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1.0 INTRODUCTION

1.1 Background

Holtec International (Holtec) is planning to deploy its 300MWe Small Modular Reactor (SMR-300) in the United Kingdom (UK). As the first step, Holtec (via its UK Division, Holtec Britain) is submitting its SMR-300 design for Steps 1 and 2 of the Generic Design Assessment (GDA) process by the UK nuclear regulators, namely the Office for Nuclear Regulation (ONR), the Environment Agency and Natural Resources Wales.

To complete Steps 1 and 2 of the GDA, Holtec is required to submit safety, security, safeguards and environmental documentation for assessment by the regulators during both steps of the GDA. This document, the Preliminary Safeguards Report (PSgR), is the safeguards submission to ONR in support of Step 1 of the GDA.

1.2 Aim and Objectives of the GDA Step 1 Preliminary Safeguards Report

ONR provides technical guidance on the expected GDA safety, security and safeguards submissions [1]. On safeguards, this ONR guidance states that '*During GDA, it is expected that the documentation submitted by the RP* (Requesting Party) *will need to demonstrate their understanding of safeguards requirements at the generic (international/national) level and how they will be accommodated in the generic design'*. However, no specific guidance is given as to what is expected to be submitted on safeguards for each step of the GDA.

In the absence of specific guidance, the objectives of this Step 1 PSgR are to:

- Present Holtec's understanding of the safeguards requirement at the generic (international and UK domestic) level and relevant good practice (RGP).
- Outline at a high level the SMR-300 safeguards programme, i.e. how the safeguards requirements will be delivered for the SMR-300 through all phases of its lifecycle.
- Present an outline of the SMR-300 safeguards case and the main safeguards claims, showing how these claims integrate with the SMR-300 Safety, Security and Environmental case.
- Provide the basis for the accommodation of the safeguards requirement in the generic SMR-300 design, including information on the development of the safeguards design objective and safeguards design principles, and the implementation of Safeguards by Design (SgBD).
- Outline the evolution of the Step 1 PSgR to the GDA Step 2 safeguards submission. This will provide ONR with the documentary basis for the safeguards documentation that will be submitted for assessment at Step 2.

The overall aim of this Step 1 PSgR is to provide ONR with the confidence that it will be able to carry out a meaningful assessment of the safeguards topic during Step 2 and thereby contribute positively to the ONR Step 1 public statement that the SMR-300 design can proceed to Step 2 of the GDA.

1.3 Structure of Step 1 PSgR

This GDA Step 1 PSgR delivers the above objectives as follows:

Table 1: Structure of PSgR

Section	Presents:
3.0	Holtec's understanding of the International and UK safeguards framework.
4.0	RGP relevant to the deployment of an SMR-300 in the UK.
5.0	Outline of the SMR-300 safeguards programme.
6.0	Outline of the SMR-300 safeguards case.
7.0	Development of the safeguard design objective and safeguard principles, and incorporation of SgBD.
8.0	The evolution from this document to the GDA Step 2 safeguards submission.

2.0 ABBREVIATIONS

2.1 Project Abbreviations

Term	Definition
ACP	Accountancy and Control Plan
AP	Additional Protocol
BTC	Basic Technical Characteristics
CNSC	Canadian Nuclear Safety Commission
c/s	Containment and Surveillance
CSA	Comprehensive Safeguards Agreement
DIV	Design Information Verification
EU	European Union
FSE	Fundamental Safeguards Expectations
GDA	Generic Design Assessment
IAEA	International Atomic Energy Agency
IMSR400	Integral Molten Salt Reactor 400MWe
KMP	Key Measurement Point
MACE	Nuclear Material Accounting and Control Expectations
MBA	Material Balance Area
MWe	Mega Watt Electric
NMAC	Nuclear Material Accounting and Control
NMACS	Nuclear Material Accounting, Control and Safeguards
NPT	Non-Proliferation of Nuclear Weapons Treaty
NSR19	Nuclear Safeguards Regulation 2019
ONR	Office for Nuclear Regulation
ONMACS	ONR Nuclear Material Accounting, Control and Safeguards
PIV	Physical Inventory Verification
PSgR	Preliminary Safeguards Report
QNF	Qualifying Nuclear Facility
QNM	Qualifying Nuclear Material
RGP	Relevant Good Practice
RP	Requesting Party
RR SMR	Rolls Royce Small Modular Reactor
SgBD	Safeguards by Design
SgC	Safeguards Claim
SgDP	Safeguards Design Principles
SMR-300	Small Modular Reactor 300MWe
SQ	Significant Quantity
SQEP	Suitably Qualified and Experienced Personnel
SRA	State or Regional Authority
SSAC	State System of Accounting for Control of Nuclear Material
SSEC	Safety, Security and Environmental Case
SSC	Structure, System and Component
TIG	Technical Inspection Guide

Term	Definition
USNRC	United States Nuclear Regulatory Commission
UK	United Kingdom of Great Britain and Northern Ireland
VDR	Vendor Design Review
VOA	Voluntary Offer Agreement

3.0 INTERNATIONAL AND NATIONAL SAFEGUARDS FRAMEWORK

3.1 International Framework

The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) [2] places a responsibility on the International Atomic Energy Agency (IAEA) to independently verify that non-nuclear-weapon signatory States fulfil their obligations to not divert nuclear energy from peaceful uses to nuclear weapons or other nuclear explosive devices. IAEA delivers this independent verification responsibility via a set of technical measures, collectively known as 'Safeguards'.

Non-nuclear-weapon signatory States are required by the NPT to sign a comprehensive safeguards agreement (CSA) with IAEA to enable IAEA to verify that the State has fulfilled its obligation under the treaty. The five nuclear-weapon signatory States are not required to sign a CSA by the NPT but have all signed a voluntary offer agreement (VOA) with IAEA. The basis for the CSAs and VOAs is a system of reporting/declaration (by the State) and independent verification (by IAEA).

Each State, which is a signatory to the NPT, develops a domestic safeguards framework to deliver its international safeguards obligations under the CSA or VOA. The international and domestic safeguards framework as it applies to the UK is illustrated at a high level in Figure 1. The remainder of this section provides an overview of the UK domestic framework together with the UK regulatory guidance and expectations.

