Radioactive Waste Management

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Geological Disposal

Large Waste Transport Container Summary Report

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Executive Summary

Radioactive Waste Management (RWM) has carried out work to develop a feasible concept for a reusable Type B Large Waste Transport Container (LWTC) to transport Higher Activity radioactive Waste (HAW) to a Geological Disposal Facility (GDF). The LWTC has been designed concurrently with the Larger Waste Container (LWC) to provide a Type B package which can be safely transported within the UK, and which is as large as possible to support reducing or removing the need for size reduction of larger HAW items prior to packaging and transport.

This report summarises the development work which has been carried out to date and presents the progress of the latest LWTC concepts. To date, two container variants have been considered: a top loading LWTC and an end loading LWTC. Each has undergone initial feasibility design and development.

RWM have conducted a high-level review on the latest LWTC designs, focusing on the key structural, thermal, and shielding load cases as outlined in the International Atomic Energy Agency (IAEA) Transport Regulations, as well as manufacturability considerations. This review has found that the current LWTC concept is considered broadly feasible, however certain specific further analytical demonstrations are required, as follows:

- The latest end loading LWTC variant requires additional analyses under the 9 m drop Accident Conditions of Transport (ACT) impact scenario following further development of the impact limiters, ensuring that all analyses run to completion. Specifically, the impact limiter material should be revisited and undergo further analysis to ensure representative behaviour of the finite element model. This further analysis would need to confirm that there are no predicted material failures in the lid bolts or body, and lid gaps fall within the limits for ensuring containment.
- The latest top loading LWTC variant requires further analysis under ACT thermal scenarios to ensure that lid seal temperatures do not exceed limits which could results in material degradation, and that lid gaps from thermal expansion fall within the limits for ensuring containment.

A Forward Action Plan has been developed which captures these analyses, as well as the further actions and considerations which are recommended to progress the LWTC to a complete conceptual design. These further design development considerations include:

- Updating the User and System requirements, as required.
- Establishing an Integrated Test, Evaluation and Acceptance Plan (ITEAP) and a Verification, Validation and Requirements Matrix (VVRM) to support and manage further design development.
- Undertaking an iterative design process which includes:
  - Further analysis under the full set of ACT and Normal Conditions of Transport (NCT) scenarios as outlined in the IAEA Transport Regulations; and
  - Further operability and handling considerations, including incorporation of additional lifting and handling features as well as further study of associated process and equipment requirements.
- Undertaking a further manufacturability assessment as the LWTC design develops, including supply chain capability, bolt material selection and casting method considerations.

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List of Acronyms

ACT	Accident Conditions of Transport
ADR	European Agreement Concerning the International Carriage of Dangerous Goods by Road
CDG	Carriage of Dangerous Goods and Use of Transportable Pressure Equipment (Amendment) Regulations 2019
CDSA	Criticality, Dose and Shielding Assessment
DSS	Disposal System Specification
DSSC	Disposal System Safety Case
EPDM	Ethylene-Propylene-Diene-Monomer
FEA	Finite Element Analysis
GDFD	Generic Disposal Facility Design
GDF	Geological Disposal Facility
HAW	Higher Activity Waste
IAEA	International Atomic Energy Agency
ILW	Intermediate Level radioactive Waste
ITEAP	Integrated Test, Evaluation and Acceptance Plan
LOLER	Lifting Operations and Lifting Equipment Regulations
LWC	Larger Waste Container
LWTC	Large Waste Transport Container
NCT	Normal Conditions of Transport
NDA	Nuclear Decommissioning Authority
NDE	Non-Destructive Examination
ONR	Office for Nuclear Regulation
OPEX	Operational Experience
PUWER	Provision and Use of Working Equipment Regulations
RA	Route Availability
RSILW	Robust Shielded Intermediate Level Waste container
RWM	Radioactive Waste Management
SILW	Shielded Intermediate Level Waste container
SLC	Site Licence Company
SR	System Requirement
SRD	System Requirements Document
SSoN	Single Statement of Need
SSR-6	Specific Safety Requirements 6
STGO	Road Vehicles (Authorisation of Special Types) (General Order)
SWL	Safe Working Load
SWTC	Standard Waste Transport Container
TCSC	Transport Container Standardisation Committee
TRAM	Throughput Reliability Availability Maintenance
UILW	Unshielded Intermediate Level Waste container
UR	User Requirement
URD	User Requirements Document
UTS	Ultimate Tensile Strength
V&V	Verification and Validation
VVRM	Verification and Validation Requirements Matrix
WAC	Waste Acceptance Criteria
WPS	Waste Package Specifications

1 Introduction

1.1 Background

The policy for the long term waste management of Higher Activity Waste (HAW) in England [1] and Wales [2] is for disposal in a Geological Disposal Facility (GDF) . Radioactive Waste Management (RWM) has a mission to deliver the GDF and provide radioactive waste management solutions [3].

Plans for the construction of the GDF are at an early, illustrative design stage, so in order to have confidence that the conditioning and packaging of radioactive waste will result in waste packages that are compatible with future transport to, and disposal in the GDF, RWM has implemented a Disposability Assessment process [4]. This process considers the performance and safety of waste packages against a suite of Waste Package Specifications (WPS) [5]. The WPS define the bounding package requirements anticipated for transport to and disposal in the GDF, as set out in the generic Disposal System Safety Case (DSSC) [6]. A key aspect of the process is to consider the feasibility of safe, compliant transport of waste packages through the public domain to the GDF.

A waste container is deemed to be any vessel into which a wasteform is placed to form a waste package suitable for handling, transport, storage and disposal [5]. RWM's generic Disposal System Specification (DSS) identifies a range of standardised designs of waste container that have been shown to be suitable for the packaging of Intermediate Level radioactive Waste (ILW) for geological disposal [7]. These standardised containers fall into three broad categories [8], as summarised in Table 1.

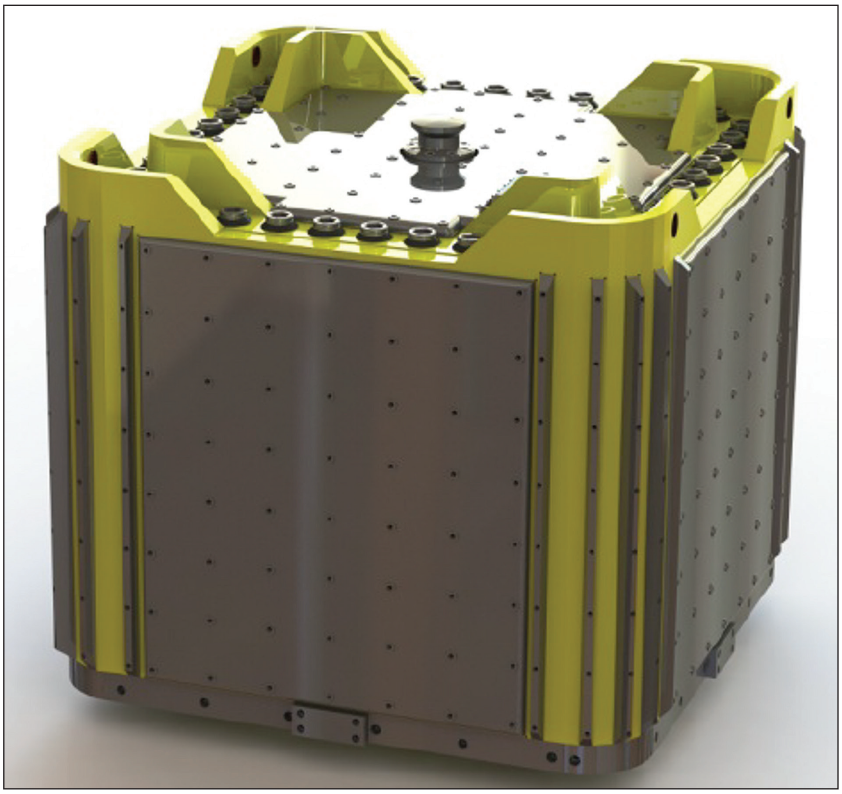
Table 1 - Standardised waste container types

Container Type	Description [8]
Unshielded ILW (UILW) Containers	• Thin-walled metal containers typically made from stainless steel. • Typically used for packaging wastes with high specific activity and/or significant quantities of fissile nuclides. • Transported within robust, reusable Type B transport containers. • Typically require remote handling during operations and interim storage on-site, and at a GDF.
Shielded ILW (SILW) Containers	• Thin-walled metal containers with thick (few hundred mm) internal concrete shielding, or thick-walled reinforced concrete containers. • Typically used for packaging wastes with low specific activity. • Generally designed to be IP-2 transport packages. • Can typically be contact handled and stored in personnel-accessible interim stores.
Robust Shielded ILW (RSILW) Containers	• Thick-walled (up to a few hundred mm) containers, typically made from cast iron. • Suitable for packaging of wastes with a wide range of specific activities and fissile nuclide contents. • Can be designed as transport packages in their own right, or transported in a reusable transport container. • Can typically be contact handled and stored in personnel-accessible interim stores.

[1] The Scottish Government's Implementation strategy supporting their Higher Activity Radioactive Waste Policy states that that long-term management of HAW should be in near-surface facilities [33].

As noted above, it is intended that a UILW package would be placed in a reusable transport container for transport as a Type B package according to the International Atomic Energy Agency (IAEA) Transport Regulations [9]. The current range of UILW containers identified in the DSS are intended to be transported using the Standard Waste Transport Container (SWTC) [10] as illustrated in Figure 1. However, it was identified that a larger transport container could enable the opportunity for development of a larger UILW container, which could in turn have benefits for waste packagers in terms of avoiding, or reducing the need for, size reduction of waste prior to packaging. As a result, RWM has undertaken work to concurrently develop concepts for a Larger Waste Container (LWC) and a Large Waste Transport Container (LWTC).

Figure 1 - SWTC-285 transport package [11]



1.2 Aims and Objectives

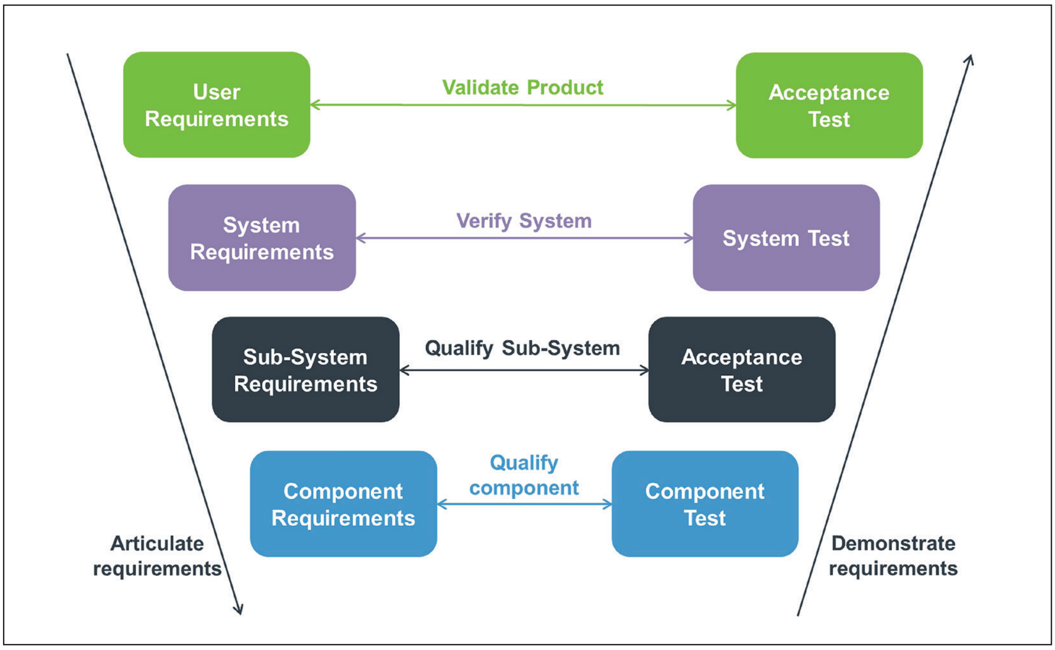
This aim of this report is to summarise the development of the LWTC concept to date and provide a synopsis of the analyses performed to assess the design. The overall objective is to review the LWTC concept, focusing on the key structural, thermal, and shielding load cases as well as manufacturability considerations, and provide a recommended forward action plan for further development to progress the LWTC towards a complete conceptual design.

2 Requirements

2.1 Background

In developing the LWTC, RWM has followed a requirements-led systems engineering approach as summarised in Figure 2.

Figure 2 - Requirements-led design approach [12]



In summary, this approach involved defining:

- A single statement of need (SSoN), which is the highest-level expression of requirements.
- User Requirements (URs), which identify the outcomes, effects, and services that the future users of the capability need to achieve. A user is defined as any person who is involved in the operation of the capability. Therefore, for the LWTC, users would include:
  - Waste packagers (including the Nuclear Decommissioning Authority's (NDA's) site licence companies (SLCs)).
  - Waste consignors and shippers.
  - RWM, as developer and future operator of a GDF.
  - Regulators, notably the Office for Nuclear Regulation (ONR), which is the UK Competent Authority.

- System Requirements (SRs), which identify the systems, functions and performance levels required to fulfil the needs or address the outcomes identified in the URs.

The requirements for the LWTC are captured in a User Requirements Document (URD) [13] and System Requirements Document (SRD) [14]. These documents identify and prioritise the requirements and set out measures to allow them to be verified and validated. The full list of URs and SRs for the LWTC are provided in Appendix A.

