Defining Design Authority Elements in Nuclear Power Plant Construction Projects.

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DECLARATION

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ABSTRACT

In Nuclear Power Plant operation, Nuclear Safety is paramount to protect the personnel, public, environment and the plant from the potentially harmful effects of nuclear radiation. This is evidenced by nuclear accidents such as Chernobyl and Fukushima. The ability to ensure that the design of a nuclear plant remains aligned to the design intent of its safety systems and components is fundamental to nuclear safety. This responsibility lies with the Design Authority appointed in the operating organisation.

With many nuclear power plants being built around the world in countries which have not operated nuclear plants previously, it is imperative that these organisations are supported with guidance on what is needed to establish the Design Authority function. The lack of comprehensive industry guidance has led the researcher to the primary research question: *What elements should be considered for the effective establishment of the Design Authority function at commercial operation of a New Nuclear Power Plant Construction project?* Based on a comprehensive literature review of existing international industry regulations, standards and guidance documents, followed by a survey of internal nuclear experts, the critical elements for establishing the Design Authority function were identified. The survey covered existing power plant operations and nuclear build projects, as applicable, in countries which included the, United States of America France, United Kingdom, South Korea, Canada, Romania, China, South Africa and. United Arab Emirates

The study identified the fundamental elements in establishing the Design Authority function as; acquiring the design knowledge and skills to execute the function; securing the plants design information; and establishing and ensuring compliance to a configuration management process.

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LIST OF ABREVIATIONS

AERB	Atomic Energy Regulatory Board
APR	Advanced Power Reactor
ASME	American Society of Mechanical Engineers
CDSV	Carolina, Duke, South, Virginia
CM	Configuration Management
CMBG	Configuration Management Benchmarking Group
CNSC	Canadian Nuclear Safety Commission
COLA	Combined Operating Licence Application
CORDEL	Cooperation in Reactor Design Evaluation and Licensing
CSNPTC	China State Nuclear Power Technology Corporation
DCD	Design Change Document
DIN	Nuclear Engineering Division
DID	Defence in Depth
DTI	Department of Trade and Industry
EASA	European Aviation Safety Agency
EDF	Electricite de France
EPC	Engineer, Procure and Construct
EPCO	Engineer, Procure, Construct and Operate
EPRI	Electric Power Research Institute
IAEA	International Atomic Energy Agency
ICAO	International Civil Aviation Organisation
INL	Idaho National Labs
INSAG	International Nuclear Safety Advisory Group
JAEC	Japan Atomic Energy Corporation
KEPCO E&C	Korea Electric Power Company Engineering and Construction
KHNP	Korea Hydro and Nuclear Power
KINS	Korea Institute of Nuclear Safety
LTO	Long-Term Outage

MWe	Megawatt electrical
NEA	Nuclear Energy Agency
NEI	Nuclear Engineering International
NSSS	Nuclear Steam Supply Systems
NUREG	Nuclear Regulations
OEM	Original Equipment Manufacturer
ONR	Office of the Nuclear Regulator
PEI	Power Engineering International
RBMK	Reaktor Bolshoy Moshchnosti Kanalniy
SAT	Systematic Approach to Training
SSC	System, Structure and Components
TEPCO	Tokyo Electric Power Company
USNRC	United States Nuclear Regulatory Commission
WENRA	Western European Nuclear Regulators' Association
WNA	World Nuclear Association
WNN	World Nuclear News

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CHAPTER ONE
INTRODUCTION

1.1 General Introduction

The year 2018 marked 32 years since the Chernobyl nuclear disaster in the Ukraine in 1986 and 7 years since the Fukushima disaster in Japan in 2011 (NEI-1, 2015). The analysis of both of these accidents highlighted fundamental shortfalls in the plant design and operations, which if pre-emptively addressed, could have prevented or mitigated the severity of the events. These accidents re-enforced the need for nuclear safety as being very important for nuclear power plant operators. While the Fukushima event was considered a beyond design basis accident, the evolution of the accident highlighted the inadequacy in plant design features which were required as standard design safety features at later built nuclear plants. A nuclear power plant with a projected life of 60 years will most likely undergo various plant component and system modifications to support continued safe operations. The original design intent should be fully understood when making these changes (WNA, 2012:6).

Nuclear energy regulatory bodies around the world therefore require operating organisations to have a formally appointed entity to own the design knowledge and control. The International Atomic Energy Agency (IAEA) calls this entity the “Design Authority” (IAEA, 2003:4). In commercial nuclear power plant operation, the responsibility is typically placed onto the licence holder, who would be the operating utility. As a cornerstone to safe nuclear operation, significant emphasis is placed on the ability of the Design Authority to ensure that the plant design meets all applicable safety requirements, and in particular that the plant’s design basis remains valid for the entire plant life. The challenge for many new utilities is that they do not hold all the detailed knowledge and specialist skills of the safety significant plant systems and components. This is required to fulfil the Design Authority function independently (WNA, 2012:4). Many Generation III nuclear plants have been sold on a turnkey basis which makes securing and transferring design knowledge even more challenging, as utilities may be in countries building their first nuclear power plants, as in the case of the UAE (WNA, 2015:1).

1.2 Aim of The Research

The study aims to define the role of a Design Authority within a nuclear utility. It will then identify the critical elements required for the Design Authority to be effective to support safe plant operation after nuclear power plant construction. The study will further explore the functional elements in support of the Design Authority function.

1.3 Problem Statement

Nuclear Energy Regulatory bodies require the licensee to be legally responsible for the safe operation of the nuclear power plant (WNA, 2017:8). The IAEA Safety Standard – Safety of Nuclear Power Plants: Design – SSR No. 2/1(IAEA, 2012:8); states that "*The prime responsibility for safety rests with the person or organization responsible for facilities and activities that give rise to the radiation risks*" i.e. the operating organisation. It is therefore imperative for operators fulfilling the function of the Design Authority and making decisions on design changes to fully understand the level of responsibility, the effects of the proposed change, and resources required to effectively perform the role.