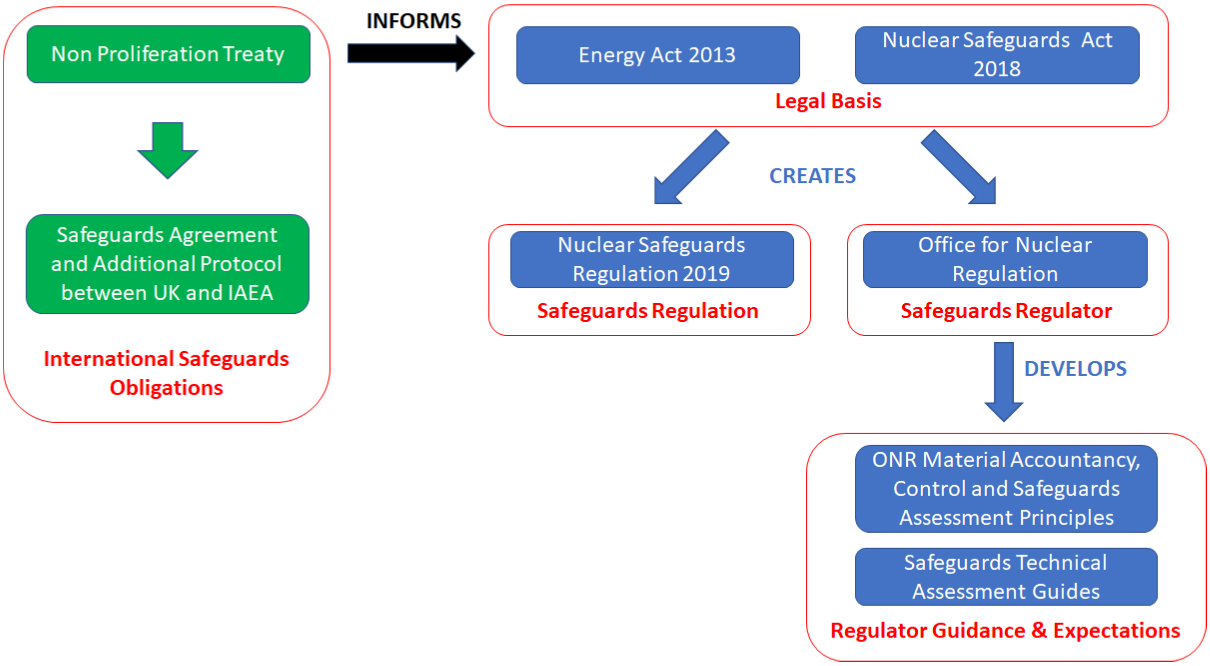

Figure 1: International and UK Safeguards Framework

3.2 UK International Safeguards Obligations

As a nuclear-weapon State, the UK's international safeguards obligations originate from the signing of the VOA [3] with IAEA. The common objective of this VOA is *'the timely detection of withdrawal from civil activities, except as provided for in this Agreement, of significant quantities of nuclear material which is being safeguarded in facilities'.* The VOA prescribes a safeguards regime of reporting (by the UK) and independent verification (by IAEA).

Additionally, the UK has signed an Additional Protocol (AP) to the VOA [4]. The AP extends the UK reporting to provide IAEA with additional verification measures aimed at strengthening and improving the efficiency of IAEA safeguards processes.

3.3 UK Safeguards Legal Basis and Regulatory Framework

The Energy Act 2013 [5] and the Nuclear Safeguards Act 2018 [6] provide the legal basis for the delivery of the UK's international safeguards obligations. Under the powers contained within these Acts:

- The Nuclear Safeguards Regulations (EU Exit) 2019 (NSR19) [7] were made to define the domestic safeguards regime for delivery of the UK's international safeguards obligations. Parts of the regulations are prescriptive, while others are outcome-focused in line with the extant UK regulatory approach for the nuclear industry.
- ONR was established as the UK safeguards regulator, responsible for the implementation of the domestic safeguards regime to enable the UK to meet its international safeguards obligations.

As the UK's State Regulatory Authority (SRA) for safeguards, ONR is the focal point of contact between the UK and IAEA on safeguards and is responsible for:

- Establishing, implementing, and maintaining the UK State System of Accounting for and Control of nuclear material (SSAC) within the civil nuclear programme. A high-level overview of the UK SSAC framework is illustrated in Figure 2 below.

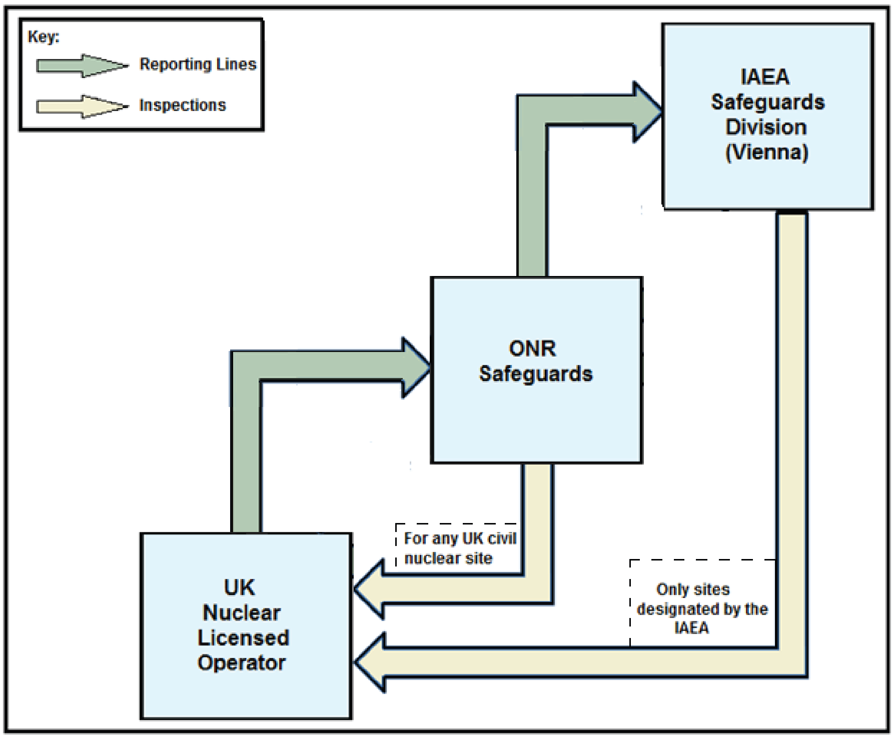

Figure 2: High Level Overview of the UK SSAC Framework
(Reproduced from [8])

Referring to Figure 2, ONR's responsibilities include the:

- Provision of nuclear material accounting and control (NMAC) reports and safeguards declarations to the IAEA required under the VOA.
- Provision of additional safeguards reports to the IAEA required under the AP.
- Provision of assurance that the UK SSAC is functioning correctly via inspections at UK civil nuclear sites.
- Facilitation of IAEA's safeguards verification activities at sites designated by the IAEA from a Facilities List of civil nuclear sites.

- The provision of an annual safeguards report to the UK government and the publication of prescribed UK nuclear material inventory information on the ONR website.

To deliver these responsibilities, ONR maintain and provide to IAEA a Facilities List of UK civil nuclear facilities subject to safeguards (referred to as a Qualifying Nuclear Facility (QNF)) and carry out a range of activities associated with these QNFs, which include:

- Ensuring compliance with NSR19 at the QNFs via reviews and compliance inspections.