2.2 LWTC Single Statement of Need (SSoN)

The SSoN for the LWTC is defined as follows [13]:

> *"The United Kingdom has a need to safely transport a variety of Intermediate Level Wastes with radioactive levels or fissile contents that require a Type B Fissile package with the minimum of size reduction necessary."*

2.3 LWTC User and System Requirements

The full set of URs and SRs for the LWTC, as detailed in the URD [13] and SRD [14], are listed in Appendix A for ease of reference. The required measure of effectiveness for each requirement is expressed in terms of the following limits:

- Threshold - relating to lowest limit of acceptable performance. If this limit is not met, then a base functional objective has not been met;
- Objective - relating to a goal to aim towards, which exceeds the threshold condition and provides an enhanced performance than the minimum required[2].

The SRs, linked to specific URs, are split into three categories within the SRD [14]: dimensions, handling and transport (regulations).

[2] *As indicated in Appendix A, not all URs and SRs have been assigned an Objective measure of effectiveness.*

2.4 LWTC Requirements Synopsis

The LWTC requirements have been summarised within four broad categories for the purpose of this report. These are discussed in more detail in the following sub-sections.

2.4.1 LWC

One of the main drivers for the development of LWTC concept is to support the development of a waste container that is larger than the existing standardised containers included in the DSS to, in turn, support the safe packaging and transport of as many ILW waste streams as possible. A concept for this waste container, known as the LWC, has been developed concurrently with the LWTC. As the LWC is an unshielded waste container, the LWTC must provide sufficient shielding to meet the shielding requirements in the transport regulations for the range of wastes that may be packaged in an LWC. For the purpose of the design, it is also conservative to assume that the LWTC must meet the regulatory requirements for containment with no contribution from the waste package itself. Figure 3 shows a rendering of this LWC concept [11] and the dimensions and mass of the latest LWC concept are given in Table 2.

Figure 3 - Rendering of the LWC concept [11]

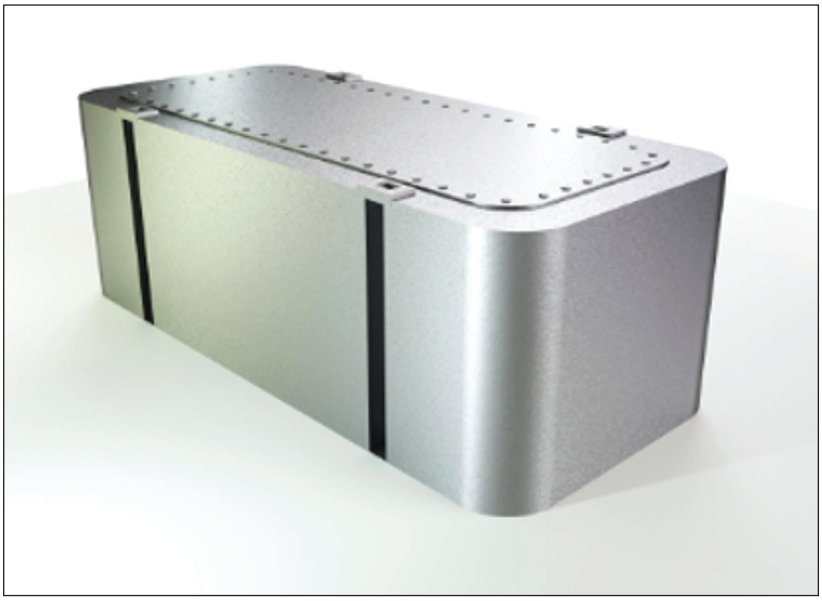


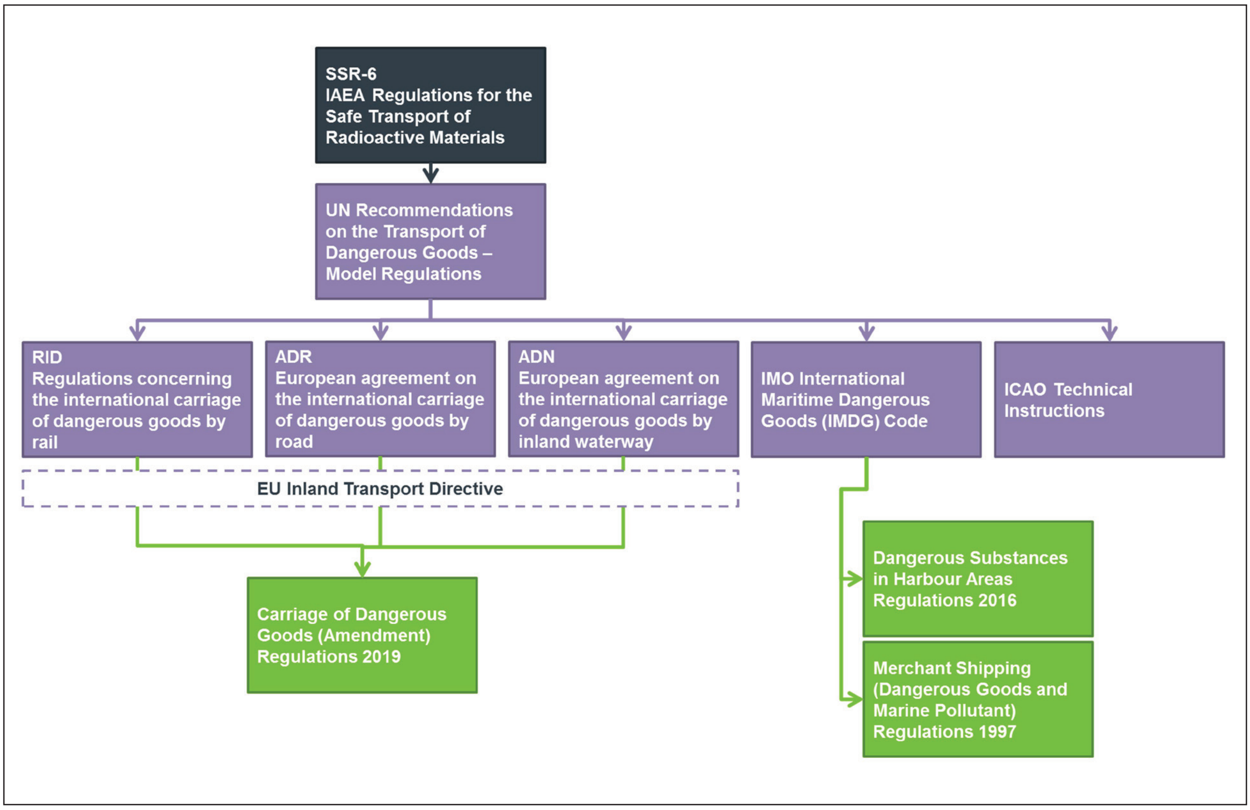
Table 2 - LWC Parameters

Parameter	Value
External Height	1,394 mm
External Width	1,760 mm
External Length	3,910 mm
Gross mass	30 tonnes

2.4.2 Regulatory Compliance

The transportation of radioactive materials in the UK must be in compliance with the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment (Amendment) Regulations 2019 (CDG) [15]. These implement into UK law through the provisions of the IAEA Transport Regulations [9], as illustrated in Figure 4 below.

Figure 4 - Radioactive material transport regulations and directives



The Transport Regulations [9] set standards of safety to protect people, property and the environment during transport of radioactive material by ensuring containment of the radioactive contents, control of external dose rate, prevention of criticality and prevention of damage by heat. The regulations define a range of packages, with increasing levels of protection depending on the hazards posed by the contents. As defined by the SSoN, the LWTC needs to be designed to transport a variety of ILW with amounts of radioactivity and/or fissile material that require a Type B Fissile package, with minimal size reduction required. This means that the LWTC needs to be designed to withstand Routine, Normal and Accident Conditions of Transport (RCT, NCT, ACT).

Appendix B sets out the paragraphs of the IAEA Transport Regulations applicable to a Type B package, and which therefore need to be considered in the design of the LWTC. It also sets out the associated paragraphs from the European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR) [16].

In addition to the IAEA Transport Regulations [9], the design of the LWTC is influenced by a number of other appropriate codes and standards as well as other regulations such as the Lifting Operations and Lifting Equipment Regulations (LOLER) [17] and the Provision and Use of Work Equipment Regulations (PUWER) [18].

2.4.3 Dimensional and Mass Constraints

A key objective of the LWTC is to provide a Type B transport container that is as large as possible which can be safely transported within the UK. NDA strategy [19] sets out a preference for the use of rail transport over road, where practicable, for radioactive waste. Given that the location for a GDF has not yet been identified, dimensional and mass constraints are applied to the LWTC via the following parameters to enable it to be transportable across as large a portion of the UK's rail network as possible:

- Rail gauge, which dictates the permissible sectional dimensions of the transport container due to restrictions imposed by tunnels, bridges, station platforms etc.
- Route availability (RA), which defines the maximum permissible load per wagon axle along the route.

The threshold rail gauge and RA limits [14] for the LWTC, defined in UR9 and SR1.6 are shown below in Table 3. The RA10 limit defines a maximum axle load of 25.4 tonnes for an 8-axle wagon, however axle spacing considerations also apply.

Table 3 - Rail transport limiting parameters

Limiting Parameter	Limit
Rail Gauge	W6a
Route Availability	RA10 (8 axle)

SR1.5 defines the threshold limits for road transport as being in adherence with Road Vehicles (Authorisation of Special Types) (General Order) STGO Cat 3 [20] which implies a maximum total weight of 150 tonnes and axle load of 16.5 tonnes.

2.4.4 Operability and Handling

The design of the LWTC needs to enable safe operation and handling at possible waste consignment sites as well as the GDF. The Generic Disposal Facility Design (GDFD) [21] outlines the process for receipt and unloading of SWTCs at the GDF. It is assumed that the LWTC would follow a similar process, being transferred in its transport configuration, and unloaded within a remotely-operated cell. These operability and handling considerations impose mass and dimensional restrictions on the LWTC, including those relating to transfer underground, which will either be via a drift (incline) or a shaft (vertical), depending on the host environment of a GDF. The threshold limits for these methods defined in SR1.1 - SR1.4 are shown below in Table 4. It should be noted that the threshold limits for both transfer methods exceed the baseline assumptions outlined in the GDFD [21], but have been assessed as feasible limit values. As such, a change to the generic GDF designs would be required to cater for the LWTC, if and when further development of the concept is undertaken; this would also apply to the Safe Working Load (SWL) capacity for overhead travelling cranes that would need to be used for underground handling of the LWTC.

Table 4 - GDF handling and operability limits

GDF Transfer Method	Dimension Limit	Gross Mass Limit
Drift (rack and pinion rail)	W6a	120 tonnes
Shaft (cage)	7.3 m × 3.0 m	120 tonnes

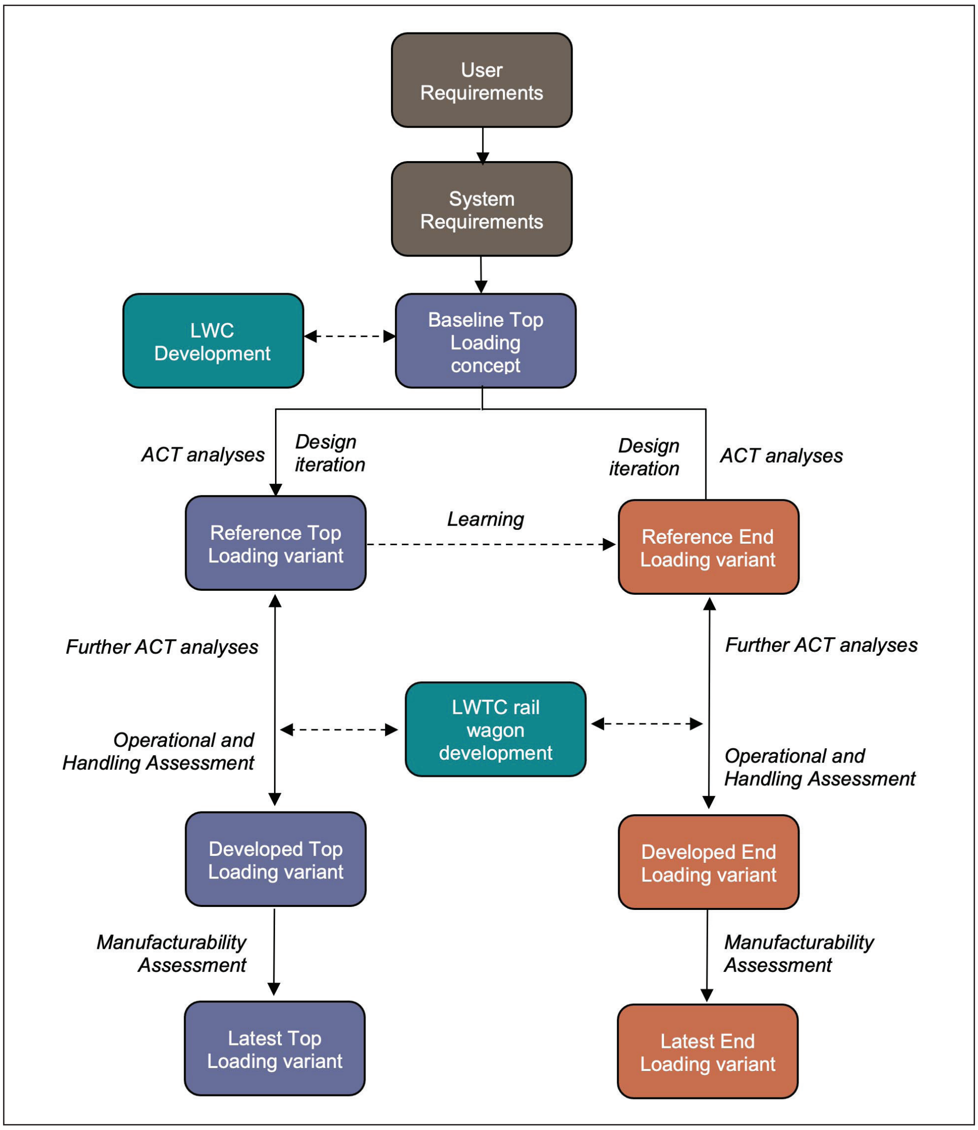
3 LWTC Development

This section provides a summary of the work that has been undertaken to date in developing the LWTC concept. Initial development began with a top loading variant which was shortly followed by concurrent development of an end loading variant to compare performance.