In current day nuclear power plant construction projects, the various phases of design, construction and commissioning could be shared between a number of original designers, vendors, major component manufacturers and utility departments (IAEA, 2012:2). Major equipment manufacturers may include the vendor for the reactor vessel, steam generators, turbines, electrical distribution systems and major pumps. These systems and components would all be considered critical to nuclear safety. Even though detailed design knowledge would be transferred to the operating organisation in the form of the safety analysis report, the highly specialised skills required to actually do the design will be with the original designer. There is no guarantee that these vendors would still be in operation after several decades of plant operation and the risk is that when these are lost the design knowledge would be lost too (IAEA, 2003:9).

The International Nuclear Safety Advisory Group (INSAG) to the IAEA in their report INSAG – 19 "*Maintaining the Design Integrity of Nuclear Installations throughout their Operating Life*" (IAEA, 2003:5) introduced the concept of the 'Responsible Designers', to which the formally designated Design Authority could assign specific responsibilities for part of the plant design process. The operating organisation would then be required to develop a formal system for managing the design for the lifetime of the plant (IAEA, 2012:9). It would be necessary that the management system requirements are also strictly applied to all vendors, consultants or technical support organisations performing activities related to the design process (AERB, 2014:10).

A strict interpretation of the safety guidance above would imply that operating organisations worldwide would have all the design resources and knowledge to understand the plant design. This would include the mathematical modelling of the safety case supporting plant design and the in-depth plant system and component behaviour, to understand the potential consequences of plant design changes. This would in some organisations be considered impractical and uneconomic expectations. To meet the safety requirements, some operating organisations have developed sound knowledge of the plant's design and the ability to manage its design specifications, but have opted to rely on specialist design agencies or the original plant designer for complex modelling. The Japanese Fukushima nuclear disaster serves as an example of where design changes, which had been implemented at other plants, but not fully implemented at the Fukushima Daichi Power Plant, could have mitigated the consequences and the progression of the nuclear accident (WNA, 2012:6).

For Generation III nuclear plants being built around the world as turnkey projects, the challenge of acquiring all the design knowledge could be even more complicated, as the number of operating utilities and countries increase. Turnkey projects have shown to have less operator involvement through the design and construction phases of the project, as the constructor is contracted to deliver a fully complete and functional plant to the owner (WNA, 2015:1).

Design changes made to a nuclear plant without a sound design knowledge base could be detrimental to nuclear safety. The study highlights that industry experience sharing and guidance to "new to nuclear" countries and utilities on design information transfer and resource requirements, in support of the Design Authority function is lacking. Further to this, no internationally agreed standards exists which ensures that the original designer guarantees that design knowledge is applied to all its international builds, as that responsibility lies with the Design Authority of the power plant.

1.4 Research Question

The main research question is as follows:

What elements should be considered for the effective establishment of the Design Authority function at commercial operation of a New Nuclear Power Plant Construction project?

1.5 Research Objectives

The objectives of this research are:

- To define the Role of a Nuclear Design Authority
- To identify key resource considerations (elements) to Nuclear Operations License Holders required to establish the Design Authority function
- To review Design Authority strategies adopted in current Nuclear Power Plant construction projects

1.6 Importance of Study

Current industry guidance on the Design Authority function within nuclear power plants has been developed over many years of nuclear power plant operation and is mainly focused on mature operating organisations. With the increase in construction activity there is a need to enhance the available guidance specifically focused on the Design Authority function for new nuclear utilities and countries. Furthermore, contractual approaches to new build nuclear power plants, especially in countries that are constructing their first nuclear power plants, may influence the role and responsibilities of the Design Authority (ONR, 2016:2).

The IAEA through its safety guidance states that no temporary or permanent modifications to a nuclear power plant should effect the safe operation of the plant, in accordance with the intent and assumptions of the plant design (IAEA, 2001:3). The current design, procurement and construction of new nuclear plants are different from the past. Technological advances have led to the extensive usage of multi-dimensional modelling, databases, and other intelligent design tools. Design information is therefore more dependent on electronic information with an inability of the operating organisation to replicate these, if not delivered as part of the design information transfer from the construction and design entities (EPRI, 2016:5).

The continued safety of nuclear power plants requires that any modifications to the plant design be done with the full understanding of the plant's design basis and the design specifications for plant components and systems. Even though a rigorous regulatory framework exists for the review and approval of changes to the plant design, it is supported by an understanding which would include detailed knowledge of the plant design (IAEA, 2003-1:3).

1.7 Limitations and Scope of Research

For the purposes of the study it is assumed that the industry standards and guidance which have been established by organisations such as the International Atomic Energy Agency, The World Nuclear Association and the Electric Power Research Institute are widely recognised and accepted by global members and international nuclear energy utilities. This is evidenced by the fact that the IAEA has 171 member states which includes the 30 countries currently operating commercial nuclear power plants worldwide (IAEA, 2019).

The research was mainly limited to a selection of five of the top nuclear energy producing countries which included France, UK, USA, South Korea and Canada. The selection was performed on the bases of access to information and participation in the World Nuclear Association's Working Group on Cooperation in Reactor Design Evaluation and Licensing's study on Design Authority. The research included an industry survey completed by 12 industry experts. Their experience had been drawn from nine countries, and eight nuclear build projects. Responses therefore included experience beyond the five selected countries and expanded to the United Arab Emirates, China, Romania and South Africa.

Research into the nuclear regulatory framework was limited to three countries, namely; India, Canada and the UK. Research into the Indian regulatory requirements informed insights into the roles and responsibilities of the Design Authority. These countries were selected as their nuclear technology designs are fundamentally different and the legal approach to issuing nuclear operating licences vary.

It is also important to note that the subject of the "Nuclear Design Authority" in operating nuclear power plants or nuclear construction projects has not been widely studied or published. The study therefore depended on limited publications from international nuclear organisations and associations as well as governmental regulatory guidance, as core literature on the subject.

CHAPTER TWO
LITERATURE REVIEW

2.1 The Current Nuclear Power Plant Landscape

In the world today, there are 30 countries operating 403 nuclear power reactors with a total installed capacity of 351 GW. This is a reduction of 35 operating reactors since the peak of 438 reactors in 2002 (Schneider, 2017:23). The annual electricity generated from nuclear power plants in 2016 reached 2 476 TWh (IAEA-PRIS, 2018). Figure 2.1 shows the current reactor population and the reduction in numbers of operating plants as plant life is reached. The World Nuclear Association (WNA, 2018:4) states that China remains the country with the largest growth. Kadak in his paper titled "*Made in China*" argues that China is not only emerging as an economic super power, but also as a world leader in the design, construction and operation of new nuclear energy plants (Kadak, 2011:15). At the start of 2018, China had 38 nuclear reactors in operation, representing approximately 9% of the world's nuclear capacity. The country continues to lead the new-nuclear build market, with three of the four new reactor grid connections in 2017, and 11 of the 54 reactors under construction (WNA, 2018:4).