- Reviewing the Basic Technical Characteristics (BTC) for QNFs and, if considered necessary, imposing 'particular safeguards provisions'[1] on the QNF operator[2].
- Inspections of QNFs to ensure that the QNF NMAC system is functioning correctly, and that the operator is submitting accurate and up to date NMAC reports to ONR. This may include the use seals and other tamper-indicating devices to ensure continuity of knowledge.
- Arranging for the installation by the QNF operator of IAEA safeguards verification equipment and arranging IAEA access to the QNF to facilitate the independent verification activities[3].

A summary of the safeguard's activities carried out by ONR as the SRA for safeguards is reported in the ONR Safeguards Annual Reports [9].

3.4 UK Regulatory Guidance and Expectations

ONR publish guidance and expectations to QNF operators to facilitate the delivery of its responsibilities as SRA. Some of this guidance is necessarily prescriptive to facilitate ONR's own reporting to the IAEA.

Most of the guidance relate to QNFs during, or close to commencing, the operational phase of the facility lifecycle. However, the guidance provides invaluable information to inform design developments as part of SgBD. This guidance includes the following key documents:

[1] 'Particular safeguards provisions' are particular safeguards provisions imposed by ONR under regulation 5 of NSR19.
[2] Operator is defined in NSR19 as 'a person or undertaking setting up, operating, closing down or decommissioning a qualifying nuclear facility for the production, processing, storage, handling, disposal or other use of qualifying nuclear material'.
[3] Under the UK VOA, IAEA designate QNFs for independent verification from a Facilities List of QNFs provided by ONR to IAEA.

Table 2: Key ONR Safeguards Regulatory Guidance

ONR Document	Description
ONR Nuclear Material Accountancy, Control, and Safeguards (ONMACS) Assessment Principles [8]	This document details the regulatory expectations for compliance with NSR19 for new or existing QNFs throughout the facility lifecycle. More specifically it presents the Fundamental Safeguards Expectations (FSE) for the operator's NMAC system and reporting. It details the outcomes to be achieved for each FSE via one or more Nuclear Material Accountancy and Control Expectations (MACE). There are ten FSEs covering both Nuclear Material Accountancy, Control, and Safeguards (NMACS) strategic enablers and nuclear material control: <u>Strategic Enablers</u> FSE 1 NMACS Leadership and Management FSE 2 Organisational Culture FSE 3 Competence Management FSE 4 Reporting, Anomalies, and Investigations FSE 5 Reliability, Resilience, and Sustainability <u>Nuclear Material Control</u> FSE 6 Measurement Programme and Control FSE 7 Nuclear Material Tracking FSE 8 Data Processing and Control FSE 9 Material Balance FSE 10 NMACS Quality Assurance and Control
Safeguards Technical Assessment Guide (TAG) [10]	This document presents the regulatory expectations for the following NMAC reporting and safeguards declarations by the QNF operator, as required by NSR19: • QNF BTC. • Annual Outline Programme of Activities. • Accountancy and Control Plan (ACP).
Nuclear Material Accountancy TAG [11]	This document presents the regulatory expectations for the detailed nuclear material inventory reporting and special reports by the QNF operator, as required by NSR19.
Safeguards Technical Inspection Guide (TIG) [12]	This document provides guidance and a framework for ONR inspectors assessing the compliance with NSR19, inspecting the QNF NMAC systems, and the facilitation of IAEA verification activities on designated sites.
Reporting under the AP [13]	This document provides guidance for the reporting under the AP. This includes declarations on nuclear fuel cycle-related research and development activities with a non-nuclear weapon State, approved plans relevant to the development of the civil nuclear fuel cycle and specific exports and imports to non-nuclear weapon States.

4.0 RELEVANT GOOD PRACTICE

4.1 UK RGP

The ONR safeguards guidance documents identified in Table 2 represent RGP for the delivery of the safeguards requirements in the UK. Specific safeguards RGP for design development, licensing and GDA of new reactors in the UK is currently limited.

RGP on safeguards during the design development and licensing of a new reactor plant in the UK can be inferred from publicly available ONR safeguards assessment reports [17], [18], [19] related to the licensing for the Hinkley Point C nuclear power plant. Although these ONR assessments were performed prior to the issue of NSR19, the RGP remains applicable. These ONR reports identify the importance of early and regular proactive interaction with ONR during the licensing process[4] to demonstrate the operator's commitment, discuss the BTC, and exchange information with the view of agreeing efficient and effective NMAC and safeguards arrangements as part of the SgBD process. The GDA presents an early opportunity to commence the interactions with ONR (and IAEA if required by ONR at this stage) in these areas and demonstrate Holtec's commitment to safeguards.

The first GDA which has included safeguards is the GDA of the Rolls Royce Small Modular Reactor (RR SMR). The RR SMR Step 1 safeguards submission is publicly available [20] and has informed this PSgR.

4.2 International RGP

The ONR safeguards guidance has been informed by the IAEA safeguards guidance and associated documentation which, themselves, provide a broader source of RGP. During the design development for a new reactor plant, licensing and the GDA, the following two IAEA publications provide relevant RGP information:

1. NP-T-2.8 International Safeguards in Nuclear Facility Design and Construction [14].
2. NP-T-2.9 International Safeguards in the Design of Nuclear Reactors [16].

Informed by IAEA documentation and their own CSA (or VOA), SRAs around the world publish guidance for use in the delivery of the nation's safeguards obligations. This guidance is an additional source of RGP, but the guidance needs to be considered with care for UK purposes as it will have been tailored to the nation's individual agreement with IAEA and their nuclear regulatory approach, both of which may be different to the UK. However, the principles of safeguards and SgBD remain the same.

Noting the above, a relevant source of RGP for the development of the NMACS arrangements and SgBD for the Holtec SMR-300 is the United States Nuclear Regulatory Commission (USNRC). This is because the generic SMR-300 Reactor is being designed in the US in accordance with USNRC regulatory requirements, including SgBD.

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[4] It is noted that ONR highlights the importance of early engagement in their licensing guide [21], in which they state that '*Early engagement with us is both a requirement under NSR19 (for example, preliminary information on new facilities must be provided to ONR before construction starts) and key to defining effective and efficient arrangements for safeguards verification and inspection activities*'.

Additionally, and specifically to the GDA, Canada has a pre-licensing process with similar aims to the GDA in which vendors can submit their generic reactor design for the assessment by the Canadian Nuclear Safety Commission (CNSC) as part of their Vendor Design Review (VDR) process [22]. One of the CNSC VDR Focus Areas (Focus Area 15) of the VDR covers safeguards [23]. Although the Canadian safeguards obligations differ from the UK in that Canada has a CSA with IAEA (and not a VOA) and the detailed reporting requirements differ, the safeguards objectives and principles remain the same. Hence the Canadian safeguards VDR experience can be considered relevant, in particular for SgBD during design development. The experience gained supporting the safeguards elements of the VDR for the Terrestrial Energy Integral Molten Salt Reactor 400MWe (IMSR400) [24] and the development of and discussions with CNSC/IAEA on the SgBD Design Information Questionnaire (DIQ) which is the equivalent of the BTC has informed this PSgR.