3.1 Development Summary

Figure 5 shows the full development path of the LWTC graphically.

Figure 5 - LWTC development path



3.2 LWTC Conceptual Design

A schematic representation of the latest conceptual designs for both LWTC variants and summary of the main features is given in Figure 6. Table 5 provides a more detailed breakdown of the dimensions and materials associated with each variant.

Figure 6 - Latest LWTC design variants and summary

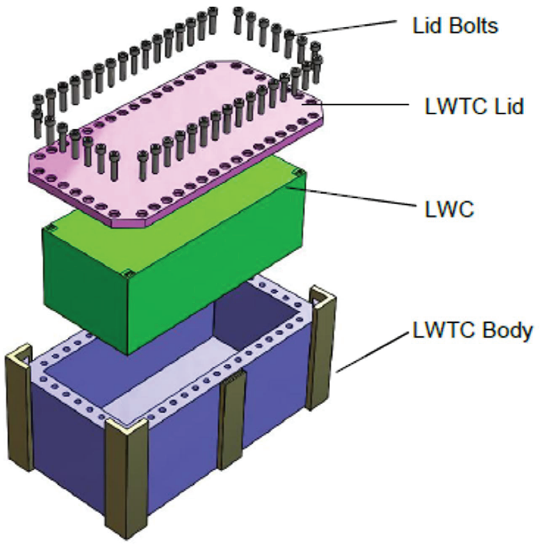
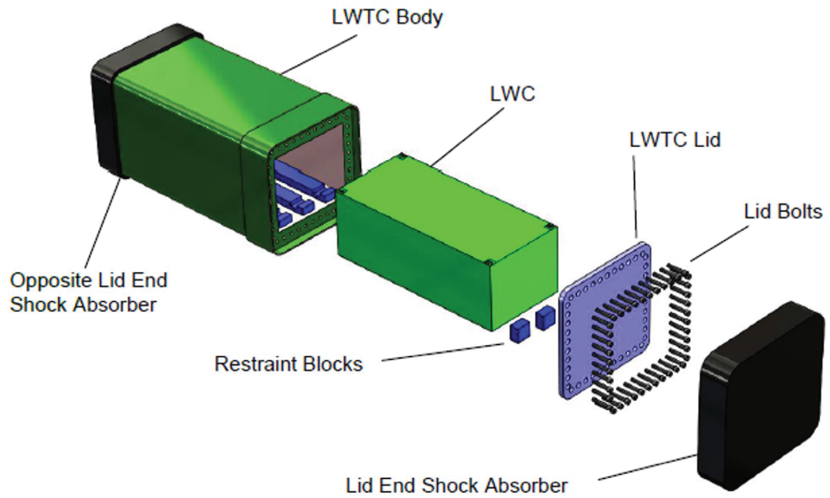
Top Loading LWTC [22] [23]	End Loading LWTC [24] [25] [26]
	
• Cast stainless steel body • Top mounted and bolted lid with spigot and chamfered corners • Partially hollow upstands for impact absorption. Corner upstands 100 mm above lid. Mid length impact absorbers flush with lid.	• Cast stainless steel body • End mounted and bolted lid with spigot • Grain-oriented wooden shock absorbers encased in thin-walled stainless steel on both LWTC ends • Restraint blocks to secure LWC and skate plates for removal.

Table 5 – Latest LWTC concept dimensions and details

Top Loading LWTC		End Loading LWTC	
Feature	**Value**	**Feature**	**Value**
External Length incl upstands	4,790 mm	External Length incl absorbers	5,275 mm
External Width incl upstands	2,640 mm	External Width incl absorbers	2,404 mm
External Height incl upstands	2,050 mm	External Height incl absorbers	2,593 mm
LWTC External Length	4,590 mm	LWTC External Length	4,675 mm
LWTC External Width	2,440 mm	LWTC External Width	2,316 mm
LWTC External Height	1,743 mm	LWTC External Height	2,086 mm
LWTC Internal Length	3,980 mm	LWTC Internal Length	4,275 mm
LWTC Internal Width	1,830 mm	LWTC Internal Width	1,820 mm
LWTC Internal Height	1,500 mm	LWTC Internal Height	1,590 mm
Wall Thickness	305 mm	Wall Thickness	200 mm
Body Material	CA6NM*	Body Material	CA6NM*
Lid Thickness	240 mm	Lid Thickness	200 mm
Spigot	100 mm	Spigot	100 mm
Body/Lid Material	CA6NM*	Body/Lid Material	CA6NM*
Lid Bolts	46 × ø85	Lid Bolts	38 × ø68
Bolt Material	BS898 12.9	Bolt Material	BS898 12.9
Seal Material	EPDM-30H	Seal Material	EPDM-30H
Empty Mass	86.5 tonnes	Empty Mass	72.7 tonnes
Gross Mass	121 tonnes	Gross Mass	107.7 tonnes
Assumed Payload Mass	34.5 tonnes	Assumed Payload Mass	35 tonnes
Base Thickness	243 mm	Shock Absorber Rib Thickness	10 mm
Corner Upstand External Length	460 mm	Shock Absorber Carcass Material	316L
Corner Upstand External Width	460 mm	Shock Absorber Infill Material	Wood
Corner Upstand Protrusion	100 mm	Skate Depth	170 mm
Upstand Material	304L	Skate Material	CA6NM*

**CA6NM is a martensitic iron-chromium-nickel-molybdenum alloy. This was identified as the most appropriate material during the development of the SWTC concept and this informed the credible decision to use this alloy in the initial material selection for the LWTC* [26].

The dimensions and masses outlined in **Table 5** are representative of the latest LWTC variants as detailed in the underpinning reports [23] [24]. In the initial feasibility stage, development was focused on the key concept components including the body, lid, closure features and impact protection features. Additional features, such as feet and lifting points, e.g. trunnions, would require further consideration and incorporation into the design during future development.

3.3 Performance Evaluation Criteria

The development of both LWTC variants to date has been substantiated by analyses against a series of performance evaluation criteria. In reference to the SRs (Appendix A), these performance evaluation criteria have been defined as thresholds, proportionate for assessing feasibility, to ensure that there would be no release of radioactive material from the containment boundary by considering:

- Adequate compression is maintained within the lid seals.
- No material failures are predicted in the lid bolts or body.

3.3.1 Maximum Lid Gap

Both LWTC variants implement an Ethylene-Propylene-Diene-Monomer (EPDM) material O-ring seal with a proposed cord diameter of 15 mm to seal the lid to the body of the container. The design compression of the seal is assumed to be 30% of the cord diameter (4.5 mm). The maximum allowable lid gap to ensure containment, as per as per Transport Container Standardisation Committee (TCSC) guidance [27], is defined by subtracting a minimum allowable retained compression from the design compression. The minimum allowable retained compression is taken as 10% of the cord diameter (1.5 mm), giving a maximum allowable lid gap of 3 mm. The allowable lid gap was used as one of the main limiting criteria when assessing the LWTC variants against ACT impact and thermal tests.

3.3.2 Lid Bolt Shank Plastic Strain Limit

A 5% plastic strain limit on the bolt shanks was applied as an initial assessment criterion for the ACT tests across all the analyses for both LWTC variants. Based on previous package assessments, which have been reviewed by the ONR, a degree of plastic strain may be accepted during ACT analyses and for an early stage design the 5% plastic limit is deemed to be appropriate. It is recommended that for NCT, strains remain within elastic limits [23]. An additional 10% body strain criterion was also considered when assessing the end loading LWTC [24].

3.3.3 Thermal Parameters

The thermal analyses for both LWTC variants focus on the O-ring seal performance under elevated temperatures. This includes consideration of thermally induced material degradation of the seal, and an assessment of lid gap openings and bolt strains as a result of thermal stress.

Additional thermal performance evaluation criteria are addressed in the form of temperature limits from heat transfer as follows [24]:

- Outer surface temperatures during routine conditions without solar insolation < 85°C.
- Lid seal temperatures < 155°C during NCT and ACT to limit seal degradation. Note: this is a recommended limit for EPDM specified by a seal manufacturer.

3.4 LWTC Concept Development

A brief summary of the development undertaken to produce the latest conceptual designs for both LWTC variants is provided in Table 6 below.

Table 6 - LWTC concept development details

Top Loading LWTC	End Loading LWTC
• **Main Body:** ◦ Following an assessment **[22]** by Sellafield Ltd.'s criticality, dose and shielding assessment (CDSA) team, a minimum steel thickness of 240 mm was initially identified as being sufficient to provide shielding for transport of the vast majority of the ILW inventory[3]. This exceeded the threshold measure of SR3.2 (50% of ILW inventory). ◦ Through Finite Element Analysis (FEA) modelling, increasing wall thickness was identified as having the most significant effect on maintaining containment following the 9 m drop ACT impact tests. However, it was identified that wall thickness also had a significant impact on the container mass. ◦ Dimensional combinations were investigated and refined using FEA pre-processing and meshing tools and a Design of Experiments sampling methodology **[23]**. • **Lid and Bolts:** ◦ Initially an arrangement of 42 × M68 bolts using A2-70 material was preferred. ◦ The number of lid bolts was calculated using the length of the bolt centrelines to equally space the bolts around the LWTC body. ◦ The effect of varying bolt diameter was investigated using a force analysis, which considered axial, shear and bending moment assessments. A range of increasing bolt diameters was assumed to reduce plastic strains in the bolt shanks. ◦ Bolt material was changed from A2-70 to BS 898-1 12.9 to increase the Ultimate Tensile Strength (UTS). ◦ To reduce the shear stress in the lid bolts, a counterbore was utilised, with varying depths into the walls and lid assessed. A spigot was introduced into to the lid to move the shear load path and minimise plastic shear strain in the bolt shanks. ◦ The bolt arrangement was modified to cater for addition of corner upstands and giving 46 × M85 bolts. **[23]**. ◦ Investigation into the use of lid relief found that it was an effective measure in reducing the residual lid gap as well as reducing plastic bolt strain during modelled ACT scenarios **[22]**.	• **Main Body:** ◦ Dimensions were initially specified using findings from the top loading concept development. A cylindrical cross section was considered but rail gauge limitations led to a rectangular section being preferred **[26]**. ◦ The threshold measure of SR3.2 (50% of ILW inventory) was used to define a minimum steel wall thickness of 25 mm to ensure sufficient shielding, but a starting wall thickness of 200 mm was based upon good design practice for a bolted connection using learning from the SWTC-285 design. The position of lid and lid bolts were identified as impacting the minimum wall thickness. ◦ Wall thickness was increased at the body ends for localised lid protection and shock absorber attachment considerations. ◦ Clearance limits around the contents were initially assumed to be similar to those provided in the SWTC-285. Body length was increased to allow for a payload restraint system. • **Lid and Bolts:** ◦ Initially an arrangement of 42 × M68 bolts. The number of corner bolts was reduced from two to one to improve localised bolt spacing and increase the amount of lid material resulting in 38 × M68 bolts **[24]**. ◦ Bolt material was initially assumed as BS 970 817M40 as per SWTC-285. This was then changed to BS 898-1 12.9 during development of the concept to increase UTS and align with the top-loading variant. ◦ The use of a hinged lid was initially considered, but a removable bolt-on lid was preferred due to its simplicity and superior containment under FEA modelled ACT scenarios **[26]**. ◦ As with the top loading variant, a spigot was incorporated into the lid to reduce shear load through the bolt shanks.

[3] *Excluding 1C01, and 3S306 waste streams.*

Table 6 - LWTC concept development details - Continued

Top Loading LWTC	End Loading LWTC
• **Shock Absorbers:** ◦ Upstands were developed as ancillary features to aid in the absorption and dissipation of energy under ACT impact tests. ◦ Initially the absorbers were stainless steel fins, but these were subsequently replaced by more substantial upstands located at the body corners with crushable feet **[22]**. ◦ The upstands were initially modelled as solid then changed to hollow to reduce plastic bolt strains. ◦ Methods of improving the upstand stiffness were investigated, including increasing the thickness and adding internal ribs and additional bracing. Hollow upstands with a solid internal block were preferred **[23]**.	• **Shock Absorbers:** ◦ Shock absorbers were developed to provide increased protection and containment under FEA modelled ACT impact scenarios. ◦ Different material properties were investigated for the impact absorbing component, including foam, balsa wood and yellow pine. Various designs were considered leading to a thin-walled austenitic stainless-steel structure that encases compressible grain-orientated wooden blocks **[24].** • **Ancillaries:** ◦ A skate and restraint system was incorporated to aid with the handling requirements of the payload and restrict its movement within the LWTC. ◦ A 170 mm deep skate was selected as providing ample clearance for most commercial off the shelf equipment. The restraints were placed within engineered cutaways.

3.5 LWTC Concept Performance Analyses

A summary of the analyses performed to substantiate the conceptual design of both LWTC variants is provided in this section. This is separated into mechanical impact analyses (Table 7) and thermal analyses (Table 8).