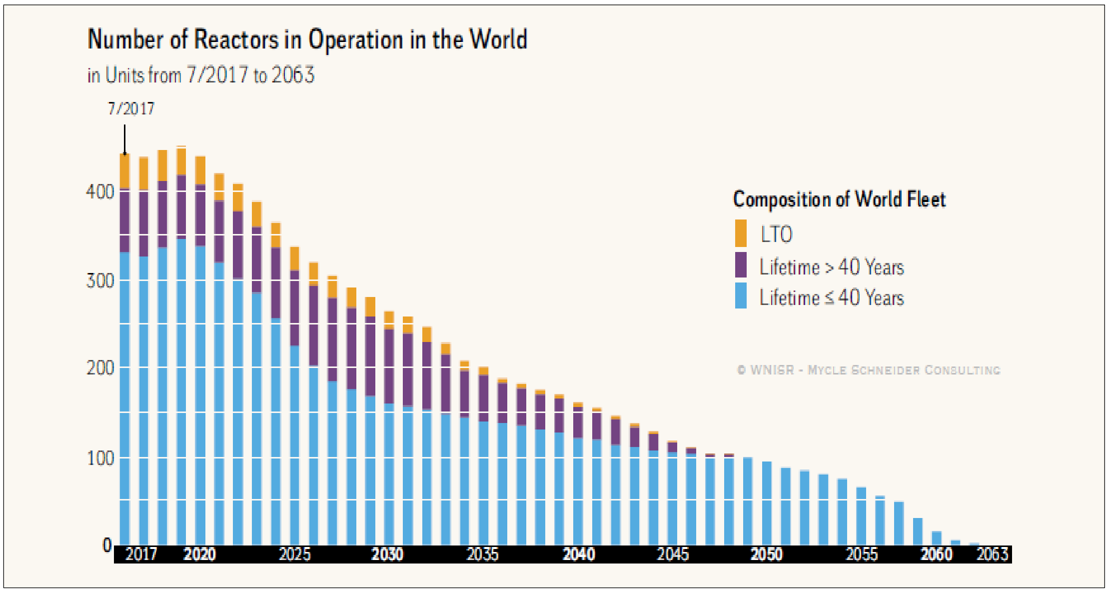

Figure 2.1: Nuclear Power Plants in Operation Worldwide (Schneider, 2017:42).

2.1.1 Nuclear power plant construction

Since 2016 twelve nuclear power reactors started operation worldwide, one in the USA, six in China, two in Pakistan, one in India, one in Russia and one in South Korea. During the same period four were shutdown, one in Russia, one in the USA, one in Sweden and one in South Korea. The reactors which were shut down in Sweden and South Korea were the oldest in those countries with over 40 years of nuclear power generation (Schneider, 2017:23).

New nuclear power plants are currently being built in thirteen countries. Figure 2.2 shows a total of 54 reactors under construction as of December 2018 (IAEA-PRIS, 2018). The projected capacity of these units being built is 53.2 GW (WNA, 2018:3). Schneider (2017:15) argues that the current growth is significant against a history of 51 units being constructed in the last decade with an average construction time of 10.1 years. This has however been influenced by reactors which have been in construction for a significant time, three in Russia which started more than 30 years ago, two units in India and Finland which has been in construction for greater than 10 years and one in Japan and France which have just about reached 10 years. Since 2016 construction began on four reactors, two in China, one in India and one in Pakistan. (Schneider, 2017:15).

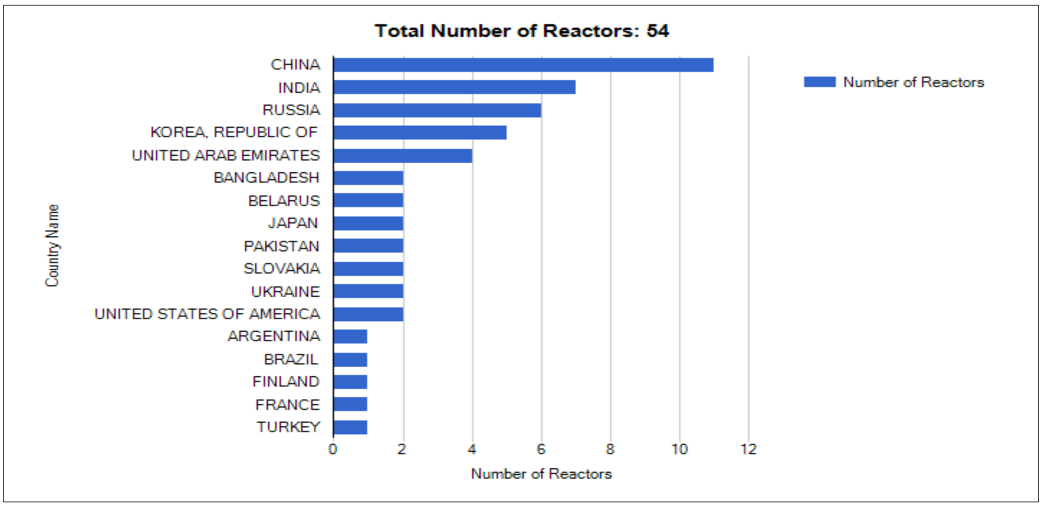

Figure 2.2: Nuclear Power Plants in Construction – December 2018 (IAEA-PRIS, 2018).

2.1.2 Future nuclear power plant projects

The IAEA has stated that the world's total energy output from nuclear power would be doubled by the year 2050. The argument assumes substantial future construction in China, India, South Korea and a significant increase in "new to nuclear" countries such as Saudi Arabia (IAEA-RDS, 2016:17).

Schneider (2017:104), argues that there are more than 20 countries in which nuclear power projects are being constructed or planned for the first time. These have been broken down into the following groups.

