package export are summarized in Table E6.6-1. The analysis presented here includes the assignment of preliminary HEPs in accordance with the methodology described in Section E3.2 and Appendix E.III of this analysis. Section E4.2 provides details on the use of expert judgment in this preliminary analysis.

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Table E6.6-1. HFE Group #6 Descriptions and Preliminary Analysis

HFE ID	HFE Description	Applicable ESD	Preliminary Value	Justification
51A-OpWPCollide1-HFI-NOD	*Operator Causes Low-Speed Collision of WPTT During Transfer to Waste Package Loadout Room:* As the WPTT is moved from the Waste Package Positioning Room to the Waste Package Loadout Room, the operator can cause the WPTT to collide into an SSC. Due to the WPTT motor design all collisions of the WPTT are low-speed.	10	3E−03	The WPTT is on rails, but an operator can cause a collision of the WPTT with an object in its path or into an SSC. The WPTT speed is limited by motor design; therefore, all collisions of the WPTT would be low-speed collisions. This failure is nearly identical to collision of the railcar while entering the facility (51A-OpRCCollide1-HFI-NOD; Section E6.1, HFE Group #1) and was assigned the same probability. This is a conservative preliminary value because the path the WPTT travels is expected to have fewer obstructions (e.g., doors, potential objects in the path) to collide with. This is the same failure as collision of the WPTT during transfer to the closure area (51A-OpWPCollide1-HFI-NOD; Section E6.5, HFE Group #5).
51A-OpTiltDown01-HFI-NOD	*Operator Initiates Premature Tilt-Down During Transfer to Waste Package Loadout Room:* The operator can inadvertently initiate tilt-down of the waste package during transfer to the Waste Package Loadout Room. If the waste package is near a facility structure, then this could result in a collision of the waste package.	10	1.0	The operator can cause the WPTT to prematurely tilt down. The WPTT operator is in the process of driving the WPTT to the Loadout Room. Tilt-down only occurs during waste package loadout in the Waste Package Loadout Room, and the controller for the WPTT tilt-down is distinct from other WPTT controls. In order to accomplish this failure, an interlock must also fail. This interlock, between the tilt-down mechanism and the docking station, has no bypass. As was previously discussed, the HRA Team has assigned all unsafe actions that are combined with interlocks an HEP of 1.0. This is the same failure as premature tilt-down of the WPTT during transfer to the closure area (51A-OpTiltDown01-HFI-NOD; Section E6.5, HFE Group #5).
WPTT derailment	*Operator Causes Derailment of WPTT*: The WPTT travels on rail from the Waste Package Positioning Room to the Waste Package Loadout Room. During this transfer the operator can cause the WPTT to derail by running over a large object left on the rail or through other such mechanisms.	10	N/A[a]	In this step, the WPTT moves on rail from the Waste Package Positioning Room to the Waste Package Loadout Room. During this travel, there is a probability that the WPTT can derail, leading to a tipover of the WPTT. This HFE was not explicitly quantified because the probability of derailment due to human failure is incorporated in the historical data used to provide a general failure probability for derailment. Documentation for this failure can be found in Attachment C.
51A-OpSDClose001-HFI-NOD	*Operator Closes Shield Door on Conveyance*: The WPTT passes through shield doors as it enters the Waste Package Loadout Room. During this transfer, the operator can close the shield door on the WPTT.	6	1.0	The WPTT passes through shield doors as it enters the Waste Package Loadout Room. During this transfer, the operator can close the shield door on the WPTT. See Section E6.0.2.3.3 for a justification of these preliminary values.
TEV_Collision	*Operator Drives TEV into Waste Package*: The TEV is pre-staged in the Waste Package Loadout Room with power off, ready to receive a waste package. Because the TEV is not moved in this operation, this failure was omitted from analysis.	11	N/A	The TEV is pre-staged in the Waste Package Loadout Room with power off, ready to receive a waste package. Because the TEV is not moved in this operation, this failure was omitted from analysis.
51A-OpTEVDrClosd-HFI-NOD	*Operator begins Waste Package Extraction before TEV Doors Open*: If the operator extracts the waste package before opening the TEV shield doors, then the waste package runs into the TEV.	11	1E−03	The TEV is pre-staged, and TEV operations in this respect are very standard, so it is unlikely that the TEV operator would not open the TEV shield door/extend bed plate (0.01). The shield doors and bedplate are very visible, and there is adequate time between WPTT tilt-down and TEV loading for the operators to notice that the TEV has not been properly staged before tilt-down (fail to notice, 0.1). Therefore, the preliminary value for waste package impact due to extraction before TEV doors are open is 0.001.
51A-OpCraneIntfr-HFI-NOD	*Operator Causes Crane to Interfere with TEV or WPTT:* If the operator fails to properly stow the crane rigging, then the WPTT can impact the crane hook while tilting down.	11	1E−04	This operation was given the same preliminary value as “Cask Tipover during Upending and Removal” (HFE 51A-OpTipover001-HFI-NOD; Section E6.2, HFE Group #2) because it is a similar operation (i.e., movement with the crane using the same type of rigging/attachments) and has similar failure modes (i.e., failure to properly stow crane rigging).
51A-OpWPTiltUp01-HFI-NOD	*Operator Causes Premature Tilt-up of WPTT*: If the operator signals the WPTT to tilt up while the waste package is being extracted, this would result in a drop of the waste package.	11	1.0	While moving a waste package into the TEV, the operator can inadvertently cause the WPTT to tilt up, resulting in a drop of the waste package. In order to accomplish this, there are interlock(s) that must also fail. To be conservative, all unsafe actions that require an equipment failure to cause an initiating event have been assigned an HEP of 1.0.
Drop of object on WP	*Operator Drops Heavy Object on Waste Package:* During waste package export, the waste package shield ring is removed. It is possible that the shield ring can be dropped onto the waste package during this operation.	11	N/A[a]	In this step the operator moves the waste package shield ring over the waste package; the operator can potentially drop the shield ring onto the waste package. This HFE was not explicitly quantified because the probability of a crane drop due to human failure is incorporated in the historical data used to provide general failure probabilities for drops involving various crane/rigging types. Documentation for this failure can be found in Attachment C.