Table 7 - Mechanical impact performance analyses summary

Top Loading LWTC	End Loading LWTC
• A 9 m drop onto a flat, unyielding, horizontal surface was modelled using eleven orientations covering drops on all corners, faces and edges with centre of gravity acting directly over the point of impact [23]. • The lid down drop resulted in a peak lid gap above 3 mm, however all eleven drop orientations resulted in a residual lid gap of less than 3 mm [23]. • The plastic strains in the lid bolt shanks were below 5% in all of the drop orientations [23]. • A drop orientation study was conducted and validated the eleven orientations as being proportionately representative of the worst case for this design stage [23]. • Payload mass was assumed as 34.5 tonnes. throughout the analyses. • Additional dynamic crushing and puncture scenarios, as outlined in the IAEA Transport Regulations [9], were not modelled at this stage, as the 9 m drop was considered the most challenging scenario for this initial feasibility assessment. • A study conducted using an earlier iteration of the top loading LWTC variant indicated that secondary or tertiary impacts could produce more adverse effects than the primary impacts due to the increased velocity at impact [23]. This was not repeated for the latest version of the concept, as the results and conclusions of the earlier analysis were deemed representative. • The underpinning report [23] indicates that further analyses, including secondary and tertiary impacts would be required during further design development stages.	• The 9 m drop impact ACT scenario was also modelled using ten drop orientations which were deemed as proportionately representative of the worst case for this design stage [24]. • Of the ten analyses, only five ran to completion. All five analyses that ran to completion passed the bolt strain and lid gap criteria, and only one drop orientation failed the 10% body strain criteria [24]. • The five analyses that didn't run to completion stopped early due to a modelling solver error resulting from excessive deformation of the shock absorber material [24]. • The failure caused by the compressibility in the absorber material would ultimately lead to a transfer of the remaining kinetic energy from the impact through the other LWTC components, including the lid and lid bolts [24]. This could lead to lid gaps and bolt strains exceeding the failure criteria. Subsequent calculations have shown that satisfactory impact performance may be possible, but it would depend on sufficient isotropic deformation of the impact limiters. • Three analyses exceeded the 10% body strain limit through the outer body shroud [24]. • The payload mass was modelled as 30 tonnes during the analyses. • As per the top loading LWTC, additional dynamic crushing and puncture scenarios, as outlined in IAEA Transport Regulations [9], were not modelled at this stage, and the 9 m drop was considered the bounding scenario for this initial feasibility assessment.

Table 8 - Thermal performance analyses summary

Top Loading LWTC	End Loading LWTC
• The latest conceptual design of the top loading LWTC variant was not analysed under thermal ACT scenarios. An earlier iteration was assessed in terms of heat transfer and thermal stress [22] where the peak seal temperature reached 192°C, exceeding the maximum seal operating temperature for several hours. However alternative seal materials with higher operating temperatures could be adopted to mitigate this challenge. • The thermal stress analyses used the effective temperatures from the heat transfer analyses to predict thermal expansion. The lid gaps exceeded the 3 mm limit for a short period and increased in the fire simulations, but reduced during the cooldown period to a residual gap of less than 3 mm.	• The latest conceptual design of the end loading LWTC variant was assessed for heat transfer and thermal stress [24]. For the ACT scenarios modelled, all temperatures fell within the required ranges. The peak seal temperature of 91°C remained within the recommended operational window for optimal lifespan and below the expected threshold for material degradation [24]. The thermal stress analysis predicted a nominal lid gap opening of 0.27 mm. No plastic bolt strains were predicted as a result of the thermal stress and deformation [24].

3.6 LWTC Concept Handling and Operability Assessment

This section summarises the findings from a handling and operational review conducted for both LWTC variants [28], and an additional operational assessment for the end loading LWTC [25]. The review proposes operational sequences at both the waste consignment site and at the GDF. The loading and unloading operations were effectively mirrored processes. The lid unbolting and tightening operations are proposed to be conducted outside of a shielded cell to allow for intervention, if required. Further study is recommended to investigate the required capability of cranes and other handling systems as well as consequence assessments for dropped loads [28]. The specific findings from these assessments are listed in Table 9.

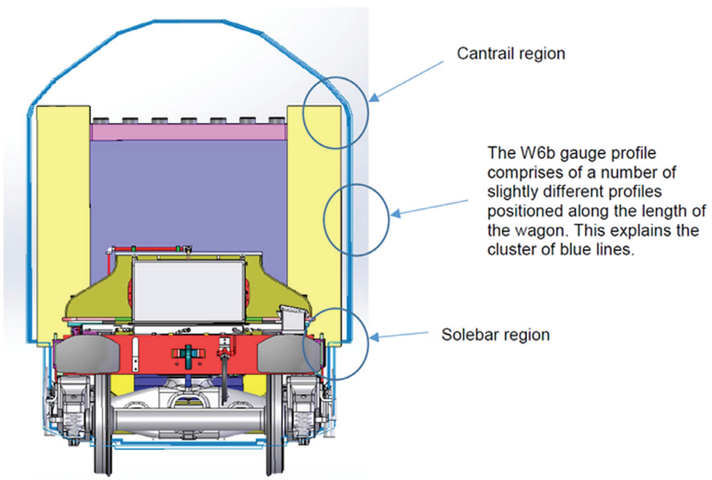
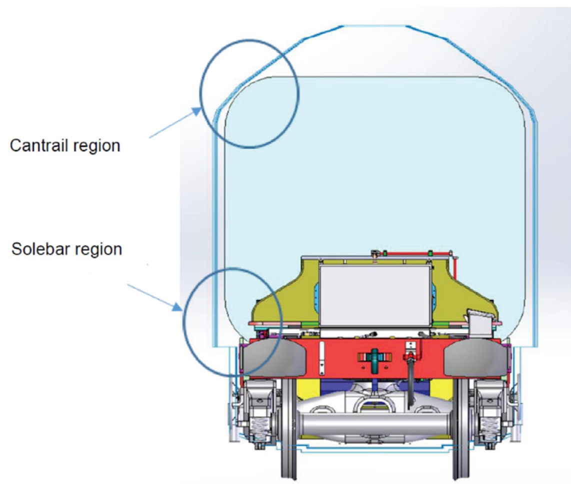
Table 9 - LWTC concept handing and operability assessment summary

Top Loading LWTC	End Loading LWTC
• The top loading LWTC has a more conventional handling procedure than the end loading design and more operational experience (OPEX) exists across the industry with this vertical lift method with packages of similar size [28]. • The top loading LWTC requires less ancillary equipment with a simpler process for placement and removal of the lid bolts and lid. • Although an operational sequence has been outlined, further design considerations are required, including the specification of handling features. • The top loading LWTC would likely require a longer leak testing time due to the lid seal length which is nearly double that of the end loading concept. OPEX also generally indicates that an increase in seal length generally results in an increase in operational time. • The top loading LWTC would require a larger bolting machine than the end-loading LWTC.	• There are expected to be a number of benefits, as well as operational and engineering challenges associated with loading the payload into the end loading LWTC using the proposed handling sequence. • The greatest challenge will involve loading or removing the payload from the LWTC. This could require a powered skate and track system along with additional ancillary equipment. A system for reliable removal and replacement of the restraint blocks would be required. • There would be challenges in replacing and handling the lid via a two-stage process of horizontal traverse then vertical lift. A system for retaining the lid would also be required. • There are a number of areas that are outlined as requiring further design development in order for the process to be fully operational, particularly the development of lifting and handling features. • The end loading concept would result in reduced lifting height requirement for loading of the contents, which may be beneficial. • Additionally, the end loading concept would allow for greater flexibility for payload handling by potentially enabling both base and top lifting of the payload. • The reduced number and diameter of lid bolts required by the end loading LWTC also offers a benefit in terms of the practicality of handling and storage.

3.7 LWTC Concept Transportability Assessment

A rail feasibility study was conducted to assess the transportability of the LWTC variants [29]. A summary of the outcomes is provided in Figure 7. The rail feasibility study introduces a new, bespoke W6b rail gauge which is used throughout. This W6b rail gauge features a slightly more limiting sectional area compared to W6a, to allow access to larger proportion of UK rail network. A study was undertaken to investigate the possibility of increasing the fatigue life of the NDA owned high capacity, 8-axle rail wagons, designated KXA-Cs. This study found that more detailed consideration of the fatigue life for the wagon bed would be needed [29].

Figure 7 - LWTC concept rail feasibility summary

Top Loading LWTC	End Loading LWTC
 • The top loading LWTC, whilst mounted on the concept rail wagon, infringes upon the W6b gauge in the solebar region, with a small clearance in the cantrail region. If the LWTC were to be raised so that the feet rested on the gauge line in the solebar region, there would be a clearance of 0 mm in the cantrail region. This is deemed sufficient as the dimensions of the impact absorbers are not precisely defined at this stage of design.	 • The end loading LWTC does not infringe upon the W6b even with the inclusion of the shock absorbers.

3.8 LWTC Manufacturability Assessment

A manufacturability assessment was conducted on the latest conceptual design of both LWTC variants [30] to supplement previous studies on earlier designs. The key findings from this assessment are summarised below:

- There are currently no specific material or process issues that should challenge general good foundry practice in relation to casting the body and lid of either variant using CA6NM. CA6NM was identified as the most appropriate material during the development of the SWTC concept and this informed the credible decision to use this alloy in the initial material selection for the LWTC [28].
- It is noted, however, that care is required when identifying the supply chain capability, as limited foundries would have the ability to produce 100 t and larger castings.
- Both LWTC variants were analysed as being cast horizontally. Horizontal casting would require the end loading LWTC variant to be cast with a window at the closed end over which a plate would need to be welded. It is recommended that vertical casting should be investigated in the future to remove the need for the window, which in turn would reduce welding requirements.
- The assessment showed a clear preference for the top loading LWTC from a foundry and subsequent machining perspective. The end loading LWTC potentially introduces additional welding and Non-Destructive Examination (NDE) requirements.
- The assessment identifies that the lid bolt material may need to be reconsidered due to concerns relating to material strength, compatibility, and corrosion.
- It was noted that at the current stage of development, with limited available detail, it was difficult to determine feasible post casting costs. However, the assessment estimates that both LWTC variants would have a similar indicative final cost with the top loading concept at £1 million, and the end loading concept at £1.1 million.

4 LWTC Concept Review

The section reviews both LWTC variants against the underpinning requirements to give an understanding as to the current stage of design development, as well as informing the forward planning of further development stages. A summary is also presented focusing on the key structural, thermal, and shielding load cases, as well as manufacturability considerations, to assess the feasibility of the LWTC concept and outline any further analyses required on the conceptual design.

4.1 Dimensions

The fully laden mass of the top loading LWTC variant (121 tonnes) [23] exceeds the 120 tonne threshold derived from the KA8 axle loading and GDF requirements. However, since the threshold is exceeded by such a small amount, it is deemed to be achievable with minor adjustments and therefore does not challenge the feasibility of the LWTC concept. The end loading LWTC variant is compliant with this fully laden mass threshold.

Both LWTC variants are compliant with the dimensional requirements for rail transportability and GDF accessibility. No specific assessment is made for either LWTC variant with regards to the road transportability, or ability to transport alternative payloads, however no fundamental issues are expected that would challenge the feasibility of the LWTC concept.

4.2 Handling

As identified in Section 3.2, the development of both LWTC variants to date has focused on the key concept components including the body, lid, closure features and impact protection features. Additional features, such as feet and lifting points, e.g. trunnions, would require further consideration and incorporation into the design during future development. It is noted that these could have an impact on the mechanical and thermal analyses, however this is not expected to challenge the feasibility of the LWTC through further design.

Further study is required to confirm the capability of cranes and other GDF handling systems for handling the LWTC, and the GDFD [21] should be updated accordingly if new systems are required. The geometry and masses associated with the LWTC design variants are not expected to exceed the achievable capacity of overhead cranes and therefore RWM has identified that both LWTC variants could be considered feasible with further consideration.

The end loading LWTC variant requires further development to validate the additional process and equipment requirements associated with the removal and replacement of lid and contents by remote or automated techniques [28] [25]. A ski/slide mechanism allows for the remote loading and unloading of the payload, but a system still needs to be devised that would enable the restraint blocks to be removed and replaced reliably. However, this is not expected to challenge the feasibility of the LWTC concept through further design during later stages of development.

GDF throughput is also not yet directly considered and a Throughput Reliability Availability Maintenance (TRAM) assessment should be conducted for both LWTC variants over the whole disposability cycle during the next stage of development. In addition, a further consequence assessment for dropped loads is recommended [28].

The static and dynamic load cases required for threshold GDF safe handling and GDF site safety case impact requirements are not yet addressed. However, it is noted that these impact requirements are expected to be aligned similarly with the Type B container impact requirements, as covered in the following sub-section.

Both LWTC concepts are considered to be compliant in terms of material compatibility with unshielded waste packages, as well as their feasibility to transport the LWC payload.

4.3 Transport

Compliance with the IAEA Transport Regulations [9], including NCT and ACT containment requirements has been demonstrated as being feasible for both LWTC variants, noting that further stages of design development would require this to be validated through a combination of further analysis and physical testing. The performance evaluation criteria used in both the impact and thermal modelling is based around residual seal compression limits to ensure leak tightness.

In terms of the ACT impact modelling requirements for a Type B(M) package, the 9 m impact onto an unyielding surface was considered to be the most challenging structural load case with the most adverse effects on containment. Further assessment to demonstrate satisfactory performance under the other load cases would be required to allow the LWTC to be considered a complete conceptual design

The resulting residual lid gaps and plastic bolt strains following the 9 m impact analyses all fell within the performance criteria limits for the top loading LWTC. For the end loading LWTC, the analyses which ran to completion also met these limits, however several runs stopped early due to a modelling solver error resulting from excessive deformation of the shock absorber material. The end loading LWTC would therefore also require further assessment to demonstrate satisfactory performance under the 9 m impact load case.

The thermal ACT modelling requirements for a Type B(M) package have been partially addressed for the top loading LWTC through an earlier conceptual design iteration [22]. This earlier modelling exceeded operating conditions briefly, but the results were considered provisional as they were based on room temperature material properties and not those required by the ACT scenarios [24]. Thermal modelling for the end loading LWTC variant indicated positive results. Due to the assumptions included in the analyses [22] [23] [24], both LWTC variants would require further thermal testing. Additionally, combined impact and thermal testing would be required in further design stages of the LWTC development, however this is not expected to challenge the feasibility of the LWTC concept.

Both LWTC variants used design temperatures within the specified range for routine transport of Type B packages resulting in surface temperatures below the maximum limit for a package under exclusive use [23] [24].