- **Plants under construction**

  Nuclear power plants are being constructed in the following countries for the first time:

  - **United Arab Emirates** - The Barakah nuclear project is in the process of constructing four APR 1400 reactors. The contract was signed between the Emirates Nuclear Energy Company and South Korean designer and constructor Korean Electric Power Company in 2009 with a construction license being issued in 2010. The first unit is scheduled to go commercial in the 3rd quarter of 2019 (NEI, 2016-2).

  - **Belarus** – Construction of two 1200 MWe AES-2006 Russian design reactors started in 2012. The contract between the Belarus Directorate for Nuclear Power Plant Construction and the Russian company, Atomstryexport (a Rosatom subsidiary), was signed in July 2012 with a projected completion in 2019 and 2020 for each unit respectively after several delays were encountered (NEI, 2016-1).

- **Signed contracts and well-developed regulatory infrastructure**

    - **Bangladesh –** The Economic Relations Division of Bangladesh and the Russian Finance Ministry signed an agreement to start the preparatory work for two Russian 1000MW reactors, with formal construction on the Rooppur project targeted for 2015 (Laxman, 2011). In December 2015, however the Russian design and construction company Rosatom signed a revised contract with the Bangladesh Atomic Energy Commission for a capacity of 2.4 GW (WNN, 2015-1). The government of Bangladesh has since shortlisted eight potential build sites for a second nuclear power plant in addition to Rooppur (Rasel, 2016).

    - **Turkey** - The Turkish government has adopted a strategy to build three different design reactors. The first contract was signed with Rosatom in 2010 with a projected construction start in 2015 to build four VVER 1200 reactors at the Akkuyu plant, but a construction licence is yet to be issued (NEI, 2017). The second proposed project is at Sinop to build a 4.4GW plant using the Mitsubishi and AREVA ATMEA reactor design (WNN, 2015-2). The government also indicated that plans were being developed to undertake a third project at Igneada, with the build most likely being done by the China State Nuclear Power Technology Corporation (CSNPTC) and Westinghouse (NEI, 2016-3).

    - **Vietnam** - In 2010, Vietnam signed a contract with Atomstryexport to build VVER 1200 MW reactors at the Ninh Thuan-1 nuclear site. Due to various reasons the Vietnam Atomic Energy Institute postponed the construction start to 2028 (Schneider, 2017:113); however, in 2016 the government cancelled the proposed nuclear project due to a decrease on electricity demand and an increase in construction cost (Nguyen, 2016).

- **Lithuania** – The Lithuanian government had been planning to replace the two RBMK reactors the last of which was shut down in 2009. In 2016, the Energy Minister reported that the project had been placed on hold due to economic reasons (Vilnius, 2016).

- **Committed plans and developing regulatory infrastructure**

  These are countries who have progressed through various stages of acquiring approval and financial resources for the first nuclear power plant build project.

  - **Egypt** has signed initial contracts with Russia for construction works and the training of personnel with the placement of commercial contracts expected later. The build plans are for four Rosatom VVER 1200 reactors at the Dabaa plant (Tass, 2017).

  - **Jordan** established the Jordan Atomic Energy Commission (JAEC) in 2007 and contracted Worley Parsons Engineering from Australia to preform pre-construction consulting in 2009 (WNN, 2009). After signing a developmental framework in 2014, the JAEC has been working with Rosatom to finance and build two VVER light water reactors which has not been concluded to date (Ghazal, 2016).

  - **Poland** released a Polish Nuclear Power Programme in 2014 which proposed to build 6GW of nuclear power generating capacity (Kubacki, 2014:7). In 2013 Worley Parsons was contracted by the Polish utility (Polska Grupa Energetyczna – PGE), to conduct the study for the site selection and construction and in 2017 the environmental assessment started at two potential sites (Schneider, 2017:117).

- **Countries with well-developed plans or developing plans**

    - **Thailand** – The Electricity Generating Authority of Thailand has proposed the construction of two 1GW reactors with targeted operation by 2028 (WNN, 2016).
    - **Kazakhstan** – In 2016 the government of Kazakhstan, the largest uranium producer in the world, announced that research was being started into five potential build sites for a new nuclear power plant (NEI, 2016).
    - **Chile** – The Chilean Energy Minister in 2010 announced that Chile would be constructing the first nuclear power plant of 1.1MW to start operation in 2024 with the construction of three more thereafter (WNA, 2017-1).
    - **Saudi Arabia** – The King Abdulla City for Atomic and Renewable Energy in 2011 announced plans to construct 16 reactors the first of which was planned to be operational in 2030 (WNA,2017-2)
    - **Indonesia** – The plans to build 6GW of nuclear power was cancelled by the Indonesian government in 2015 with a focus on alternate energy sources (NEI, 2015).
    - **Kenya** – The Kenyan Nuclear Electricity plans to build a 1GW reactor by 2027 and has signed co-operation agreements with South Korea and China (Wanjala, 2016).
    - **Algeria** – The Algerian government have been in discussions with Rosatom about building a 2GW nuclear plant targeted to start operation in 2026 (PEI, 2016).
    - **Malaysia** – The Malaysian economic transformation programme planned for two nuclear power plants being operated by 2021, however no firm decision has been taken to date (Bernama, 2016).
    - **Laos** – In 2016 a memorandum was signed to Russia for the construction of two nuclear power plants. To be built, operated and then transferred to the national government (WNN, 2016-1).

- **Morocco** – The Moroccan government undertook an Integrated Infrastructure Review mission in 2015 as it considers to build nuclear generating plants (IAEA, 2016).

Figure 2.3 below summarises the current nuclear construction or planning projects in countries which have not previously build or operated nuclear power plants.

Countries	Reactor Name	Proposed Vendor	Initial Startup Date	Proposed Construction Start	Official Startup date
			Under Construction		
Belarus	Ostrovets	Rosatom	2016/18		2019/20
UAE	Barakah	KEPCO	2017/18/19/20		2018/18/19/20
			Contract Signed or Advanced Development		
Bangladesh	Rooppur	Rosatom	2018	Decision expected 2017	
Lithuania	Visegrade	Hitachi	2020	Suspended	
Turkey	Akkuyu	Rosatom	2015	Final investment expected 2017	2023
	Sinop	Mitsubishi/Areva		?	
	Ingeada	SNPTC/Westinghouse		2019	
Vietnam	Ninh Thuan	Rosatom	2020	Suspended	
			Committed Plans		
Egypt		Rosatom	2019	Decision expected 2017	
Jordan		Rosatom		2019	
Poland				?	
			Well Developed Plans		
Chile			2024	Suspended	
Indonesia		Rosatom		Indefinitely Postponed	
Kazakhstan		Rosatom or Westinghouse		?	
Saudi Arabia			2020	?	2040
Thailand			2020-8	?	2036

Figure 2.3: "New to Nuclear" Power Plants in Construction and Planning (Schneider, 2017:121).