5.0 OVERVIEW OF SMR-300 SAFEGUARDS PROGRAMME

5.1 Introduction

The SMR-300 will be a QNF subjected to the full extent of the NSR19 requirements because it is a reactor and will contain sufficient quantity of qualifying nuclear material (QNM)[5]. As a QNF, any SMR-300 deployed in the UK will be included in the UK Facilities List issued by ONR to IAEA for safeguards purposes, and hence may be subject to independent verification by the IAEA.

Holtec is fully committed to supporting ONR in the delivery of the UK's international obligations under the UK VOA and AP. Equally, Holtec is committed to SgBD during the design development process. To this end, Holtec is developing and implementing a holistic through-life safeguards programme for the SMR-300, starting during the design development phase.

5.2 SMR-300 Safeguards Programme

An illustration of the key elements of the SMR-300 safeguards programme and the associated regulatory interface is given in Figure 3 and an overview is provided below in this section, concentrating on the earlier stages of the programme which are directly relevant to the GDA.

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Figure 3: SMR-300 Safeguards Programme

[5] Under NSR19, a QNF is a facility that is used for the production, processing, storage, handling, disposal, or other use of QNM (i.e. plutonium, high enriched uranium (20% enrichment or above), low enriched uranium, natural uranium, depleted uranium and thorium). A QNF is subjected to the full extent of the NSR19 requirements unless it is:

- A 'qualifying nuclear facility with limited operations' in accordance Regulation 2 of NSR19 because of the type of facility and quantity of QNM within it, in which case the operator may apply to ONR for the facility to be subjected to a safeguards 'regime with limited operation' as defined in Part 7 of NSR19.
- Exempted in accordance with Regulation 32 of NSR19 because it is an educational establishment with a small holding of QNM or it holds 'only end products which are used for non-nuclear purposes and which incorporate qualifying nuclear material that is, in practice, irrecoverable'.

5.2.1 Safeguards Programme Enablers

The SMR-300 safeguards programme recognises that while SgBD is a key enabler to the delivery of the UK's international obligations and is the focus of the programme during design development, a robust safeguards management system and supportive culture are required during all stages of the project lifecycle (see Figure 4) to ensure a successful cost-effective and efficient delivery.

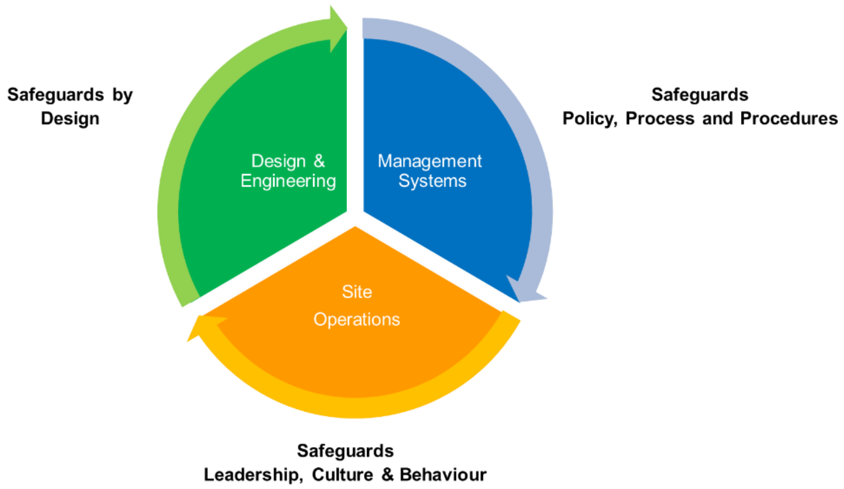

Figure 4: SMR-300 Safeguards Programme Enablers

5.2.2 Design Development and GDA

The SMR-300 safeguards programme starts during design development, as illustrated in Figure 3. International safeguards experience shows that considering safeguards as an integral part of the design process rather than retrospectively offers many benefits to all stakeholders (designer, site-specific operator, SRA and IAEA) and so this is promoted by IAEA as part of SgBD [15].

SgBD is the focus of the SMR-300 safeguards programme during design development/GDA and the main activities during this period are to:

(a) Include safeguards in the Holtec SMR-300 design processes (e.g. design principles, design review processes).

(b) Build inherent proliferation resistance in the design of the SMR-300 by, for example:

- Reducing the attractiveness of the nuclear material.
- Minimising withdrawal paths.
- Minimising the possibility of misuse of the plant[6].

(c) Facilitate the development of a cost-effective NMACS approach by:

[6] IAEA refers to misuse as the 'misuse of a safeguarded facility for undeclared activities or the undeclared production of weapons usable material' [16].

- Identifying and minimising Material Balance Areas (MBAs)[7] and Key Measurement Points (KMPs)[8].
- Identifying potential NMACS equipment for the SMR-300.

(d) Safeguards-inform the SMR-300 design and layout to:

- Accommodate the potential SMR-300 NMACS system and equipment (e.g. space, uninterruptible power supply, cabling, penetrations).
- Accommodate the potential ONR safeguards equipment required for inspection purposes and facilitate access by ONR to the equipment.
- Make provisions to accommodate IAEA safeguards equipment for their independent verification activities, should the SMR-300 be designated by IAEA for independent verification from the Facilities List.

(e) Integrate safeguards with nuclear safety, nuclear security and operations at the SMR-300, for example to:

- Deliver an optimised design (e.g. via the common use of equipment).
- Ensure that NMACS equipment and supporting infrastructure is adequately protected against sabotage[9] by the SMR-300 security arrangements.
- Ensure that NMACS equipment and supporting infrastructure has sufficient hazard withstand capability to remain operable during emergency conditions and nuclear security events.
- Ensure that NMACS activities can be carried out without impeding operations.

(f) Start regular engagement with the ONR Safeguards Team (e.g. via the GDA interactions) and IAEA (if required by ONR) to:

- Familiarise the regulators with the SMR-300 safeguards programme, the safeguards case, relevant aspects of the SMR-300 design and operations (e.g. nuclear material inventory, fuel route) and preliminary NMACS arrangements.
- Ensure Holtec fully understand the ONMACS requirements and expectations.
- Discuss potential NMACS systems and equipment.

(g) Deliver a SgBD BTC to support engagement with ONR. The SgBD BTC will follow the format prescribed in NSR19 for '1-A Reactors' so that it can be readily updated for formal issue to ONR at a later stage in the SMR-300 safeguards programme (See Section 5.2.3 (b) below).