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Table E6.6-1. HFE Group #6 Descriptions and Preliminary Analysis (Continued)

HFE ID	HFE Description	Applicable ESD	Preliminary Value	Justification
51A-OpDirExpose3-HFI-NOD	*Operator Opens Facility Door during TEV Loading*: There is a gap between the tilted down WPTT and the TEV; if the operator opens the facility door while the waste package is pulled into the TEV, the operator would get a direct exposure.	12	1E−03	In the process of TEV loading, the waste package is purposefully exposed to the Waste Package Loadout Room. Because of this "shine by design" mode of TEV loading, there are many safeguards to prevent personnel from being in the Waste Package Loadout Room during TEV loading. There are two general ways for a person to be in the Waste Package Loadout Room during this operation: an operator is left in the Waste Package Loadout Room when the operation begins, or an operator enters the room after operations begin. There are procedural controls associated with the radiation protection program that limit who can be and when people can be in the Waste Package Loadout Room. There are also at least two separate checks of the room before operations begin: one locally and one from the IHF Control Room via camera. Finally, there are radiation lights and alarms (non-ITS) that activate when operations begin. If a person is left in the Waste Package Loadout Room, that person has several minutes to exit the room through clearly marked exits before they are exposed. For an operator to enter the room after operations begin, the door must be unlocked. There is an interlock that ensures that the shield doors are locked before the WPTT enters the Waste Package Loadout Room. For the shield doors to be unlocked, then, the interlock would have to fail, or a worker must ask the IHF Control Room supervisor for permission to enter. If the supervisor chooses to grant permission, the supervisor must stop operations, move the waste package to a safe and shielded state, and then unlock the shield door. If the supervisor fails to stop operations before letting the worker in, or if the operations are prematurely restarted before the worker leaves, then the worker would get a direct exposure. This failure was assessed to be "highly unlikely" and assigned a preliminary value of 0.001.
51A-OpShieldRing-HFI-NOD	*Operator Fails to Install Waste Package Shield Ring in WPTT*: If a waste package shield ring is not preinstalled in the WPTT before the canister is placed inside the waste package during CTM activities, then when operators approach the waste package to remove the shield ring in the Waste Package Loadout Room, they would get a direct exposure.	12	1E−04	The waste package shield ring is installed as part of the staging activities before IHF operations for waste package loading begin. Shield ring installation is checked off by the staging crew and is also checked off by the operations crew directly before operations begin as part of the prejob plan. If the shield ring is not installed, the CTM operator has the chance to notice when emplacing the canister inside the waste package (via a camera view looking down on the missing shield ring). If the canister is emplaced in the waste package, then once the CTM moves away from the port, there would be a direct exposure. This failure received a preliminary value of 0.01 for failure to install shield ring and 0.01 for failure to notice before a direct exposure occurs, resulting in a total preliminary value of 0.0001.
51A-OpFailRstInt-HFI-NOM	*Operator Fails to Restore Interlock after Maintenance*: There is an interlock that prevents the waste package port gate from opening if a waste package containing a shield ring is not below the port. This interlock may be bypassed during normal maintenance. If the bypass is not restored, this could contribute to HFE 51A-OpShieldRing-HFI-NOD.	12	1E−02	There is an interlock that prevents the port gate from opening if a waste package containing a waste package shield ring is not below the port. This interlock may be bypassed during normal maintenance. If the bypass is not restored by the maintenance worker and not discovered by the prejob check, this could contribute to HFE 51A- OpShieldRing-HFI-NOD. This failure was assigned a preliminary value of 0.01, which corresponds to the generic value for the pre-initiator 'failure to properly restore an operating system to service when the degraded state is not easily detectable.'
WPTT uncontrolled tilt-down	*Operator causes uncontrolled tilt-down of WPTT*	10	N/A	No human actions were identified that would contribute to an uncontrolled tilt-down.