In summary the "current nuclear power plant landscape" argues that more nuclear power plants are being constructed or are planned to be constructed than in the last decade. The above figure shows at least 14 projects in "new to nuclear" countries. These countries would carry no experience in nuclear power plant operation or power plant design integrity control. It is imperative that these countries fully understand the elements required to establish a nuclear Design Authority and the responsibility that comes with preserving the plants design basis.

2.2 Nuclear Power Plant Design Philosophy

History has proven the power of nuclear fission to be catastrophic when control of its concentrated energy is not harnessed correctly or is used as weapons of mass destruction. Nuclear power plants are therefore designed with the aim of achieving the highest levels of safety which can reasonably be achieved (IAEA, 2003-1:1). The International Nuclear Power Operators Organisation (INPO) in its guidance on Nuclear Safety Culture has a view that nuclear power is unique and should be recognised as special (INPO, 2004:1). Wilkerson (2016) has a view that even in the absence of a nuclear incident, nuclear power production inevitably produces dangerous radioactive materials and waste. To ensure nuclear safety, the design of a nuclear power plant is necessarily complex requiring stringent control during plant operations to maintain the plants design base (IAEA, 2003-1:1).

Nuclear regulatory bodies have been consistent in requiring comprehensive safety assessments of the plant design as part of the licensing process prior to, during and post commercial operation. Commercial operation is defined as the point at which all commissioning tests have been completed and the plant is connected to the electrical grid (IAEA, 2020). This is performed to identify all the sources of radiation and to evaluate the potential levels of radiation dose to workers, members of the public and the environment, through normal operations, anticipated transients and accident conditions (IAEA, 2012:5). The Office of the Nuclear Regulator in the UK (ONR, 2018) states that the assessment "*allows the regulators to get involved with designers at the earliest stage, where they have the most influence. By assessing at the design stage, any potential issues can be identified and highlighted so they can be addressed by the requesting parties*". The capability of the plant design to withstand these incidents and accidents become inputs into safety assessments, emergency planning and operational philosophies, regardless of how low the probability of the occurrence of an accident is (IAEA, 2012:6).

The IAEA in its Safety Standard SSR - 2/1 (2012:13) , Safety of Nuclear Power Plants: Design states that "*The design for a nuclear power plant shall ensure that* *the plant and items important to safety have the appropriate characteristics to ensure that safety functions can be performed with the necessary reliability, that the plant can be operated safely within the operational limits and conditions for the full duration of its design life and can be safely decommissioned, and that impacts on the environment are minimized*" . It is imperative at the early stages of a build project through the design and construction phases to ensure that systems, structures and components (SSCs) and design, are built and tested to the approved codes, standards, quality and regulatory requirements. This extends to ensuring that all design, supply and manufacturing work is performed by appropriately qualified staff with sufficient levels of control. It is incumbent on the regulatory body to review the processes developed by the licence applicant to ensure that all organisations involved in the design and construction have the ability to meet these requirements (IAEA, 2010:25).

The IAEA (2012:1) states that the fundamental objective of a nuclear power plant design is to achieve the highest level of safety that can reasonably be achieved consistent with the following:

- To prevent accidents with damaging consequences as a result of the loss of control of the reactor core or other radioactive sources and to mitigate the consequences of any accident which occurs (IAEA, 2012:1).
- To ensure that for all postulated accidents taken into account for the design, that potential radiological consequences are below the applicable limits and be kept as low as reasonably possible (IAEA, 2012:1).
- To ensure that the probability of the occurrence of an accident with serious radiological consequences is very low and that all practical measures will be taken to mitigate such radiological consequences (IAEA, 2012:1).

2.2.1 The concept of Defence in Depth

The concept of Defence in Depth (DID) is to develop a tiered approach to all safety related activities in an independent manner, so that the failure at one level would be detected and mitigated or corrected appropriately by the next level (AERB, 2014:7). The USNRC (2017) defines the concept of DID as being an approach to designing and operating nuclear power plant that averts and mitigates incidents that release radiation or hazardous materials. The crucial factor is creating multiple independent and redundant layers of defence to compensate for human error and plant equipment failures so that no one layer, no matter how strong, is overly relied upon. The AERB (2014:7) explains that this is done to ultimately protect people and the environment from the harmful effects of radiation. The concept is applied to design, organisational and behaviour related activities in all phases of nuclear power plant operation, shutdown or full power. The approach has become the primary means of preventing or mitigating the consequences of accidents at nuclear facilities (AERB, 2014:7).

The operations phases are identified and clustered into a set number of categories according to their probability (or frequency) of occurrence. The categories typically include normal operation, anticipated operational occurrences or evolutions, design basis accidents and beyond design base conditions, including severe accidents with significant degradation of the reactor core (AERB, 2014:7).

The NEA (2016:12) argues that the effectiveness of the protection is established using the principles of redundancy, diversity, segregation, physical separation and single-point failure protection (NEA, 2016:12). There are five levels of DID in the design of a nuclear power plant which are typically introduced into equipment, procedures and other inherent features (AERB, 2014:8-9). These are described in Table 2.1 which are implemented as independent levels:

Level of defence in depth	Objective	Essential means
Level 1	Prevention of abnormal operation and failures	Conservative design and high quality in construction and operation
Level 2	Control of abnormal operation and detection of failures	Control, limiting and protection systems and other surveillance features
Level 3	Control of accidents within the design basis	Engineered safety features and accident procedures
Level 4	Control of severe plant conditions, including prevention of accident progression and mitigation of the consequences of severe accidents	Complementary measures and accident management
Level 5	Mitigation of radiological consequences of significant releases of radioactive materials	Off-site emergency response

Table 2.1: Levels of DID (NEA, 2016:11)

The AERB (2014:9) states that the design philosophy and the concept of DID is critical to the understanding of the immense scope and ultimate responsibility of the Design Authority. It stretches across physical barriers as well as active and passive safety systems and inherent safety features, which support the physical barriers that are challenged during design and beyond design base events and accidents. The designs of nuclear plants are unique and requires specialist knowledge and detailed processes to maintain design integrity (AERB, 2014:9).