The wall thickness in both LWTC variants is sufficient to provide shielding to allow for the vast majority of the ILW inventory to be transportable, exceeding the threshold value for this requirement.

As covered, the development of both LWTC variants to date has focused on modelling against what were considered to be the most challenging load cases associated with the IAEA Transport Regulations. A range of further requirements will also need to be addressed through further design development stages, including those relating to stacking, tie-down, vibration and acceleration and water retention considerations. However, these are not expected to challenge the feasibility of the LWTC concept.

4.4 LWTC Concept Review Summary

Analysis of the key load cases and initial manufacturability assessment confirm that the LWTC concept is considered broadly feasible, however certain further analytical demonstrations are required, as follows:

- The latest end loading LWTC variant requires additional analyses under the 9 m drop ACT impact scenario following further development of the impact limiters, ensuring that all analyses run to completion. Specifically, the impact limiter material should be revisited and undergo further analysis to ensure representative behaviour of the finite element model. This further analysis would need to confirm that there are no predicted material failures in the lid bolts or body, and lid gaps fall within the limits for ensuring containment.
- The latest top loading LWTC variant requires further analysis under ACT thermal scenarios to ensure that lid seal temperatures do not exceed limits which could results in material degradation, and that lid gaps from thermal expansion fall within the limits for ensuring containment.

5 Forward Action Plan

This section outlines a recommended route map for further LWTC development in the form of a high-level Forward Action Plan. The Forward Action Plan focuses on addressing the specific analyses required to address the technical risks identified through this review, as well as wider considerations for further LWTC concept design development. **Figure 8** provides a visual representation of this Forward Action Plan and **Table 10** explains each step in further detail.

Figure 8 - Forward Action Plan

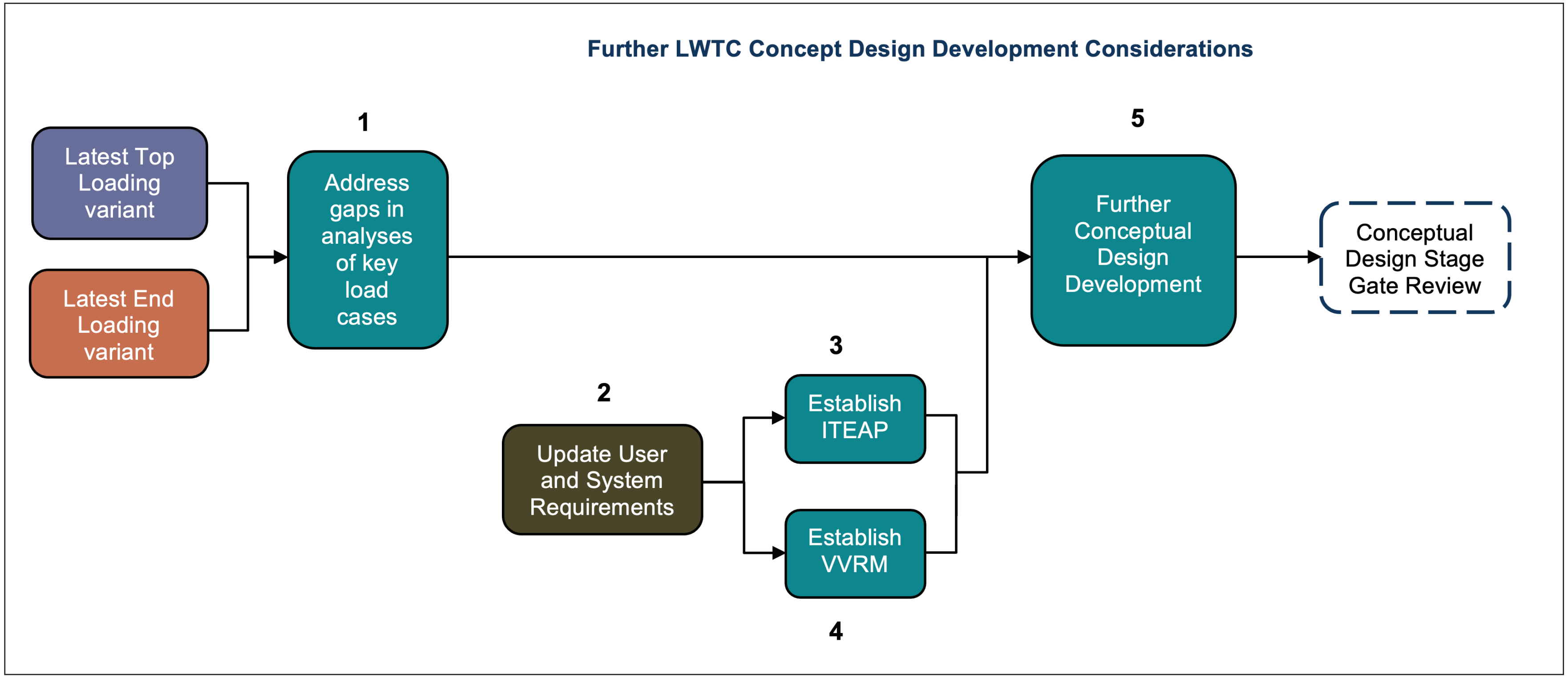


Table 10 - Forward Action Plan explanation

Step	Description	Explanation
1	Address gaps in analysis of key load cases	As outlined in Section 5, specific further analytical demonstrations for key load cases are required on the LWTC variants. These are summarised as follows: • The latest end loading LWTC variant requires further analyses under the 9 m drop ACT impact scenario following further development of the impact limiters, ensuring that all analyses run to completion. • The latest top loading LWTC variant requires further analysis under ACT thermal scenarios.
2	Update User and System Requirements	It is recommended that prior to progressing the LWTC design development, the URD and SRD should be re-visited and updated to capture any corrections or further considerations, as required. Where specific cases have been identified, these have been noted within the relevant UR/SR in Appendix A.
3	Establish ITEAP	An Integrated Test and Evaluation Plan (ITEAP) should be produced for the LWTC and linked to the updated requirements to outline a methodology and timeline to evaluate and substantiate the LWTC through further design development. An ITEAP would provide a structured and comprehensive method of aligning the key performance analyses with requirements and provide an effective platform for further development. It would help to identify the most effective modelling to measure capability and performance as well as plan an optimised use of resources and outline and manage technical and operational risks.
4	Establish VVRM	In addition to an ITEAP, a Verification and Validation Requirements Matrix (VVRM) should be established to manage the acceptance criteria, the evidence collected and evaluated and the acceptance status of the concept against the requirements during further design development.
5	Further Conceptual Design Development	An iterative process of further design development would be required for the LWTC to pass the conceptual design gate stage. The following sections provide a high level indicative summary of these further requirements, noting that the ITEAP would outline these more accurately as well as providing a more detailed timeline and methodology for this development process. **Further analyses under ACT and NCT scenarios** The LWTC will require further analysis under the full set of ACT and NCT scenarios as outlined in the IAEA Transport Regulations as the design development progresses. This should include the full range of impact and thermal testing requirements beyond those previously identified as bounding, including secondary impact effects as well as combined impact and thermal scenarios. The complete range of IAEA requirements should be covered, including, amongst others, those relating to stacking, tie-down, vibration and acceleration and water retention considerations. Further design iterations should assess the relationship between wall thickness, stiffness, impact limiter design and overall impact performance. It is also recommended that the effects of bolt pre-loading be assessed, and a bolt sizing study conducted during further development work. Additionally, these further analyses will require validating through physical modelling and testing. **Further operability and handling assessment** Additional features, such as feet and lifting point would require further consideration and incorporation into the design during further development. It is noted that these could have an impact on the mechanical and thermal analyses and therefore this would involve an iterative design process. Further study would also be required to confirm the capability of cranes and other systems for handling the LWTC at the GDF. The end loading LWTC variant would further development to validate the additional process and equipment requirements associated with the removal and replacement of lid and contents by remote or automated techniques, and a system would be required to enable the restraint blocks to be removed and replaced reliably. A TRAM assessment should be conducted for both LWTC variants over the whole disposability cycle, as well as a further consequence assessment for dropped loads. **Further rail transport feasibility assessment** In addition to the additional operability and handling assessments, as the LWTC design development progresses, further study into the feasibility of rail transport should be conducted. This should include further assessment into possible rail gauge infringements for the top loading variant as well a more detailed consideration of the fatigue life for the rail wagon bed **Further manufacturability assessment** Further manufacturability assessment will be required as the LWTC concept progresses and more specific design details are confirmed. These details will allow for a more accurate prediction to be made on the post casting costs for the LWTC. This assessment should also consider the capability of the supply chain to manufacture the LWTC concept further, noting possible limitations imposed by the available foundries. Additionally, further considerations should be made with regards to the lid bolt material selection, as well as casting methods from a welding requirement perspective.
Conceptual Design Stage Gate Review		

6 Conclusions

This report has summarised the LWTC's development path, as well as the analyses performed to substantiate both LWTC variants to date, allowing RWM to conduct a high-level review on the current LWTC conceptual design. Analysis of the key load cases and initial manufacturability assessment confirm that the LWTC is considered broadly feasible, however certain further analytical demonstrations are required, as follows:

- The latest end loading LWTC variant requires additional analyses under the 9 m drop ACT impact scenario following further development of the impact limiters, ensuring that all analyses run to completion. Specifically, the impact limiter material should be revisited and undergo further testing to ensure proper functionality so as to effectively absorb the kinetic energy on impact. This further analysis should indicate that there are no predicted material failures in the lid bolts or body, and lid gaps fall within the limits for ensuring containment.
- The latest top loading LWTC variant requires further analysis under ACT thermal scenarios to ensure that lid seal temperatures do not exceed limits which could results in material degradation, and that lid gaps from thermal expansion fall within the limits for ensuring containment.

A Forward Action Plan has been developed which captures these analyses, as well as the further actions and considerations which are recommended to progress the LWTC to a complete conceptual design. These further design development considerations include:

- Updating the User and System requirements, as required.
- Establishing an ITEAP and VVRM to support and manage further design development stages.
- Undertaking an iterative design process which includes:
  - Further analysis under the full set of ACT and NCT scenarios as outlined in the IAEA Transport Regulations; and
  - Further operability and handling considerations, including incorporation of additional lifting and handling features as well as further study of associated process and equipment requirements.
- Undertaking a further manufacturability assessment as the design develops, addressing supply chain capability, bolt material selection and casting methods.

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Appendix A - URD and SRD

The following tables present the full set of user requirements and system requirements contained within the URD [13] and SRD [14]. Following an independent peer review, further considerations have been identified and these are presented in italics/square brackets within the Justification column. These should be addressed if the URD/SRD are to be revisited, as per the recommended Forward Action Plan.

User Requirements within the URD

URID	User Requirement	Measure of Effectiveness	Justification	Validation/ Verification	Prioritisation
1	The Office for Nuclear Regulation requires a capability that complies with the Regulations for the Safe Transport of Radioactive Material. Specific Safety Requirements No. SSR-6.	THRESHOLD Type B(M)F approval OBJECTIVE Type B(U)F approval	This is a key requirement of the asset to enable the movement of ILW without the need to resort to 'Special Arrangements' THRESHOLD Compliance with relevant legislation. The UK regulations invoke European modal agreements which are based upon the IAEA Transport Regulations. The waste is anticipated to require Type B approval owing to its activity content and fissile approval owing to its fissile nuclide content. The IAEA Transport Regulations specify conditions for Type B(M)F or Multilateral approval (approval of the country of design and of each country of use). Since the capability is for exclusive UK use, the capability may use Type B(M) approval. This would permit certain allowances from the standard provisions of the regulations, such as application of the operating temperature range using UK data of temperature extremes. OBJECTIVE The IAEA Transport Regulations require that the requirements for Type B(U)F packages are met as far as practicable	DRA, DSR, ACM, CoA LoC, QAC, SAT	M
2	The Capability is required to be compliant with all relevant legislation.	THRESHOLD Demonstration of compliance with all relevant legislative requirements. (LOLER, PUWER, CDG, CE Health and Safety at Work Act etc) OBJECTIVE None	The Demonstration that the Capability meets all relevant essential health and safety requirements for a new product design.	DRA, DSR, FAT, LoC, QAC	M

URID	User Requirement	Measure of Effectiveness	Justification	Validation/ Verification	Prioritisation
3	The Capability shall enable the transport of Category III material.	THRESHOLD Demonstrable compliance with the transport regulations with respect to the movement of Category III material. OBJECTIVE None	This requirement is implicit in the need to transport ILW. *[Note: Consideration should be given to UR3 being a system requirement rather than a user requirement]*	CoA, DRA, DSR, LoC	M
4	RWM requires that design features of the Capability shall not adversely affect the performance of the unshielded waste packages to be transported.	THRESHOLD Materials used in the construction of the Capability are compatible with those of the unshielded waste packages. The design avoids the potential to cause physical damage to the unshielded waste package under routine and normal conditions of transport. OBJECTIVE None	Some materials (e.g. stainless steels) may be contaminated when abraded by contact materials (e.g. carbon steel). This may lead to unwanted corrosion mechanisms and lead to failure.	CoA, DRA, DSR, FAT, LoC	KUR
5	RWM requires that the Capability shall be reusable.	THRESHOLD Operational life of 20 years (for each Capability unit) OBJECTIVE Operational life of 30 years (for each Capability unit)	Waste producers need to transport units over approximately 70 years. Therefore, the Capability shall need to be reused a significant number of times.	DRA, DSR, CoA, FAT	KUR
6	RWM require that the lid and contents of the Capability can be removed and replaced using remote/ automated techniques.	THRESHOLD To reduce operator dose uptake to ALARP. OBJECTIVE None	The operations to unload the Capability shall be demonstrably ALARP.	CAL, CoA, DRA, DSR, SGA.	KUR