NOTE: [a] HRA preliminary value replaced by use of historic data (Attachment C).

CTM = canister transfer machine; HEP = human error probability; HFE = human failure event; IHF = Initial Handling Facility; ITS = important to safety; N/A = not applicable; SSC = structure, system, or component; TEV = transport and emplacement vehicle; WP = waste package; WPTT = waste package transfer trolley.

Source: Original

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E6.6.3 Detailed Analysis for HFE Group #6

After the preliminary screening analysis and initial quantification are completed, those HFEs that appear in dominant cut sets for event sequences that do not comply with the 10 CFR Part 63 (Ref. E8.2.1) performance objectives are subjected to a detailed analysis. The overall framework for the HRA is based upon the process guidance provided in ATHEANA (Ref. E8.1.22). Consistent with that framework, the following four steps from the methodology described in Section E3.2 provide the structure for the detailed analysis portion of the HRA:

Step 5: Identify Potential Vulnerabilities

Prior to defining specific scenarios that can lead to the HFEs of interest (Step 6), information is collected to define the context in which the failures are most likely to occur. In particular, analysts search for potential vulnerabilities in the operators' knowledge and information base for the initiating event or base case scenario(s) under study that might result in HFEs or unsafe actions. This information collection step discussed in Section E6.6.3.2.

Step 6: Search for HFE Scenarios (Scenarios of Concern)

An HFE scenario is a specific progression of actions with a specific context that leads to the failure of concern; each HFE is made up of one or more HFE scenarios. In this step, documented in Sections E6.6.3.3 and E6.6.3.4, the analyst identifies deviations from the base case scenario that are likely to result in risk-significant unsafe action(s). These unsafe actions make up an HFE scenario. In serious accidents, these HFE scenarios are usually combinations of various types of unexpected conditions.

Step 7: Quantify Probabilities of HFEs

Detailed HRA quantification methods are selected as appropriate for the characteristics of each HFE and are applied as explained in Section E6.6.3.4. Four quantification methods are utilized in this quantification:

1. ATHEANA expert judgment (Ref. E8.1.22)
2. CREAM (Ref. E8.1.18)
3. HEART/NARA (Ref. E8.1.28 and Ref. E8.1.11)
4. THERP (Ref. E8.1.26).