2.2.2 Chernobyl and Fukushima Accidents – Design Deficiencies

Chernobyl

The Chernobyl accident occurred on the 26th April 1986 and was the result of a reactor design with inherent design flaws and personnel who were inadequately trained to manage the evolution of the safety event. This resulted in a steam explosion which released radioactive material into the environment, caused multiple deaths and left the immediate surrounding area uninhabitable (WNA, 2020:1).

Chernobyl's RBMK-1000 is a Soviet-designed and built graphite moderated pressure tube type reactor. It is a boiling light water reactor, using slightly enriched (2% U-235). The most significant features of the RBMK reactor is that it is design with a positive void coefficient and steam voids could lead to an increase in core reactivity. During special testing being performed on Unit 4, operators took actions in violation of the plant's technical specifications and ran the plant at very low power, without adequate safety precautions (NEI 2008). At the time of the accident the plant configuration and power level led to a positive void coefficient. By the time that the operator attempted to shut down the reactor, it was in an unstable condition great enough to overwhelm the plants safety systems (WNA, 2020:3). These factors contributed to a power surge that lead to the destruction of the reactor and a reactor core meltdown (NEI, 2008). The design features of the reactor with damage to as little as three or four fuel elements resulted in the complete destruction of the reactor (WNA, 2020:3)

The State Committee on the Supervision of Safety in Industry and Nuclear Power released a report in 1991 on the root cause of the accident. The report concluded that operators had placed the Unit 4 reactor into an unstable condition by violating operating procedures and principals. It also concluded that the operating organisation had not been made aware of the design deficiencies, which made the RBMK reactor hazardous at low power operation (WNA, 2020:4).

Since the Chernobyl accident many modifications had been performed to address design deficiencies in all RBMK reactors still operating (WNA, 2020:10). These modifications included a reduction in the void coefficient of reactivity and improving the safety response protection systems. This was followed by changing to the operations philosophy which maintained operating safety margin and prevented safety systems from being bypassed (WNA, 2019:3).

Fukushima Daiichi

On the 11th March 2011, following a major earthquake, a tsunami damaged the power supply system and cooling capability of three Fukushima Daiichi reactors. This was significant enough to cause core damage to all three units within three days. It also resulted in high radioactive releases to the environment, particularly in contaminated water leaks. No immediate deaths were reported from the nuclear event, but almost a 100 000 people were forced to be evacuated and eventually relocated (WNA-1:2020:2).

The Fukushima Daiichi nuclear plant was originally designed with a tsunami height of 3.1 meters based on the 1960 Chile tsunami and was built about 10 meters above the sea level. During the event the tsunami wave height reached 15 meters and most of the Daiichi plant was under 5 meters of seawater (WNA-1:2020:2). The design had been based on the scientific knowledge in 1960, but 18 years before the event of 2011 new information indicated that a large earthquake could result on tsunami wave to the height of 15.7 meters at the Daiichi plant. No notable action was however taken by the operating organisation of the nuclear regulator (WNA-1:2020:2).

A critical factor that contributed to the accident was the incorrect assumption that the Japanese nuclear power plants were very safe and that an accident of this magnitude was not realistic. The accident exposed major deficiencies in the plant design, in emergency preparedness and in planning for the mitigation of a severe accident (WNA-1, 2020:18).

The accident investigation had concluded that the main safety systems of the plant were unaffected by the vibratory ground motions, as a result of the design and construction. The design safety margin for extreme flooding was however not comparable resulting in notable risk exposure (WNA, 2020:19). During the 40 years of operation at the Daiichi Plant, many countries had studied and implemented safety modifications and had established configuration requirements that could have mitigated the Fukushima Daiichi Plant accident (Acton, 2012:19). These had included safety reassessments of extreme flooding; station blackouts and loss of the ultimate heatsink. Safety experts have concluded that if these developments had informed design and configuration changes at the Daiichi Plant, the severity of the accident could have been reduced (Acton, 2012:19). The Fukushima accident had not revealed fatal flaws which were previously unknown to the nuclear industry. Rather, it emphasised the critical importance of periodically reviewing the defence in depth of the plant design to ensure sufficient margin to safety (Acton, 2012:2).

In summary, Acton argues that the body of evidence grows indicating that past nuclear accidents are as a result of the failure of the nuclear plant design especially where it was lagging behind international best practice and standards (Acton, 2012:3).

2.3 Design Basis and Design Authority

In developing an understanding of the roles, responsibilities and need for a Design Authority, it is important to define and understand the theory behind the establishment of the plant design basis for a nuclear power plant, and design basis information that would be required during plant operation. In particular, the regulatory requirements and standards that must be met when submitting the design basis of a nuclear power plant, as part of a safety case (or safety assessment), for regulatory approval (CNSC, 2008:11).

2.3.1 Defining the design basis

In nuclear power plants the design basis for structures, systems and components (SSC) defines the specific functions to be performed and the design and operating parameters, values or ranges of values supporting the parameters. The NEI (1999) states that these values may be limits derived from generally accepted operational practices for achieving safety goals. These may also be requirements developed from engineering analysis of the effects of a postulated accident, for which SSC must meet their safety and operational goals (NEI-1, 1999:2). These are typically used by plant and regulator personnel to review the acceptability of the original design and form the reference or baseline requirements for further modifications (CNSC, 2008:15).

The United States Nuclear Regulatory Commission (USNRC) 10 CFR 50.2 (Domestic Licensing of Production and utilization Facilities) (USNRC, 1991:3) defines the Design Bases as "*information which identifies the specific function to be performed by a structure, system, or component of a facility, and the specific values or ranges of values chosen for controlling parameters as reference bounds for design*"(USNRC, 1991:3).

The IAEA-TECDOC-1335 (Configuration Management in nuclear power plants) (IAEA, 2003-1:35) defines the Design Basis as **"***Any combination of the specifications, criteria, codes, standards, analyses, constraints, qualifications, and limitations which determine the functions, interfaces, and expectations of a facility, structure, system or component. The design bases identify and supports "WHY" design requirements are established. Calculations are typically considered part of the design bases. Calculations generally translate design bases into design requirements or confirm that a design requirement supports the design bases*". The "WHY" in this case refers to the reason for the design requirement being established (IAEA, 2003-1:35).