5.2.3 Site-Specific Design to Start of Operations

The SgBD activities undertaken during design development continue during this period, as appropriate, but the focus of the SMR-300 safeguards programme changes to:

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[7] An MBA is defined by NSR19 as 'an area in a qualifying nuclear facility in respect of which:
(a) the quantity of qualifying nuclear material in each transfer into or out of the area can be determined; and
(b) the physical inventory of qualifying nuclear material in the area can be determined when necessary in accordance with specified procedures, in order that the quantity of qualifying nuclear material for safeguards purposes under these Regulations can be established'.

[8] A KMP is defined by NSR19 as 'a location where qualifying nuclear material appears in such a form that it may be measured to determine material flow or inventory, including, but not limited to, the inputs and outputs (including measured discards) and storages in material balance areas'.

[9] Sabotage in this context refers to manipulation or tampering to conceal the withdrawal of nuclear material.

(a) The detailed design, procurement, installation, and commissioning of a proportional and appropriate NMACS system for the SMR-300 and associated equipment. This may also include the installation of safeguards equipment which will be required by:

- ONR for their inspections to gain assurance that the SMR-300 NMAC system was functioning correctly and accurate and up to date NMAC reports were being submitted by the SMR-300 operator.
- IAEA for their independent Physical Inventory Verification (PIV) activities, if the SMR-300 site is designated for inspection by IAEA.

(b) The formal provision of SMR-300 design information to ONR so that the Design Information Verification (DIV) can be carried out. This will be in the form prescribed in NSR19 for '1-A Reactors' and in accordance with the schedule prescribed in NSR19 for a new QNF as follows:

- The preliminary site-specific BTC as soon as the decision is taken to construct the SMR-300.
- The detailed BTC, not later than 200 days prior to the start of construction.
- The as-built BTC, not later than 200 days prior to the receipt of first nuclear fuel.

(c) Preparedness for the start of operations, informed by the ten ONMACS strategic enabler and material control FSEs [8], see Table 2 above. This will include, in accordance with NSR19:

- The implementation of any particular safeguards provisions required by ONR following their review of the SMR-300 BTC.
- The issue to ONR of the SMR-300 ACP for approval, not later than 200 days prior to the arrival of nuclear fuel on site, and the Annual Outline Programme of Activities.

At some point during this period, responsibility and leadership for the site-specific SMR-300 safeguards programme will transition from Holtec (as the designer) to the site-specific SMR-300 operator. The aim will be a seamless transition of responsibility at a date to be agreed between Holtec and the future SMR-300 operator.

5.2.4 Start of Operations to End of Life

The focus of the SMR-300 safeguards programme during the operational phase through to decommissioning (whilst the SMR-300 remains a QNF) is on NMACS reporting as prescribed by ONR [11], [13] and facilitating inspections by ONR and IAEA, as necessary [12]. This will require:

(a) The operator to issue to ONR a broad range of safeguards related information in accordance with NSR19, including:

- On an annual basis, the Annual Outline Programme of Activities to ONR prior to the start of each calendar year.
- Advance warning of at least 40 days prior to the taking of a physical inventory.
- NMAC operating records, accounting records and reports, and special reports.
- Notification of any changes that affect any of the above at the earliest opportunity.

- Notification of a change in the BTC for the SMR-300 at least 30 days prior to the day on which the change is completed unless advance notification to the ONR of such a change is required by any particular safeguard provisions imposed on the operator by ONR following their review of the BTC.
- Advanced warning of import/export of SMR-300 QNM.

(b) The maintenance and potential upgrade of SMR-300 NMACS equipment and the maintenance of a SQEP (Suitably Qualified and Experienced Personnel) resource to operate the NMAC systems and deliver the prescribed NMACS reporting.

(c) The retention of the SMR-300 NMAC records and reports for at least five years and making these available to ONR for inspection at any time.

Additionally, SgBD will continue as required, for example during the design of plant modifications.

6.0 OVERVIEW OF THE SMR-300 SAFEGUARDS CASE

6.1 Introduction

The fundamental objective of the SMR-300 safeguards case is to demonstrate how the SMR-300 safeguards programme will support ONR in the delivery of the UK obligations under the UK VOA and AP. Following on from Section 3.2, this requires that:

1. The undeclared withdrawal of a Significant Quantity (SQ) of QNM from the SMR-300 site will be detected in a timely manner[10] in accordance with the VOA.
2. The SMR-300 operator will provide the reporting required by the AP.

These two safeguards requirements are the high-level safeguards claims (SgC) delivered by the SMR-300 safeguards case, as shown diagrammatically below.

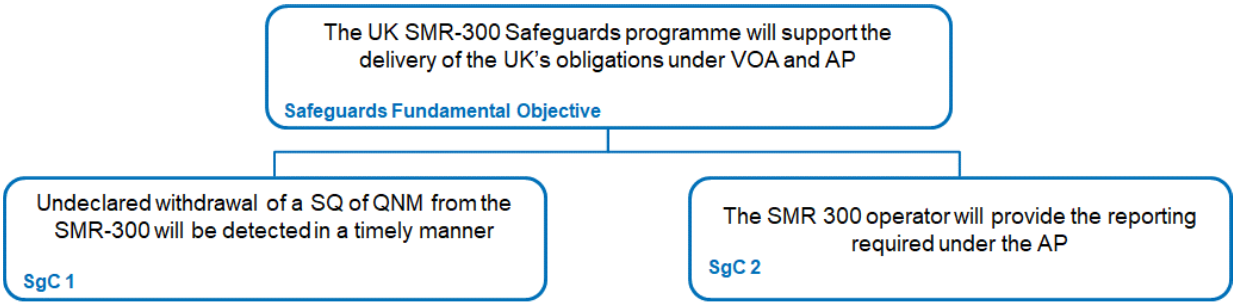

Figure 5: SMR-300 Safeguards Case Fundamental Objective and High Level SgCs

This section presents an outline of the SMR-300 SgC, focusing on the main safeguards sub-claims and general arguments supporting the above high level SgCs.

6.2 SgC 1 – Timely Detection of Undeclared Withdrawal of QNM

A holistic approach is used in the SMR-300 safeguards programme to deliver SgC 1, throughout the SMR-300 project lifecycle. This will involve a combination of design measures, procedural measures, deterrence, nuclear material accounting and reporting, inspection and independent verification which can be grouped into three safeguard sub-claims as illustrated and discussed below:

[10] The IAEA inspection goal for their verification activities at a specific QNF comprises a quantity and a timeliness component. The quantity component is derived from the 'approximate amount of nuclear material for which the possibility of manufacturing a nuclear explosive device cannot be excluded', which is defined by the IAEA as a SQ [25]. The timeliness (i.e. timely detection) component is derived from the 'time required to convert different forms of nuclear material into the metallic components of a nuclear explosive device' which is defined by the IAEA as the conversion time [25]. The SQ and conversion time current used by IAEA in establishing the quantity and timeliness components are shown in Appendix A.