There is no implication of preference in the order of listing these methods. They are jointly referred to as the "preferred methods" and are applied either individually or in combination as best suited for the unsafe action being quantified. The ATHEANA (Ref. E8.1.22) expert judgment method (as opposed to the overall ATHEANA (Ref. E8.1.22) methodology that forms the framework and steps for the performance of this HRA) is used when the other methods are deemed to be inappropriate to the unsafe action, as is often the case for cognitive EOCs.

Appendix E.IV of this analysis explains why these specific methods were selected for quantification and gives some background about when a given method is applicable, based on the focus and characteristic of the method.

All judgments used in the quantification effort are determined by the HRA team and are based on their own experience, augmented by facility-specific information and the experience of subject matter experts, as discussed in Section E4. If consensus can be reached by the HRA team on an HEP for an unsafe action, that value is used as the mean. If consensus cannot be reached, the highest opinion is used as the mean.

Step 8: Incorporate HFEs into the PCSA

After HFEs are identified, defined, and quantified, they must be incorporated into the PCSA. The summary table of HFEs by group that lists the final HEP by basic event name provides the link between the HRA and the rest of the PCSA. This table can be found in Section E6.6.4.

E6.6.3.1 Human Failure Events Requiring Detailed Analysis

The detailed analysis methodology, Sections E3.2.5 through E3.2.9, states that HFEs of concern are identified for detailed quantification through the preliminary analysis (Section E3.2.4). An initial quantification of the IHF PCSA model determined that there is one HFE in this group whose preliminary value was too high to demonstrate compliance with the performance objectives stated in 10 CFR 63.111(Ref. E8.2.1). This HFE is presented in Table E6.6-2.

Table E6.6-2. Group #6 HFE Requiring Detailed Analysis

HFE	Description	Preliminary Value
51A-OpDirExpose3-HFI-NOD	Operator causes direct exposure while loading TEV	1E−03

NOTE: HFE = human failure event; TEV = transport and emplacement vehicle.

Source: Original

E6.6.3.2 Assessment of Potential Vulnerabilities (Step 5)

For those HFEs requiring detailed analysis, the first step in the ATHEANA (Ref. E8.1.22) approach to detailed quantification is to identify and characterize factors that could create potential vulnerabilities in the crew's ability to respond to the scenarios of interest and that might result in HFEs or unsafe actions. In this sense, the "vulnerabilities" are the context and factors that influence human performance and constitute the characteristics, conditions, rules, and tendencies that pertain to all the scenarios analyzed in detail.

These vulnerabilities are identified through activities including, but not limited to, the following:

1. The facility familiarization and information collection process discussed in Section E4.1, such as the review of design drawings and concept of operations documents.

2. Discussions with subject matter experts from a wide range of areas, as described in Section E4.2.

3. Insights gained during the performance of the other PCSA tasks (e.g., initiating events analysis, systems analysis, and event sequence analysis).

The vulnerabilities discussed in this section pertain only to those aspects of the waste package export that relate to potential human failure scenarios relevant to the listed HFE. Other vulnerabilities exist that would be relevant to other potential HFEs that can occur during the waste package export operation, but these have no bearing on this analysis.

E6.6.3.2.1 Operating Team Characteristics

WPTT Operator—Located in the Operations Room, the WPTT operator has received training for the WPTT and has observed operations prior to being allowed to operate the WPTT on a dry run. The WPTT operator has signed off to operate the WPTT based on an evaluation of proficiency during a dry run. The WPTT operator has been observed on initial operations before being signed off for solo operation. A single operator is assigned to the WPTT operation.

Waste Package Handling Crane Operator—Located in the Operations Room for this set of operations, the waste package handling crane operator has received training for crane operations and has observed operations prior to being allowed to operate the crane on a dry run. The waste package handling crane operator has signed off to operate the crane based on an evaluation of proficiency during a dry run. The waste package handling crane operator has been observed on initial operations before being signed off for solo operation. A single operator is assigned to the waste package handling crane operation.

Radiation Protection Worker—The radiation worker is a fully certified health physics technician, whose job is to monitor radiation during cask-related activities. The radiation worker is responsible for stopping operations if high radiation levels are detected.