The IAEA states that the following critical plant information is embedded in the plant design basis (IAEA, 2010-1:57-67):

- The function of SSC;
- The process that satisfies the functional requirements;
- The key parameters of the function and process;
- The design safety margins;
- The dependencies and interfaces with other SSCs;
- Requirements during accident and failure scenarios;
- Industry codes and standards applied to the design (IAEA, 2010-1:57-67).

Since the Design Basis is established at a structural or system level, it sets the foundation for the specification and selection of substructures, subsystems and system components. These design bases are developed during the early stages of the design process and becomes the design reference for the life of plant (IAEA, 2003:38).

In the case of certain older plants, sections of the design basis were either irretrievable or undocumented, and the recovery required significant effort to reconstitute the design basis (INL, 2007:5). In summary the accessibility to design basis information and documents in support of the Plant Design Basis is therefore critical for plant operation and thus the execution of the Design Authority function.

2.3.2 Defining the Design Authority

In 2003 the IAEA mandated its International Nuclear Safety Advisory Group (INSAG) to develop requirements for the nuclear Design Authority function. The resultant report INSAG-19 (IAEA, 2003) – Maintaining the Design Integrity of Nuclear Installations through their Operating Life defines Design Authority as: *"The designated entity that takes the overall responsibility for the design process, approval of design changes, and for ensuring that the requisite knowledge is established, preserved and extended with experience"* (IAEA, 2003:4).

This definition has remained fairly consistent throughout industry as captured below as referenced by various agencies, utilities and regulators:

- ASME NQA-1 defines Design Authority as: "*The organization having the responsibility and authority for approving the design bases, the configuration, and changes thereto*" (ASME, 2012:5).

- The USNRC in NUREG-1397 (An assessment of design control practices and design reconstitution programmes in the nuclear power) defines Design Authority as" the *organization having responsibility for maintaining the design bases and ensuring that design output documents accurately reflect the design bases*" (USNRC, 1991:4).

- The British Office for Nuclear Regulation (ONR) guide NS-TAST-GD-079 (Nuclear Safety Technical Assessment Guide) defines Design Authority as "*the defined function of a licensee's organisation with the responsibility for, and the requisite knowledge to maintain the design integrity and the overall basis for safety of its nuclear facilities throughout the full lifecycle of those facilities. Design Authority relates to the attributes of an organisation rather than the capabilities of individual post holders*" (ONR, 2016:2).

- The Atomic Energy Regulatory Board of India in its Safety Code for the design of light water reactor based nuclear power plants defines Design Authority as: "*The defined function of a licensee's organisation with requisite knowledge and with responsibility for maintaining the design integrity and the overall basis for safety of its nuclear facilities throughout the full lifecycle of those facilities. Design Authority relates to the attributes of an organisation rather than the capabilities of individual post holders"* (AERB, 2014:3).

In summary from the literature extracts the following attributes are common to the various definitions. "The Design Authority: has the overall responsibility and authority over design changes, possesses the requisite **knowledge** and manages the **design control process** to ensure the integrity of the Nuclear Power Plant Design". The elements of "knowledge" and "a design control process" have emerged as critical considerations from these international standards.

2.3.3 The need for a Design Authority

The IAEA through various published safety standards has argued that the responsibility for the safe operation of nuclear power plants and the protection of its personnel and the public lies with the licensee (IAEA, 2012:11). It is therefore understood that the Design Authority should be in the licensee's organisation. The IAEA Safety Standard SSR 2-1 (IAEA, 2012:11) documents the requirement as: "*The operating organization shall establish a formal system for ensuring the continuing safety of the plant design throughout the lifetime of the nuclear power plant*". This requirement is consistent with the definition of Design Authority in the IAEA INSAG-19 Safety Report (IAEA, 2003:4).

The Western European Nuclear Regulators' Association (WENRA) publication Safety Reference Levels for Existing Reactors (WENRA, 2014:7) goes further in stating that: "*The licensee shall always have in-house, sufficient, and competent staff and resources to understand the licensing basis of the plant (e.g. Safety Analysis Report or Safety Case and other documents based thereon), as well as to understand the actual design and operation of the plant in all plant states*" (WENRA, 2014:7) .

The operating lifetime (construction, commissioning, operation and decommissioning) of a plant may span over decades and is likely to undergo many changes during this period. There are various reasons for plant changes, some of which may include aging of the physical structures, systems and components; obsolescence of installed plant equipment; design improvements recommended through assessments or operating experience from industry; improved analysis techniques and research of safety issues; enhanced regulation (IAEA, 2010-1: 4-6).

In the design of nuclear power plants, the original design should consider that the radiation risk to personnel and the public remains present from construction through to decommissioning, and that decommissioning aspects are included in the initial licensing application submitted to the regulator (AERB, 2014:48). During the decommissioning phase and dismantling of the plant, it remains important to understand and maintain control of the changes to the design basis and the changes to the safety functions of shared systems and components (IAEA, 2010-1:16). The AERB (AERB, 2014:12) further states that: "*The responsible organisation shall establish a formal system within its management system for ensuring that the plant design remains safe throughout the lifetime of the nuclear power plant including decommissioning*". The potential impact of plant modification to the decommissioning process should therefore be understood by the Design Authority, and the change information should be made available to the organisation managing the decommissioning plans for the plant (IAEA, 2011:38). The Design Authority function therefore continues through decommissioning of the plant.

Since the Design Authority carries the responsibility for changes to the nuclear plant design and becomes the authorising entity for the implementation of changes to that design, the WNA (2015:4) concludes that the Design Authority also carries the authority not to implement certain modifications considering economic, local and regulatory conditions. As evidenced by the Fukushima disaster, the risk of not implementing proposed safety modifications could be detrimental in the event of a nuclear accident (WNA, 2015:4).

The IAEA in its safety standard for plant configuration (IAEA, 2010) explains that engineering design changes are the most significant way to implement changes or modify a nuclear power plant (IAEA, 2010-2:5). It entails any physical or functional amendment (addition, deletion or replacement) to the design or design basis of SSC. These design changes are to be implemented within the requirements and limitations of the applicable codes, standards, licence requirements, specifications, procedures and prescribed safety restrictions (IAEA, 2010-2:5).