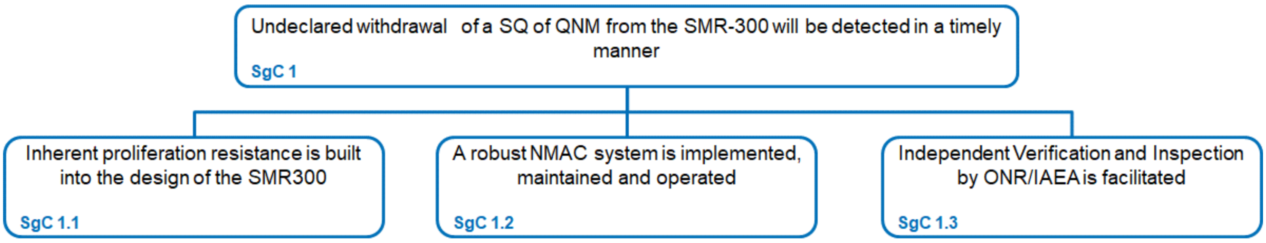

Figure 6: SMR-300 SgC 1 and Sub-claims

6.2.1 SgC 1.1 Inherent Proliferation Resistance

The need for safeguards at an SMR-300 site cannot be eliminated via the SgBD process. This is because it is a reactor that will contain enough QNM that can be withdrawn for proliferation purposes and hence a QNF under NSR19 (see footnote 5 on page 15).

However, consideration is given as part of the SgBD process during the design development phase, to design measures that reduce the attractiveness and potential for the UK State to covertly divert significant quantities of QNM abruptly or protractedly[11] from an SMR-300 plant for the manufacture of nuclear weapons. These include consideration of the following during design development, as appropriate:

- Attractiveness of the nuclear material within the SMR-300 site for the manufacture of nuclear weapons.
- Minimisation of QNM storage areas and accumulation of QNM within the site.
- Minimisation of paths for the abrupt or protracted withdrawal of significant quantities of QNM.
- Accessibility to potential withdrawal paths to make it difficult to covertly remove QNM.
- Optimisation of layout/space to prohibit the covert misuse of the SMR-300 site for proliferation purposes.

6.2.2 SgC 1.2 Implementation of a Robust NMAC System

Given that the potential for undeclared withdrawal of significant quantities of QNM by the UK State cannot be eliminated at a SMR-300 plant by SgBD, regular nuclear material inventory taking is required to be able to identify missing QNM in a timely manner. This requires the implementation of a robust NMAC system to track QNM flow into the SMR-300 site, within the site and out of the site, and in the process identify any missing QNM. The NMAC system is required to be effective throughout the operational phase of the QNF including during emergency conditions and nuclear security events.

To this end, a NMAC system will be implemented, operated and maintained at the SMR-300 site, which:

[11] IAEA considers two types of diversion which can be read across to withdrawals: abrupt and protracted. In an abrupt diversion scenario, the IAEA assumes that a large quantity of nuclear material is removed in one batch from one location. In a protracted diversion, the removal occurs over a long period, perhaps more than a year, and can be a continuous flow, intermittent or even taken from different locations [16].

- Has been optimised as part of the SgBD process during design development, e.g. via design considerations, including:
  - A simple fuel path, from the arrival of new fuel on site to the long-term on-site storage of spent fuel and eventual removal from site.
  - Minimising fuel storage locations and quantities of fuel in those locations.
  - Minimising MBAs/KMPs to keep the NMAC system simple to operate and facilitate reporting.

- Has been provided as part of SgBD with, for example:
  - Sufficient space in the plant layout for it to be accommodated and facilitate its operation and maintenance.
  - The supporting services required for its operation (e.g. Uninterruptible Power Supply).

- Meets ONR's FSEs as presented in the ONMACS principles [8] and to deliver accurate accounting reports as specified by ONR [10], [11].
- Is complemented by containment/surveillance (c/s) to ensure continuity of knowledge, i.e. to detect un-declared movement and tampering with safeguards equipment, in order to confirm already verified information.
- Has sufficient hazard withstand capability to remain operable during emergency conditions and nuclear security events.
- Is protected against sabotage (physical, cyber, blended) by the SMR-300 security arrangements.
- Is supported by a robust safeguards management system and operated by a SQEP team.

6.2.3 SgC 1.3 Inspection and Independent Verification

Inspection by ONR and independent verification by IAEA provide assurance that the NMAC system is functioning correctly and guards against the falsification of inventory reports obtained from the SMR-300 NMAC system in order to mask withdrawal of QNM from the site. This inspection verification will be carried out by ONR and IAEA (if designated by IAEA as a site for inspection).

This inspection and independent verification will be facilitated via, for example, the:

- Provision of information on SMR-300 design and layout as well as the safeguards arrangements to ONR via the BTC together with regular engagement with ONR to support their DIV.
- Provision of electronic NMAC reports to ONR direct from the NMAC system.
- Provision, as part of the SgBD process, of:
  - Space to accommodate, operate and maintain inspection and independent verification equipment.
  - Supporting services (e.g. `Uninterruptible Power Supply) to inspection and verification equipment.

- Protection against sabotage (physical, cyber, blended) of the inspection and verification equipment by the SMR-300 security arrangements.

6.3 SgC 2 - AP Reporting

The SMR-300 safeguards programme will include reporting arrangements to meet the requirements of the AP, as prescribed by ONR [13].

6.4 Integration with the Safety, Security and Environmental Case

The SMR-300 safeguards case integrates with the SMR-300 Safety, Security and Environmental Case (SSEC) via the SMR-300 Fundamental Purpose [14] as illustrated below.

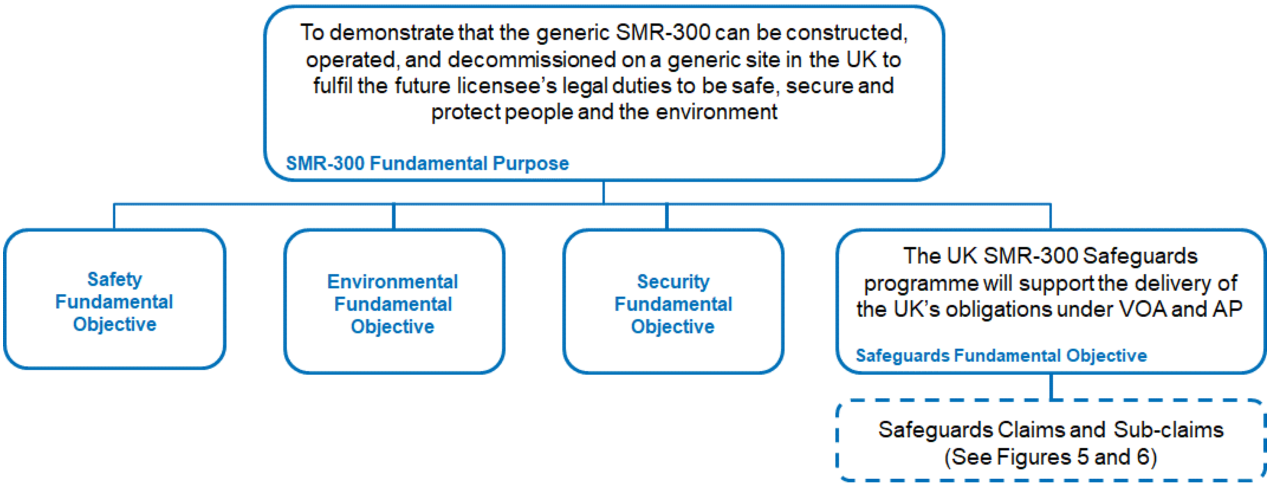

Figure 7: Integration of the Safeguards Case with the SSEC

7.0 SAFEGUARDS BY DESIGN

7.1 Introduction

The previous two sections show how the SgBD process makes a significant contribution to the SMR-300 safeguards programme and safeguards case throughout the SMR-300 project lifecycle.