URID	User Requirement	Measure of Effectiveness	Justification	Validation/ Verification	Prioritisation
7	Consignors require that the lid and contents of the Capability can be loaded and replaced using remote/automated techniques.	THRESHOLD To reduce operator dose uptake to ALARP. OBJECTIVE None	The operations to unload the Capability shall be demonstrably ALARP.	CAL, CoA, DRA, DSR, SGA.	KUR
8	The Capability shall enable the transport of the UK ILW radioactive waste inventory.	THRESHOLD The Capability can enable the transport 50% of all ILW. OBJECTIVE The Capability can enable the transport of all ILW with no exceptions.	To provide an adaptable Capability that can be configured to transport a range of waste packages. The larger capacity of this Capability has the potential to reduce the need for size reduction of waste.	CoA, DRA, DSR, LoC	KUR
9	RWM requires a Capability that is compatible with the UK Rail Network.	THRESHOLD Compatible with Route Availability 10 and W6A rail gauge. OBJECTIVE Compatible with Route Availability 8 and W6A rail gauge.	The NDA transport strategy is for use of rail in preference to road where practicable. It is anticipated that the Capability shall primarily arrive at a GDF using rail transport. Some waste storage/arising sites may not have on site availability of a railhead and therefore some road transport will be necessary. Transport may involve sea or inland waterway transport in addition to road or rail transport, but the physical constraints for sea or inland waterway are anticipated to be bounded by those for road or rail transport.	DRA, DSR, ICM, LoC	KUR
10	The SLC's require the Capability to transport ILW packages, in the public domain, to a GDF or Intermediate storage site.	THRESHOLD Large Waste Container (LWC) OBJECTIVE Single or multiple disposal units of: i. Four 500 litre Drums in a disposal stillage. ii. 500 litre Robust Shielded Drum in a Stillage iii. 3 cubic metre Box (Side or corner lifting) iv. 3 cubic metre Drum v. Miscellaneous Beta Gamma Waste Store box	THRESHOLD The principle purpose of the Capability is to transport the LWC. OBJECTIVE The Capability may also be used to transport other ILW in the UK radioactive waste inventory that require a Type B or Fissile transport. These waste packages could be transported as single disposal units or multiples.	CoA, DRA, DSR, ICM, LoC, QAC, SAT	KUR

URID	User Requirement	Measure of Effectiveness	Justification	Validation/ Verification	Prioritisation
11	The SLC's require the Capability to transport HAW to a GDF by different transport modes.	THRESHOLD Compatibility with UK road and rail transport regulations. OBJECTIVE Compatibility with UK road, rail and sea transport regulations.	In order to facilitate transport in the public domain, the Capability must adhere to specific modal regulations. The NDA transport strategy states that rail should be used over road wherever practicable. However, some sites do not have direct access to a railhead so limited road transport (to a rail head) may be necessary in some cases.	CoA, DRA, DSR, ICM, LoC, QAC	KUR
12	RWM requires that the maximum gross mass of the Capability is compatible with GDF handling systems.	THRESHOLD Gross mass of up to 120 tonnes. OBJECTIVE Gross mass of up to 65 tonnes.	The gross mass of the Capability must allow it to enter the GDF via the drift. The gross mass of the Capability must allow it to enter the GDF via the vertical shaft.	DRA, DSR, ICM, LoC, QAC	1
13	RWM requires that the external dimensions of the Capability are compatible with GDF handling systems.	THRESHOLD Up to W6a rail gauge for width and height and 7000mm in length. OBJECTIVE Up to 6058mm length, 2438mm wide and 2591mm high.	The external dimensions of the Capability must allow it to enter the GDF via the drift. The external dimensions of the Capability must allow it to enter the GDF via the vertical shaft. Within the dimensional constraints the Capability will need to provide adequate packaging of the waste package.	DRA, DSR, ICM, LoC, QAC	1
14	The Capability shall be compliant with all relevant industry codes of practice/ standards.	THRESHOLD Demonstration of compliance with all relevant codes of practice. OBJECTIVE None	Ensures that the application of good engineering practice and Learning From Experience from the industries' major stakeholders is visible to the applicable Competent Authorities.	DRA, DSR, FAT, LoC, QAC	1
15	RWM requires a Capability that can deliver LWC packages to the GDF in line with assumed GDF throughput rates.	THRESHOLD Transport of 300 LWC units per year. OBJECTIVE Transport of 750 LWC units per year.	The number of LWC moves to a GDF and rate of arrival are not known. It is therefore assumed that LWC's would fill approximately one waste vault in the Higher Strength Rock illustrative disposal facility design, this being 5% of the total number of UILW vaults. This would comprise approximately 3000 LWC containers. It is assumed that a vault would be filled during a period of 4 to 10 years. This gives rise to the threshold throughput rate of 300 per year and objective of 750 per year.	CoA, DRA, DSR, FAT, ICM, LoC	1

URID	User Requirement	Measure of Effectiveness	Justification	Validation/ Verification	Prioritisation
16	The Capability shall be designed making use of materials that ensure compliance with IAEA regulations.	THRESHOLD Materials used meet the requirements of a B(M)F Package OBJECTIVE Materials used meet the requirements of a B(U)F Package.	Ensures that compliance with the transport regulations is justifiable. The regulations prescribe ambient temperature conditions for package designs. This can have a major deleterious effect on the performance of the materials of construction both at elevated temperatures in a fire accident (reduction in tensile properties) and impact performance in sub-zero temperatures (ductile/ brittle transition). *[Note: Consideration should be given to remove this UR as it is implicit within UR1 and UR2]*	CoA, DRA, DSR, LoC, QAC	KUR M
17	SLC's require that the Capability has the ability to be monitored for contamination.	THRESHOLD Materials of construction, surface treatments and geometry of the Capability enable access for monitoring operations. OBJECTIVE None	Enables the Capability to be consigned for transport in the public domain. Reduces the degree of difficulty in swabbing surfaces and decreases the time for completing the operation. Supports efficient plant throughput.	ACM, CoA, DRA, DSR, ICM, LoC, QAC,SAT	KUR
18	The Capability shall be able to secure transport approval for the movement of ILW.	THRESHOLD The Capability can be approved by a competent body for the transport of ILW in the public domain. OBJECTIVE None	This is a key requirement of the asset to enable the movement of ILW without the need to resort to 'Special Arrangements' *[Note: Consideration should be given to remove this UR as it is implicit within UR1, UR2, UR3 and UR10]*	CoA, DRA, DSR, LoC	KUR
19	SLC's require that the Capability has the ability to be easily decontaminated.	THRESHOLD Applicable Industry Codes of Practice for surface finish of transport containers have been complied with. OBJECTIVE None	In order to comply with the relevant transport regulations, the non-fixed surface contamination on external surfaces of a transport container shall be kept within prescribed limits. Additionally, to allow consignment as an empty container, the non-fixed contamination on internal surface of a transport container shall also be kept within prescribed limits. Repeated use in transporting ILW packages these limits could be exceeded without regular and effective decontamination. Supports the need to prevent the spread of contamination across multiple sites.	ACM, CoA, DRA, DSR, ICM, LoC, QAC, SAT	1

URID	User Requirement	Measure of Effectiveness	Justification	Validation/ Verification	Prioritisation
20	The Capability shall be decommissionable.	THRESHOLD The System shall be demonstrated to allow effective/efficient decommissioning. OBJECTIVE None	Design Lessons Drawn from the Decommissioning of Nuclear Facilities. The System shall be designed to enable cost effective decommissioning of the asset at the end of its operational life.	DRA, QAC	2

System Requirements within the SRD
External dimensions

SRID	System Requirement	Remark	Justification	Measure of Performance	Verification Codes	UR IDs
1.1	The System shall be suitably sized so that it can be accommodated by the GDF vertical shaft.	The external dimensions of the System must allow it to enter the GDF via the vertical shaft. Note: It is probable that for waste producers, the Systems dimensions will be a constraint on future despatch plant design rather than the reverse. It is likely that the external dimensions and mass of the system will be constrained by the requirements for rail transport.	The GDF Design Enhancement Study (Qualter Hall Report) gives an intended size of shaft of between 8 and 12m diameter and up to 1000m depth. Generic Disposal Facility Design.	THRESHOLD The System shall be demonstrated as compatible with a 9m vertical shaft with a cage floor dimension of 7.3m x 3m. OBJECTIVE None	CoA, DRA, DSR, FAT	UR-2 UR-5 UR-8 UR-10 UR-13 UR-15
1.2	The System shall have a mass that can be accommodated by the GDF vertical shaft.	The mass of the System must allow it to enter the GDF via the vertical shaft. Note: It is probable that for waste producers, the Systems dimensions will be a constraint on future despatch plant design rather than the reverse. It is likely that the external dimensions and mass of the system will be constrained by the requirements for rail transport.	The GDF Design Enhancement Study (Qualter Hall Report) indicates a WLL of approximately 110 Tonnes. Generic Disposal Facility Design.	THRESHOLD The System shall be demonstrated as compatible with a cage WLL of 120 tonnes. OBJECTIVE The System shall be demonstrated as compatible with a cage WLL of 65 tonnes.	CoA, DRA, DSR, FAT	UR-2 UR-5 UR-8 UR-10 UR-12 UR-15
1.3	The System shall be suitably sized so that it can be accommodated by the GDF drift.	The external dimensions of the System must allow it to enter the GDF via the drift.	Lloyds Register Report on rail wagon for carrying the LWTC. Generic Disposal Facility Design. Note: A variant would need to be produced that can work with a rack and pinion	THRESHOLD The loaded System on a wagon shall not exceed the W6a rail gauge. OBJECTIVE None	CoA, DRA, DSR, FAT	UR-2 UR-5 UR-8 UR-10 UR-13 UR-15

SRID	System Requirement	Remark	Justification	Measure of Performance	Verification Codes	UR IDs
1.4	The System shall have a mass that can be accommodated by the GDF drift.	The mass of this System must allow it to enter the GDF via the drift.	Lloyds Register Report on rail wagon for carrying the LWTC. Generic Disposal Facility Design.	THRESHOLD The loaded System shall not exceed the W6a rail gauge (120 tonnes) OBJECTIVE 65 tonnes	CoA, DRA, DSR, FAT	UR-2 UR-5 UR-8 UR-10 UR-12 UR-15
1.5	The System shall be transportable by road.	The external dimensions of the System are to be bounded by the maximum external dimensions when transported by road. Note: The external dimensions of this package must allow it to travel to the GDF via a route that may involve sea transport. However, at this issue of the document it is not possible to define the limits of this requirement but are expected to be bounded by the constraints for road/rail.	Not every waste producing site is near a rail head for rail transport to the GDF. It will therefore be necessary for packages to travel by road to the nearest rail head. This will impose mass and dimensional constraints on the design.	THRESHOLD Road Vehicles (Authorisation of Special Types) (General Order) STGO Cat 3. OBJECTIVE Road Vehicles (Authorisation of Special Types) (General Order) STGO Cat 1.	CoA, DRA, DSR, FAT	UR-2 UR-5 UR-8 UR-10 UR-11 UR-12 UR-13 UR-15
1.6	The System shall be transportable by rail.	The external dimensions of the System shall allow it to travel to the GDF via rail network Note: The external dimensions of this package must allow it to travel to the GDF via a route that may involve sea transport. However, at this issue of the document it is not possible to define the limits of this requirement but are expected to be bounded by the constraints for road/rail.	The primary intended transport route to the GDF is via the rail network. Lloyds Register Report on rail wagon for carrying the LWTC. Generic Disposal Facility Design.	THRESHOLD The package shall not exceed the W6a rail gauge and RA10 (8 axle Wagon). OBJECTIVE None	CoA, DRA, DSR, FAT	UR-2 UR-5 UR-8 UR-9 UR-10 UR-11 UR-12 UR-13 UR-15

Design for Handling

SRID	System Requirement	Remark	Justification	Measure of Performance	Verification Codes	UR IDs
2.1	The System shall be reusable	The System shall be capable of multiple reuses over an extended operational life	Waste producers require to transport disposal units over approximately 70 years. Therefore, individual System units shall need to be reused a significant number of times.	THRESHOLD Each System unit shall be reusable over an operational life of 20 years with appropriate ongoing maintenance. OBJECTIVE Each System unit shall be reusable over an operational life of 30 years with appropriate ongoing maintenance.	CoA, DRA, DSR, FAT	UR-2 UR-3 UR-4 UR-5 UR-6 UR-7 UR-8 UR-10 UR-11 UR-12 UR-13 UR-15 UR-17
2.2	Design features of the System shall not adversely affect the performance of the unshielded waste packages to be transported	The materials of construction of the System shall be compatible with those of the unshielded waste container so as not to compromise the waste container design justification.	Some materials (e.g. stainless steels) may be contaminated when abraded by contact materials (e.g. carbon steel). This may lead to unwanted corrosion mechanisms and lead to failure.	THRESHOLD Materials used in the construction of the System are shown to be compatible with those of the unshielded waste packages. The design of the System avoids the potential to cause physical damage to the unshielded waste package under routine and normal conditions of transport. The following materials shall be considered as appropriate; -304L -316L -Lean Duplex OBJECTIVE None	CoA, DRA, DSR, FAT	UR-3 UR-4 UR-5