Supervisor—The supervisor is in the IHF Control Room during TEV loading. The supervisor is in charge of verifying proper operations and is also the only one who can grant other personnel access to the Waste Package Loadout Room (via pass code and key) from the IHF Control Room.

E6.6.3.2.2 Operation and Design Characteristics

No humans are in the Waste Package Loadout Room during this operation; all operators are located remotely in the IHF Control Room. Crew members only enter this room for waste package preparation, which happens before the waste package is loaded. The height of the hoist yoke is displayed digitally on a control panel. A joystick is used for fine motion alignment of the grapple (which can move the hoist within the bell). Flat screen displays show the view from a camera mounted on the boom above the yoke. The control interface for adjustable speed drive (ASD) is incorporated into the panel.

All doors from the Waste Package Loadout Room can be opened from the inside in case of an emergency.

To open the facility shield door to the Waste Package Loadout Room, two people are required: one person has to unlock the shield door locally, and the other (a supervisor) has to unlock the door from the IHF Control Room.

The personnel access door can only be opened from the IHF Control Room and requires two separate actions (i.e., entering a pass code and then inserting a key). Only a supervisor is able to perform this action. However, the personnel access door is unlocked during waste package preparation and must be relocked before TEV loading begins.

Radiation control signs and flashing lights are provided outside the door during TEV loading. These are non-ITS equipment.

After personnel have removed the waste package shield ring and left the loadout area, the radiation protection worker or other pre-designated person ensures that the Waste Package Loadout Room is vacant and signals the WPTT operator that it is safe to begin tilt-down.

A public address announcement is made inside the area to alert workers to clear the area before the WPTT is tilted. Intercom communications and television monitoring between workers and the IHF Control Room ensure that the operator knows if exit is delayed.

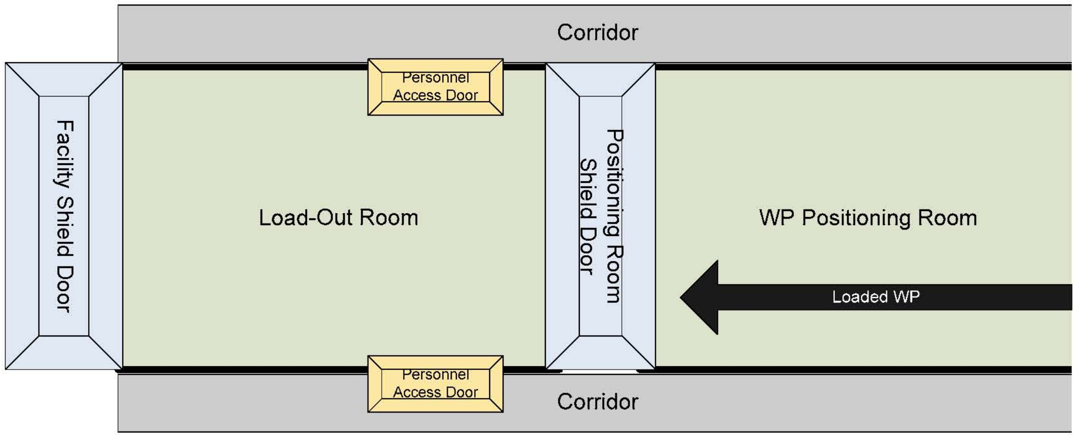
Interlocks—The Waste Package Positioning Room has a load cell that can differentiate between an empty waste package and a loaded waste package. If there is a loaded waste package in the Waste Package Positioning Room, the Waste Package Positioning Room shield door cannot open to allow the WPTT to move to the Waste Package Loadout Room for export unless the facility shield door and the personnel shield doors are locked. Figure E6.6-2 shows the location of the various shield doors; this illustration is conceptual and does not provide a precise representation of the actual configuration.

E6.6.3.2.3 Operational Conditions

There are no specific influencing operational conditions for this HFE group.