SgBD is the process by which it is ensured 'that safeguards requirements are fully integrated into the design process stages (design, construction, commissioning, operation, and decommissioning) and the project management structure from project inception' [8].

International safeguards experience has shown that integrating safeguards into the design process from project inception delivers a cost-effective and efficient safeguards solution. This is in contrast with the traditional approach to considering safeguards retrospectively when the design and layout has been frozen, which in some cases had 'resulted in costly redesign and project delays and had reduced the efficiency and effectiveness of safeguards implementation' [14].

7.2 SMR-300 SgBD Process

The key elements of the SMR-300 SgBD process are illustrated in Figure 8 and an overview is given below.

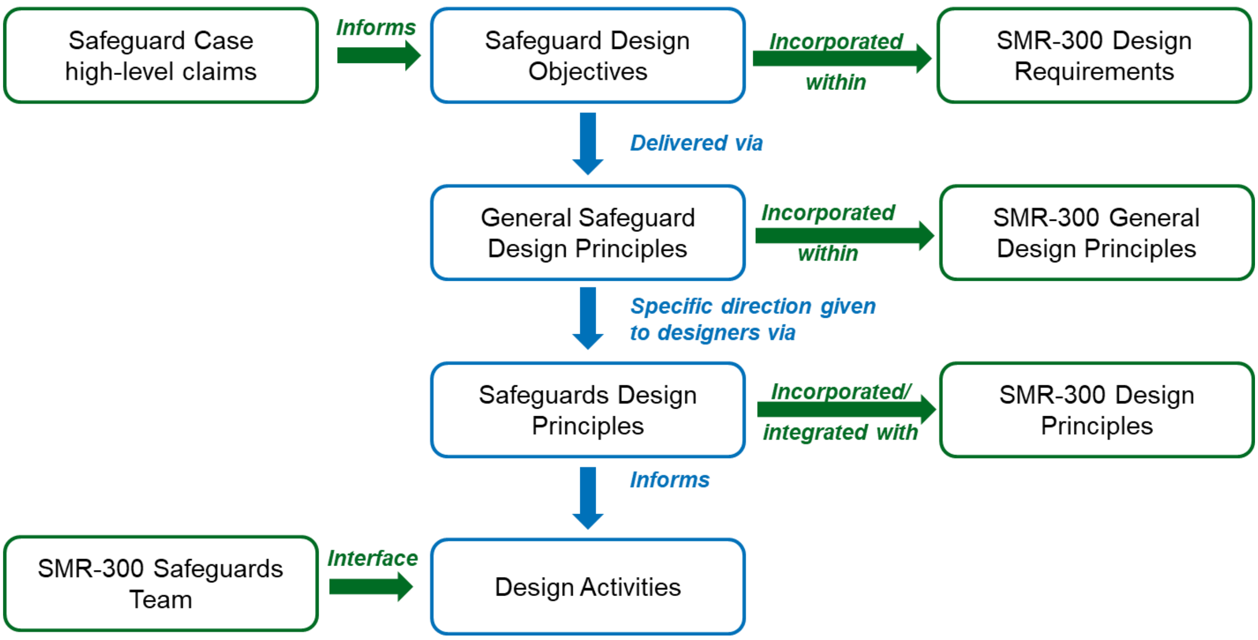

Figure 8: SMR-300 SgBD Process

7.2.1 Safeguards Design Objective

The SgBD process starts with the review of the safeguards requirements which are presented in Section 6.1 as the high-level SMR-300 SgCs. Of these two high-level SgCs, only SgC 1 is relevant to the design of the SMR-300, namely:

‘Undeclared Withdrawal of a SQ of QNM from the SMR-300 shall be detected in a timely manner’

This high-level SgC becomes the safeguards design objective and is incorporated within the overall SMR-300 design requirements log.

7.2.2 General Safeguards Design Principles

The three sub-claims associated with SgC 1 form the basis for the SMR-300 general safeguards design principles (SgDP) as tabulated in Table 3.

Similarly, these general SgDPs are incorporated within the overall SMR-300 general design principles log.

Table 3: SMR-300 General SgDPs

#	Design Principle
SgDP 1	Inherent proliferation resistance shall be built into the design of the SMR-300.
SgDP 2	A robust NMAC system shall be implemented, maintained and operated.
SgDP 3	Independent Verification and Inspection by ONR/IAEA shall be facilitated.

7.2.3 Safeguards Design Principles

Detailed direction to the designers on the implementation of these three generals SgDPs are provided via a set of specific SgDPs. The development of these SgDPs is guided by a SgBD hierarchy of control (See Section 7.3) where appropriate. Illustrative examples, based on the discussions on SgC 1 in Section 6.2 are given in Table 4.

Table 4: SMR-300 SgDPs associated with General SgDP 2

General SgDP	Specific SgDP
SgDP 1	SgDP 1.1 – Storage areas for new and spent fuel within the SMR-300 site should be minimised.
	SgDP 1.2 – Potential withdrawal paths along the SMR-300 fuel route should be minimised.
SgDP 2	SgDP 2.1 – The SMR-300 plant layout shall provide sufficient space to accommodate, operate and maintain the NMAC systems.
	SgDP 2.2 – c/s equipment shall be provided within the SMR-300 plant to ensure continuity of knowledge by detecting undeclared movement of QNM and tampering with safeguards equipment along the fuel route.
SgDP 3	SgDP 3.1 – The SMR-300 plant layout shall provide the necessary services (e.g. uninterruptible power supply) to operate and maintain safeguards equipment used for independent verification.
	SgDP 3.2 – The safeguards equipment used for independent verification shall be provided with protection against sabotage (physical, cyber, blended).

It is noted that some of the specific SgDP in Table 4 are compulsory; these are identified by the use of the verb ‘shall’, e.g. SgDPs 2 to 4. Others SgDP are not compulsory but are desirable to deliver an effective and efficient safeguards solution; these are identified by the use of the word ‘should’, e.g. SgDPs 1 and 2.