SRID	System Requirement	Remark	Justification	Measure of Performance	Verification Codes	UR IDs
2.3	The System shall have the capability of delivering packages to the GDF in line with assumed GDF throughput rates.	The System design shall be as simple as possible and easily integrated with semi-automatic plant handling systems	All GDF subsystems shall be designed to achieve the required throughput rates so that no one subsystem becomes a bottleneck. The number of LWC moves to a GDF and rate of arrival are not known. It is therefore assumed that LWC's would fill approximately one waste vault in the Higher Strength Rock illustrative disposal facility design, this being 5% of the total number of UILW vaults. This would comprise approximately 3000 LWC containers. It is assumed that a vault would be filled during a period of 4 to 10 years. This gives rise to the threshold throughput rate of 300 per year and objective of 750 per year.	THRESHOLD The transport of 300 LWC units from storage sites to the GDF per year. OBJECTIVE The transport of 750 LWC units from storage sites to the GDF per year	DRA, FAT, LoC, SAT	UR-5 UR-6 UR-7 UR-8 UR-9 UR-10 UR-11 UR-12 UR-13 UR-15
2.4	The System is required to transport various types of ILW packages, in the public domain, to a GDF or Intermediate storage site.	The requirement is to provide maximum flexibility in the application of the System. However, the principle purpose of the System is to transport the LWC.	The wastes and packages required to be transported to a GDF are those that will require a Type B transport	THRESHOLD The System is capable of transporting the LWC. OBJECTIVE The System is capable of transporting single or multiple disposal units of: i. Four 500 litre Drums in a disposal stillage. ii. 500 litre Robust Shielded Drum in a Stillage iii. 3 cubic metre Box (Side or corner lifting) iv. 3 cubic metre Drum v. Miscellaneous Beta Gamma Waste Store box	CoA, DRA, DSR, ICM, LoC, QAC, SAT	UR-3 UR-4 UR-5 UR-8 UR-10 UR-11 UR-12 UR-13 UR-15

SRID	System Requirement	Remark	Justification	Measure of Performance	Verification Codes	UR IDs
2.5	The System shall enable safe handling within a GDF.	The System shall incorporate handling features to enable lifting under a load equivalent to twice the maximum specified gross mass, over two lifting points without any effect that would render it non-compliant with regulations when containing its maximum heat load. Note: It is assumed that this will bound the requirements of waste producing plants and those of Intermodal transfer locations An example of Intermodal Transfer may be; Road to rail. Rail to road. Road/rail to marine vessel. Marine vessel to road/rail	The System shall incorporate lifting features that enable it to be lifted with a load equal to twice the weight of the System.	THRESHOLD Static Loading - No permanent deformation when lifted at twice the gross mass at two diagonally opposite lifting points. Compliance with BS 2573. Dynamic Loading – Infinite Life shown against a recognised methodology OBJECTIVE Dynamic Loading - Less than infinite life is justifiable when combined with a schedule of inspections.	DRA, DSR, LoC, CAL, FAT, SAT	UR-2 UR-5 UR-10 UR-12 UR-13 UR-13 UR-15
2.6	The System shall enable the lid and contents to be removed and replaced using remote/automated techniques at the GDF.	The ability to handle the System remotely will assist in the reduction of GDF operator dose uptake.	The operations to unload the System need to be demonstrably ALARP.	THRESHOLD The System demonstrably supports an ALARP GDF plant safety case. OBJECTIVE None	DRA, DSR, LoC, CAL, FAT, SAT	UR-2 UR-3 UR-5 UR-6 UR-7 UR-15

SRID	System Requirement	Remark	Justification	Measure of Performance	Verification Codes	UR IDs
2.7	The System shall enable the lid and contents to be removed and replaced using remote/automated techniques at the Consignor's site.	The ability to handle the System remotely will assist in the reduction of Consignor operator dose uptake.	The operations to unload the System shall be demonstrably ALARP.	THRESHOLD The System demonstrably supports an ALARP Consignor plant safety case. OBJECTIVE None	DRA, DSR, LoC, CAL, FAT, SAT	UR-2 UR-3 UR-5 UR-6 UR-7 UR-15
2.8	The System gross mass shall be compatible with the mass limits of the GDF lifting equipment.	The maximum GLW of the System shall not exceed the lifting capacity of the GDF.	The System shall be compatible with the load capacity of the GDF.	THRESHOLD Demonstrable compliance with the lifting capacity limit of 120 tonnes. OBJECTIVE Demonstrable compliance with the lifting capacity limit of 65 tonnes.	DRA, DSR, CAL, FAT	UR-2 UR-5 UR-8 UR-10 UR-12 UR-15
2.9	The System shall be compatible with the lifting (overhead crane) equipment geometry of the GDF.	The System shall be compatible with the standardised lifting equipment of the GDF. Note: Compatibility with GDF handling equipment is assumed sufficient as waste producing sites and trans-shipment sites will need to integrate equivalent capability at their site. It is probable that for some waste producers, the Systems dimensions will be a constraint on future despatch plant design rather than the reverse.	The System is required to be unloaded in the GDF. To meet the requirements of LOLER.	THRESHOLD Demonstration of compliance with GDF specific handling geometry requirements. OBJECTIVE None	DRA, DSR, CAL, FAT, SAT	UR-2 UR-5 UR-8 UR-10 UR-13 UR-15

SRID	System Requirement	Remark	Justification	Measure of Performance	Verification Codes	UR IDs
2.10	The System shall enable safe handling by way of its handling features for the operational life of the package	The System has the potential to require an extended operational life whilst materials are transferred to the GDF for final disposal. This will require individual components that may deteriorate (e.g. wear/corrosion) during use, such as lifting trunnions, to be easily and routinely replaceable under an approved maintenance scheme. Consideration shall be given to installing thread inserts (e.g. Helicoils) from new in order to aid potential future repair work.	Due to the extended timescales involved in the transfer of unshielded waste to the GDF for final disposal, the requirement will be to design a System that has an operational life consistent with the transfer programme for LWC. Handling features shall incorporate corrosion/wear allowance or demonstrable resistance for the operational period. Continued compliance with the regulations and the Package Design Safety Report for the System.	THRESHOLD The integrity/safety of the System shall be maintainable for a period of 20 years following manufacture of the System. OBJECTIVE The integrity/safety of the System shall be maintainable for a period of 30 years following manufacture of the System.	DRA, DSR, CAL, CoA, FAT	UR-2 UR-5 UR-6 UR-7 UR-10 UR-12 UR-13 UR-15
2.11	The System shall provide for safe venting of the transport Package cavity.	A controlled means is required to ensure it is safe to remove the lid for unloading without inadvertently releasing radioactive contents.	Conformance to site specific containment requirements as part of the Site Safety Case justification. IRR and EPA requirements to avoid the release of radioactivity.	THRESHOLD The System allows controlled access and sampling of the ullage before the lid is removed for unloading. Compliance with the requirements of the Specific Site Safety Case and can be justified by a combination of physical/functional testing. OBJECTIVE None	DRA, DSR, CAL, CoA, FAT, SAT	UR-1 UR-2 UR-3 UR-4 UR-5 UR-6 UR-7 UR-8 UR-15

SRID	System Requirement	Remark	Justification	Measure of Performance	Verification Codes	UR IDs
2.12	The System shall provide for safe inerting of the System (Transport Package) cavity.	A controlled means is required to ensure that the Systems package cavity can be safely and effectively inerted. It is plausible that a number of LWC could produce hydrogen or methane. This hazard would be controlled by inerting the cavity.	To control and manage the hazards associated with hydrogen and methane gas in confined spaces.	THRESHOLD The System allows controlled access for the purposes of inerting the package cavity. Compliance with the requirements of the Specific Site Safety Case and can be justified by a combination of physical/functional testing. OBJECTIVE None	DRA, DSR, CAL, CoA, FAT, SAT	UR-2 UR-3 UR-4 UR-5 UR-6 UR-7 UR-8 UR-15
2.13	The System shall be durable and maintainable throughout its design life.	The System has the potential to require an extended operational life whilst materials are transferred to the GDF. Features of the System that deteriorate during operational use, need to be easily and routinely replaceable. These may be; Elastomer seals. Paint finishes. Threaded components.	Continued compliance with the regulations and the Package Design Safety Report. To enable maintenance of the System in order to meet functional and regulatory requirements.	THRESHOLD The integrity/safety/functionality of the System shall be maintainable for a period of 20 years following manufacture of the System. OBJECTIVE The integrity/safety/functionality of the System shall be maintainable for a period of 30 years following manufacture of the System.	DRA, DSR, CAL, CoA, FAT, QAC	UR-4 UR-5 UR-6 UR-17

SRID	System Requirement	Remark	Justification	Measure of Performance	Verification Codes	UR IDs
2.14	The System shall be designed to comply with all the Impact test requirements of the GDF Site Safety Case.	In addition to transport regulatory requirements the Site Safety Cases for the operational sites may require different or enhanced drop scenarios to be considered. It may be that the transport regulations bound these requirements, but it cannot be assumed. Note: It is assumed that this requirement bound those that may be required by waste producing sites	Conformance with GDF site specific dropped load requirements as part of the Site Safety Case justification.	THRESHOLD Meets all the requirements for dropped or unsafe release load for the GDF Site Safety Case. OBJECTIVE Continue to meet the requirements of a Type B package.	DRA, DSR, CAL, CoA, FEA, IMT	UR-1 UR-2 UR-3
2.15	The System shall be designed for decommissioning.	The System shall be designed to enable cost effective decommissioning of the asset at the end of its operational life. The use of materials that are easily reusable or recyclable shall be considered in the design. Avoid materials that can be activated or are toxic e.g. lead.	NDA policy is for all new assets to be designed with ultimate decommissioning in mind. Design Lessons Drawn from the Decommissioning of Nuclear Facilities.	THRESHOLD The System shall be demonstrated to allow effective/efficient decommissioning. OBJECTIVE None	DRA, QAC	UR-17 UR-19 UR-20
2.16	The System shall comply with the requirements of the Lifting Operations and Lifting Equipment Regulations (LOLER)	The System shall be designed to recognised industry codes and standards. The design is supported by adequate designer risk assessments	Compliance with UK legislation is mandatory.	THRESHOLD The System shall be demonstrated comply with the requirements of LOLER. OBJECTIVE None	CAL, DRA, DSR, FAT, ICM, QAC, SAT	UR-2 UR-5 UR-12 UR-14
2.17	The System shall comply with the requirements of the Provision and Use of Work Equipment Regulations (PUWER)	The System shall be designed to recognised industry codes and standards. The design is supported by adequate designer risk assessments	Compliance with UK legislation is mandatory.	THRESHOLD The System shall be demonstrated comply with the requirements of PUWER. OBJECTIVE None	CAL, DRA, DSR, FAT, ICM, QAC, SAT	UR-2 UR-5 UR-14

Regulatory Requirement (transport)

SRID	System Requirement	Remark	Justification	Measure of Performance	Verification Codes	UR IDs
3.1	The System shall enable the transport of Category III material.		This requirement is implicit in the need to transport ILW.	THRESHOLD Demonstrable compliance with the transport regulations with respect to the movement of Category III material. OBJECTIVE None	DRA, DSR, CoA, LoC	UR-1 UR-2 UR-3 UR-4 UR-8 UR-9 UR-10 UR-11 UR-16 UR-18
3.2	The System shall enable the transport of the UK ILW radioactive waste inventory.	To provide an adaptable System that can be configured to transport a range of waste packages and has the potential to reduce the number of transport movements	The larger capacity of this System has the potential to reduce the need for the size reduction of waste	THRESHOLD The Capability can enable the transport of 50% of all ILW. OBJECTIVE The Capability can enable the transport of all ILW with no exceptions.	DRA, DSR, CoA, LoC	UR-1 UR-2 UR-3 UR-4 UR-8 UR-9 UR-10 UR-11 UR-16 UR-18
3.3	The System shall be capable of withstanding the prescribed accelerations during transport to ensure retention of contents.	The System should be designed for retention of contents under the accelerations arising from normal conditions of transport. Consideration of movement of contents in respect of containment in Routine Conditions of Transport and Normal Conditions of Transport and in terms of the effects on external radiation levels.	IAEA Regulations for the Safe Transport of Radioactive material SSR-6. Advisory material for the IAEA regulations for the safe transport of radioactive material – safety guide no SSG-26. TCSC 1006 December 2012 - Code of practice – The Securing/Retention of Radioactive Material Packages on Conveyances.	THRESHOLD Capable of withstanding the Acceleration factors presented within Table IV-1, page 358 of SSG-26. OBJECTIVE Capable of withstanding the Acceleration factors presented within Table 2, page 7 of TSCS 1006.	DRA, DSR, CoA, CAL, FAT	UR-1 UR-2 UR-9 UR-11 UR-14 UR-16

SRID	System Requirement	Remark	Justification	Measure of Performance	Verification Codes	UR IDs
3.4	The System shall be capable of withstanding accelerations imposed during transport to ensure package retention on the conveyance.	The System should be designed for retention of the package under the accelerations arising from normal and routine conditions of transport.	IAEA Regulations for the Safe Transport of Radioactive material SSR-6. Advisory material for the IAEA regulations for the safe transport of radioactive material – safety guide no SSG-26. TCSC 1006 December 2012 - Code of practice – The Securing/Retention of Radioactive Material Packages on Conveyances.	THRESHOLD Capable of withstanding the Acceleration factors presented within Table IV-1, page 358 of SSG-26. OBJECTIVE Capable of withstanding the Acceleration factors presented within Table 2, page 7 of TSCS 1006.	DRA, DSR, CoA, CAL, FAT	UR-1 UR-2 UR-9 UR-11 UR-14 UR-16
3.5	The System shall be capable of being stacked safely (in any possible orientation) whilst loaded to the maximum mass.	The System shall be capable of withstanding stacking loads equivalent to 5 times the maximum weight of the package without contribution from the contents.	IAEA Regulations for the Safe Transport of Radioactive material SSR-6, Para 723. Advisory material for the IAEA regulations for the safe transport of radioactive material – safety guide no SSG-26.	THRESHOLD Justification by calculation or demonstration that the System can support stacking loads. Stacking performance shall be justifiable for the entire design life of the System. OBJECTIVE None	DRA, DSR, CAL, CoA, FAT	UR-1 UR-2 UR-16
3.6	The System shall be uniquely identifiable throughout its operational life.	The System will require to be traceable to its Lifetime Quality Records (LTQR) and the applicable Package Design Safety Report. The application of a unique identification enables the identification and tracking of every System throughout the different stages of its long term operational and maintenance management.	IAEA Regulations for the Safe Transport of Radioactive material SSR-6, Para 501. Advisory material for the IAEA regulations for the safe transport of radioactive material – safety guide no SSG-26.	THRESHOLD Marking is compliant with the requirements of the regulations. LTQR demonstrably traceable to the System asset. Operational and Maintenance records traceable to the System asset and support the PDSR. OBJECTIVE None	DRA, DSR, CoA, LoC, FAT	UR-1 UR-2 UR-16