E6.6.3.2.4 Formal Rules and Procedures

Procedural Controls—Procedural controls associated with the radiation protection program ensure that the operators and maintenance personnel do not enter the Waste Package Loadout Room except during scheduled times. A personnel accountability system is associated with entering and exiting the Waste Package Loadout Room. Personnel are required to check in with the supervisor and tag in and tag out before entering or after leaving the Waste Package Loadout Room.



Source: Original

Figure E6.6-2. Waste Package Positioning Room and Waste Package Loadout Room Conceptual Configuration

E6.6.3.2.5 Operator Tendencies and Informal Rules

Consequences of Failure—The operations are performed remotely. No personnel are in the vicinity of the operation, and so the threat of physical injury is absent. The WPTT operator expects that failures are mitigated by design features without serious consequences, which promotes complacency in the operations.

Anticipatory Actions—The loadout process is remote, has a high degree of automation, and problems of any kind are not expected. There is a tendency for the WPTT operator to focus on future tasks while the waste package is being loaded into the TEV.

Requests to Enter Loadout Room—The supervisor is present in the IHF Control Room and aware of the stage of TEV loading. Serious consequences are associated with personnel being present in the Waste Package Loadout Room while a TEV is being loaded. Therefore, the supervisor is very cautious not to admit anyone into the Waste Package Loadout Room during this time. If access to the room is necessary, the supervisor either stops operations and tilts up the WPTT or makes sure that the TEV is fully loaded with shield doors closed before admitting a worker into the room.

E6.6.3.2.6 Operator Expectations

Anticipatory Actions—No one attempts to enter the Waste Package Loadout Room without a compelling reason.

E6.6.3.3 HFE Scenarios and Expected Human Failures (Step 6)

Given that the vulnerabilities that provide the operational environment and features that could influence human performance have been specified, then the HFE scenarios within this environment are identified. An HFE scenario is a specific progression of actions during normal operations (with specific context) that lead to the failure of concern; each HFE is made up of one or more HFE scenarios. In accordance with the methodology, each scenario integrates the unsafe actions with the relevant equipment failures so as to provide the complete context for the understanding and quantification of the HFE.

The HAZOP evaluation is instrumental in initially scoping out the HFE scenarios, but they are then refined through discussions with subject matter experts from a wide range of areas, as described in Section E4.2.

Table E6.6-3 summarizes the HFE scenarios developed for the HFE in this group.

Table E6.6-3. HFE Scenarios and Expected Human Failures for Group #6

HFE	HFE Scenarios
51A-OpDirExpose3-HFI-NOD *Operator causes direct exposure while loading TEV*	HFE Scenario 1(a): (1) A crew member remains in the Waste Package Loadout Room after an evacuation is ordered OR a WPTT operator fails to order an evacuation; (2) radiation protection worker fails to check if room is empty or radiation protection worker fails to recognize that someone is still in the room; (3) the crew member fails to notice that loadout is occurring OR the crew member fails to exit the room in time to avoid exposure. HFE Scenario 1(b)[a]: (1) A crew member requests reentry into the Waste Package Loadout Room; (2) the supervisor agrees to allow access. HFE Scenario 1(c): (1) The personnel access shield door is left open; (2) the interlock OR the load cell fails and the WPTT enters the Waste Package Loadout Room.

NOTE: [a] This failure sequence requires several additional failures to actually result in a direct exposure once the crew member is let inside the Loadout Room, such as: the supervisor fails to request stop of the loadout operation OR WPTT operator fails to stop the operation as requested OR the supervisor fails to verify that the operation has stopped before opening door OR the supervisor prematurely restarts operation. Instead of quantifying each scenario, it is conservatively considered that if the supervisor allowed access to the Loadout Room once the WPTT was there, it would result in a direct exposure.

HFE = human failure event; WPTT = waste package transfer trolley.

Source: Original

Since there is only one HFE identified for detailed analysis in this group, the scenarios are organized under this HFE category, with the scenarios numbered as 1(a), 1(b), and 1(c).

The Boolean logic of the HFE scenarios is expressed with an implicit AND connecting the subsequent unsafe actions and OR notation wherever two unsafe action paths are possible, as shown in Table E6.6-3.

The HFE scenarios summarized in Table E6.6-3 are discussed and quantified in detail below.