The SgDPs are also incorporated into the SMR-300 design principles log. This provides the opportunity to integrate design principles to deliver an optimised and cost-effective design where possible. To illustrate this, surveillance equipment required at some locations along the fuel route to comply with SgDP 2.2 could be used also for safety, security and operational purposes.

7.2.4 Design Activities

The SgDPs inform the SMR-300 designers of the safeguards requirements that need to be considered in design activities. Design activities in this context refer to a range of activities during the project lifecycle including:

- Design of the SMR-300 site and building layouts.
- Design of plant structures systems, and components (SSCs).
- ALARP and Optioneering studies.
- Design Reviews.
- Design Modification.
- Design of plant upgrades.

The SMR-300 Safeguards Team are involved in all these design activities, by providing advice on individual design activities, resolving conflicts between safeguards requirements and other disciplines, or participating in ALARP/Optioneering studies or design review committees.

7.3 SgBD Hierarchy of Control

A SgBD hierarchy of control, adapted from the ONR security hierarchy of control [26], is used to guide the development of the SMR-300 SgDPs and the subsequent design solutions, where appropriate. This SgBD hierarchy of control is illustrated in Figure 9.

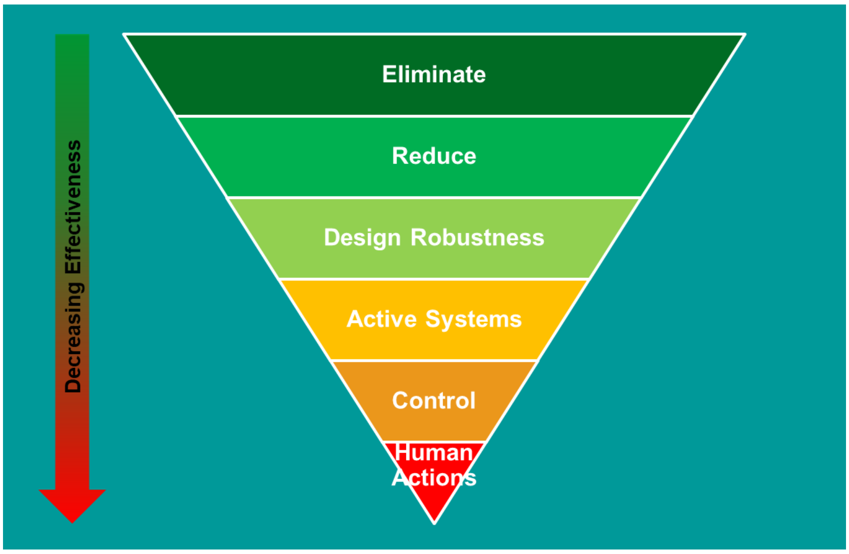

Figure 9: SgBD Hierarchy of Control

As an example, to illustrate the use of the SgBD hierarchy of control, SgDP 1 requires that 'inherent proliferation resistance shall be built into the design of the SMR-300'. Inherent proliferation resistance can be built into the design via the consideration of withdrawal paths. Referring to Figure 9, the most effective control measure would be to 'eliminate' withdrawal paths, but this is not possible, except for potentially in specific parts of the fuel route (e.g. within containment). However, it may be possible and more practical to 'reduce' the number of withdrawal points along the fuel route, hence the identification of SgDP 1.2 in Table 4 above.

8.0 EVOLUTION TO GDA STEP 2 SAFEGUARDS SUBMISSION

As noted in Section 1.2, ONR does not provide specific guidance on their expectations for the Step 2 safeguards submission. In the absence of this specific guidance, the aims of the SMR-300 GDA Step 2 safeguards submission will be to demonstrate to ONR that SgBD is being implemented in the evolving generic design of SMR-300, that safeguards is informing the design and layout, and that the UK safeguards regulatory framework and expectations are being accommodated. This demonstration will be provided via the issue of Revision 2 of the SMR-300 PSgR to ONR for assessment during Step 2.

The SMR-300 GDA Step 2 safeguards submission will be an evolution of the Step 1 PSgR to reflect the developments in the design and layout of the SMR-300 and the associated safeguards arrangements. In particular, it will present:

- Progress on the implementation of SgBD, as described in Section 7.0.
- Progress in the development of the safeguards case, as described in Section 6.0.
- Progress on the development of conceptual safeguards arrangements, including QNM Flow and potential MBA/KMPs.

- The first issue of the SMR-300 SgBD BTC (as a stand-alone appendix to the PSgR) to support engagement with ONR. This will be an informal issue noting that the first formal submission is not required until the decision to construct at a specific site is taken, see Figure 3.
- The evolution from GDA Step 2 to site licensing in the safeguards area, in accordance with the SMR-300 safeguards programme outlined in Section 5.0.

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10.0 LIST OF APPENDICES

Appendix A Significant Quantity and Conversion Times

The SQ values and conversion times currently used by IAEA to establish the quantity and timeliness components of their inspection goal for a specific QNF are reproduced below from the IAEA Safeguards Glossary [25].

TABLE 1. SIGNIFICANT QUANTITY (SQ) VALUES CURRENTLY IN USE

Material	*SQ*
Direct use nuclear material	
Plutonium[a]	8 kg *plutonium*
^{233}*U*	8 kg ^{233}*U*
High enriched uranium (HEU) ($^{235}U \geq 20\%$)	25 kg ^{235}U
Indirect use nuclear material	
Uranium ($^{235}U < 20\%$)[b]	75 kg ^{235}U (or 10 t *natural uranium* or 20 t *depleted uranium*)
Thorium	20 t *thorium*

[a] For *plutonium* containing less than 80% ^{238}Pu.
[b] Including *low enriched uranium (LEU)*, *natural uranium* and *depleted uranium*.

TABLE 2. ESTIMATED MATERIAL CONVERSION TIMES FOR FINISHED PLUTONIUM OR URANIUM METAL COMPONENTS

Beginning *material form*	*Conversion time*
Plutonium, *high enriched uranium (HEU)* or ^{233}*U* metal	Order of days (7–10)
PuO_2, $Pu(NO_3)_4$ or other pure *plutonium* compounds; *HEU* or ^{233}*U* oxide or other pure *uranium* compounds; *mixed oxide (MOX)* or other unirradiated pure mixtures containing *plutonium*, *uranium* ($^{233}U + ^{235}U \geq 20\%$); *plutonium*, *HEU* and/or ^{233}*U* in *scrap* or other miscellaneous impure compounds	Order of weeks (1–3)[a]
Plutonium, *HEU* or ^{233}*U* in irradiated fuel	Order of months (1–3)
Uranium containing <20% ^{235}U and ^{233}*U*; *thorium*	Order of months (3–12)

[a] This range is not determined by any single factor, but the pure *plutonium* and *uranium* compounds will tend to be at the lower end of the range and the mixtures and *scrap* at the higher end.