SRID	System Requirement	Remark	Justification	Measure of Performance	Verification Codes	UR IDs
3.7	The System shall ensure containment of the unshielded waste form in the public domain.	Requirement to ensure containment of the waste form to meet regulatory leakage rate criteria in both normal and accident conditions of transport.	IAEA Regulations for the Safe Transport of Radioactive material SSR-6, Para 659.	THRESHOLD The containment capability of the System is compliant with the requirements of the regulations in both NCT and ACT and can be justified by a combination of physical testing and calculation. OBJECTIVE None	DRA, DSR, CAL, CoA, FAT, FEA(i), FEA(t), IMT, SAT	UR-1 UR-2 UR-3 UR-4 UR-16
3.8	The System shall provide containment in NCT with an MNOP of 7 bar (gauge).	There is a regulatory requirement to limit the maximum pressure that can potentially develop within the System in a period of one year under specified conditions.	IAEA Regulations for the Safe Transport of Radioactive material SSR-6, Para 229. Advisory material for the IAEA regulations for the safe transport of radioactive material – safety guide no SSG-26.	THRESHOLD The System can be demonstrated to comply with the regulations. The System can maintain containment at its derived MNOP which may be less than 7 bar (gauge). OBJECTIVE None	DRA, DSR, CAL, CoA, FAT	UR-1 UR-2 UR-3 UR-16
3.9	The System shall be designed using materials that meet the regulatory temperature range.	There is a requirement that the safety of the transport package can be shown to comply with regulations through a specified temperature range including those experienced during NCT and ACT. This can have a major deleterious effect on the performance of the materials of construction both at elevated temperatures in a fire accident (reduction in tensile properties) and impact performance in sub-zero temperatures (ductile/ brittle transition).	IAEA Regulations for the Safe Transport of Radioactive material SSR-6, Para 666 and 667. Advisory material for the IAEA regulations for the safe transport of radioactive material – safety guide no SSG-26.	THRESHOLD Compliance with Type B(M) Requirements -10 to + 38 Deg. C plus insolation. OBJECTIVE Compliance with Type B(U) Requirements. -40 to + 38 Deg. C plus insolation.	DRA, DSR, CAL, CoA, FAT, FEA(t), FEA(i), TLT	UR-1 UR-2 UR-16

SRID	System Requirement	Remark	Justification	Measure of Performance	Verification Codes	UR IDs
3.10	The system shall be designed to comply with all the Impact test requirements of the transport regulations.	There are prescribed requirements for the impact performance of transport packages. This covers routine, normal and accident conditions of transport.	IAEA Regulations for the Safe Transport of Radioactive material SSR-6, Para 712 to and 737 incl. as applicable Advisory material for the IAEA regulations for the safe transport of radioactive material – safety guide no SSG-26.	THRESHOLD Meets the requirements of a Type B(M) package. OBJECTIVE Meets the requirements of a Type B(U) package.	DRA, DSR, CAL, CoA, FAT, FEA(i), IMT	UR-1 UR-2 UR-16
3.11	The system shall be designed to comply with all the thermal test requirements of the transport regulations	There is a requirement to demonstrate that the transport package remains compliant with the regulations in the event of a fire accident. This may be done by various methods; a) Fully validated and verified FEA. b) Physical testing of a full size model. c) A combination of a) and b) above.	IAEA Regulations for the Safe Transport of Radioactive material SSR-6, Para 728. Advisory material for the IAEA regulations for the safe transport of radioactive material – safety guide no SSG-26.	THRESHOLD Meets the requirements of a Type B(M) package. OBJECTIVE Meets the requirements of a Type B(U) package.	DRA, DSR, CAL, CoA, FEA(t), TLT	UR-1 UR-2 UR-16
3.12	The System shall manage / dissipate the heat generated by the waste form within the limits of the System to ensure maintenance of external geometry and avoidance of unacceptable thermal stresses.	There is a requirement to demonstrate that the transport package remains compliant with the regulations in transient conditions up to and including thermal equilibrium during routine and normal conditions of transport.	IAEA Regulations for the Safe Transport of Radioactive material SSR- 6. Advisory material for the IAEA regulations for the safe transport of radioactive material – safety guide no SSG-26.	THRESHOLD Meets the requirements of a Type B(M) package. OBJECTIVE Meets the requirements of a Type B(U) package.	DRA, DSR, CAL, CoA, FEA(t), TLT	UR-1 UR-2 UR-3 UR-4 UR-16

SRID	System Requirement	Remark	Justification	Measure of Performance	Verification Codes	UR IDs
3.13	The System shall manage / dissipate the heat generated by the waste form within the limits of the Transport Container to ensure maintenance of impact performance under accident conditions.	There is a requirement to demonstrate that the transport package remains compliant with the regulations when subjected to a series of 'drop tests' whilst at the most disadvantageous temperature.	IAEA Regulations for the Safe Transport of Radioactive material SSR- 6 commencing Para 722. Advisory material for the IAEA regulations for the safe transport of radioactive material – safety guide no SSG-26.	THRESHOLD Meets the requirements of a Type B(M) package. OBJECTIVE Meets the requirements of a Type B(U) package.	DRA, DSR, CAL, CoA, FEA(i), FEA(t), TLT	UR-1 UR-2 UR-3 UR-4 UR-16
3.14	The System shall be designed to facilitate decontamination of surfaces.	To prevent the spread of contamination across different areas of operational sites and also across different operational sites. Prevent contamination in the public domain. Protection of workers.	IAEA Regulations for the Safe Transport of Radioactive material SSR- 6 commencing Para 610. Demonstrable compliance with industry best practice for surface decontamination (e.g. IAEA safety series 048 – manual upon decontamination of surfaces). TCSC 1080 provides guidance for appropriate surface treatments upon a range of substrate materials. TCSC 1088 provides specific guidance for surface finish of transport containers manufactured from stainless steel.	THRESHOLD Surfaces to be smooth, non-porous and free from defects to demonstrate excellent ease of decontamination. As far as practicable, the System shall be so designed and finished that the external surfaces are free from protruding features and can be easily decontaminated. The surface finish and design of waste containers must allow decontamination. OBJECTIVE None	DRA, DSR, CoA, FAT	UR-1 UR-2 UR-5 UR-14 UR-16 UR-17 UR-19
3.15	The System shall prevent an increase of more than 20% in the maximum radiation level test on any external surface.	This requirement applies to Normal Conditions of Transport and includes events that may cause the contents to move. The emphasis of the regulation is for the package design to ensure compliance. Compliance with this regulatory requirement may be challenging if the waste is not encapsulated.	IAEA Regulations for the Safe Transport of Radioactive material SSR- 6 Para 648 (b). Advisory material for the IAEA regulations for the safe transport of radioactive material – safety guide no SSG-26.	THRESHOLD Demonstrate that the design ensures compliance with the requirements of paragraph 648(b) of the regulations. OBJECTIVE Demonstrate significant margins against the requirements of the regulations.	DRA, DSR, CAL, CoA, FEA(i), IMT	UR-1 UR-2 UR-3 UR-16

SRID	System Requirement	Remark	Justification	Measure of Performance	Verification Codes	UR IDs
3.16	Radiation Levels during routine shall never exceed the requirements for transport	The System shall be so designed that it provides sufficient shielding to ensure that, under routine conditions of transport and with the maximum radioactive contents that the package is designed to contain, the radiation level at any point on the external surface of the package would not exceed the values specified in SSR-6 paras 516, 527 and 528, as applicable, with account taken of paras 566(b) and 573.	IAEA Regulations for the Safe Transport of Radioactive material SSR- 6 Para 617. Advisory material for the IAEA regulations for the safe transport of radioactive material – safety guide no SSG-26.	THRESHOLD Meets the requirements of paragraph 617 of the regulations. OBJECTIVE Demonstrate significant margins against the requirements of the regulations.	DRA, DSR, CAL, CoA, SGA, FAT	UR-1 UR-2 UR-3 UR-16 UR-17 UR-19
3.17	The System shall be designed to prevent the collection and retention of water	As far as practicable, the outer layer of the System shall be so designed as to prevent the collection and the retention of water. This prevents unwanted or unseen deterioration of package components that may cause non-compliance with the regulations. Water dripping from a package may be misinterpreted as leakage of contents.	IAEA Regulations for the Safe Transport of Radioactive material SSR- 6 Para 611. Advisory material for the IAEA regulations for the safe transport of radioactive material – safety guide no SSG-26.	THRESHOLD Demonstrate that the design ensures compliance with the requirements of paragraph 611 of the SSR-6 regulations OBJECTIVE None	DRA, DSR, CAL, CoA, FAT	UR-1 UR-2 UR-16 UR-17
3.18	The System shall withstand the effects of Vibration and accelerations during routine conditions of transport	The System shall be capable of withstanding the effects of and acceleration, vibration or vibration resonance that may arise under routine conditions of transport without any deterioration in the effectiveness of the closing devices on the various receptacles or in the integrity of the package as a whole. In particular, nuts, bolts and other securing devices shall be so designed as to prevent them from becoming loose or being released unintentionally, even after repeated use.	IAEA Regulations for the Safe Transport of Radioactive material SSR- 6 Para 613. Advisory material for the IAEA regulations for the safe transport of radioactive material – safety guide no SSG-26.	THRESHOLD The System demonstrably complies with the regulatory requirements. Threaded fasteners are specified correctly along with the correct torque and hence preload settings. Fatigue and thermal cycling has been addressed in the design. OBJECTIVE None	DRA, DSR, CAL, CoA	UR-1 UR-2 UR-5 UR-9 UR-16

SRID	System Requirement	Remark	Justification	Measure of Performance	Verification Codes	UR IDs
3.19	The System shall have a means of verifying the adequacy of the containment system before shipment	Suitable testing during the manufacture of the System and the provision of a means to confirm the adequacy of sealing methods should be incorporated into the design	IAEA Regulations for the Safe Transport of Radioactive material SSR- 6. Advisory material for the IAEA regulations for the safe transport of radioactive material – safety guide no SSG-26.	THRESHOLD The System shall demonstrate an adequate and appropriate means of confirming the effectiveness of the containment barrier and the closure method, and demonstrate compliance with the requirements of a Type B package. OBJECTIVE None	CAL, DRA, DSR, FAT, ICM, QAC, SAT	UR-1 UR-2 UR-3 UR-5 UR-16
3.20	The System shall employ features for tie down that cannot, in an accident, impair the System's ability to meet regulations	e.g. It is common on some designs of transport package to employ trunnions for the purposes of package retention on conveyances. This has the potential to pose a risk to the compliance with regulations if these features were to be damaged or separated from the System during ACT and cause the shielding System to fail.	IAEA Regulations for the Safe Transport of Radioactive material SSR- 6. Advisory material for the IAEA regulations for the safe transport of radioactive material – safety guide no SSG-26.	THRESHOLD The System shall have tie down features that demonstrate compliance with the requirements of a Type B package in both NCT and ACT. OBJECTIVE None	CAL, DRA, DSR, FAT, FEA(i), IMT, QAC	UR-1 UR-2 UR-9 UR-11 UR-16

Appendix B - IAEA Transport Regulations Summary

The table below presents the list of requirements from the IAEA Transport Regulations which are applicable to the conceptual design stage of waste container development.

Requirement	SSR-6 paras [9]	ADR section [16]
Marking, labelling and placarding of container	530-544	5.2.1, 5.2.2, 5.3
Shape, mass and volume for safe transport and securing	607	6.4.2.1
Lifting attachments	608-609	6.4.2.2, 6.4.2.3
Ease of surface decontamination and smooth surface	610	6.4.2.4
Prevention of collection and retention of surface water	611	6.4.2.5
Withstanding acceleration and vibration	613	6.4.2.7
Material compatibility	614	6.4.2.8
Protection of valves	615	6.4.2.9
Routine temperature and pressure compatibility	616	6.4.2.10
Shielding to limit dose rate within limits	617	6.4.2.11
Other dangerous properties	618	6.4.2.12
General and Type A package requirements	652	6.4.8.1
NCT heat generation affecting containment and shielding	653	6.4.8.2
Routine surface temperature limits without insolation and under ambient conditions	654-657	6.4.8.3 – 6.4.8.6
Activity release test limits	659	6.4.8.8
Enhanced water immersion test	660	6.4.8.9
700 kPa max operating pressure limit	664	6.4.8.13
Ambient temperature range −40°C to +38°C.	666	6.4.8.15

Requirement	SSR-6 paras [9]	ADR section [16]
Type B(M) requirements	667	6.4.9.1
Fissile package requirements	673-674	6.4.11.1 – 6.4.11.2
NCT tests* • Water spray test • Free drop test • Stacking test • Penetration test	719-724	6.4.15.1- 6.4.15.6
ACT tests** - Mechanical (in sequence) • I – 9 m drop. • II – 1 m penetration drop onto perpendicular bar. • III – dynamic 9 m crush from 500 kg mass.	726-727	6.4.17.1- 6.4.17.2
ACT tests** - Thermal (in sequence) • Thermal equilibrium with max design internal heat generation - with insolation and 38°C ambient. • 30 minute hydrocarbon fuel-air fire at least 800°C • Post fire thermal equilibrium with max design internal heat generation - with insolation and 38°C ambient.	728	6.4.17.3
ACT tests** - Water immersion under 15 m head for 8 hours	729	6.4.17.4
ACT tests including pressure relief systems	662	6.4.8.11
ACT tests under max normal operating pressure	663	6.4.8.12

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