The established plant configuration management process ensures that this is executed within the design requirements and the original design basis. This change process ensures that all the required documentation is aligned to the resultant change and the physical plant. Figure 2.4 shows that design changes receive inputs from various sources to fully evaluate the proposed change and ensures that all the changes to the required outputs are affected (IAEA, 2010-2:5).

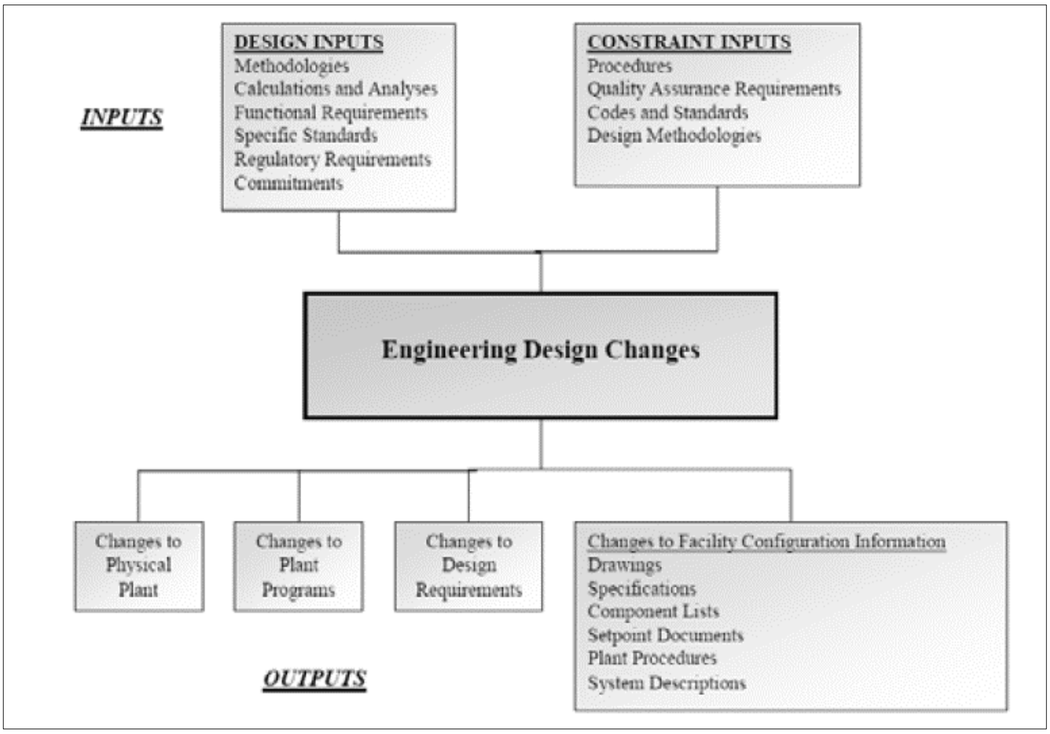

Figure 2.4: Plant Design Change Inputs and Outputs (IAEA, 2010-2:5)

In summary it is imperative for the operating organisation to setup a formal internal process to manage and maintain the plants design integrity from the point at which it takes control of the facility. This may be done by establishing internal engineering capability within the organisation or by maintaining a formal relationship with the original design organisations. These arrangements would still require the appointment of a designated entity as the Design Authority, within the operating organisation to be responsible for the process and will be required to review and approve all proposed design changes (IAEA, 2003:4).

2.4 Regulation and Standards on the establishment of the Design Authority

2.4.1 International standard

The WNA (2012:2) emphasises that nuclear energy regulatory bodies around the world require operating organisations to have an officially appointed entity to own the design knowledge and control changes to the plant design. In commercial nuclear power plant operation, the responsibility is typically placed onto the licence holder, who would be the operating utility (WNA, 2012:2).

The IAEA's Fundamental Safety Principal 1 (IAEA, 2006:6) states that *"The prime responsibility for safety must rest with the person or organisation responsible for facilities and activities that give rise to radiation risks"*. Boath (2014:5) clarifies this requirement that the responsibility may not be delegated by the licensee and that employees, contractors, suppliers, constructors and designers have legal, professional and functional responsibilities in the area of safety. The responsibility for establishing and maintaining the required competencies, establishing procedures and processes, verifying the design safety features, ensuring quality of the facility and the equipment, ensuring the safe control of radioactive material and waste is the direct obligation of the licensee (Boath, 2014:5).

The IAEA further mandated a report by its International Nuclear Safety Advisory Group which focused on maintaining the design integrity of nuclear installations throughout their operating life. The report, INSAG 19, was aimed at, amongst others, senior utility executives who are responsible for the overall safety of the nuclear facility and has since been used as the basis for the development of the IAEA Specific Safety Requirements IAEA SSR-2/1 "Safety of Nuclear Power Plants: Design" (IAEA, 2003:1). INSAG 19 provides guidance for establishing the Design Authority within the licensee organisation (WNA, 2017:6).

The IAEA Safety Guide for Modifications to Nuclear Power Plants (NS-G-2.3) (IAEA, 2001:3) captures the requirements that "*No modification to a nuclear power* *plant, whether temporary or permanent, should affect the plant's ability to be operated safely in accordance with the assumptions and intent of the de*sign". It further clarifies that management of the modifications is the responsibility of the operating organisation and that regulatory involvement should be based on the safety significance of the change which would require a formal submission and approval.

These international standards have been cascaded from IAEA guidance into various regulations developed by Nuclear Regulatory Bodies in IAEA member countries (IAEA, 2003-1).

2.4.2 Regulatory requirements for selected countries

For the purpose of the study, regulatory requirements with respect to the establishment of a Design Authority have been researched for a select few countries that have been prescriptive in the establishment of Design Authority requirements.

- **United Kingdom: Office of the Nuclear Regulator (ONR)**

  With the background that a nuclear plant design is a product of the work done by many organisations, that changes will be made periodically, but that these changes should be made with the full knowledge of the design and safety functions, the ONR has developed specific assessment principals. These, supported by a suite of guides, are used by its inspectors to review the Design Authority capability of potential and existing license holders understanding that the design knowledge has to be maintained for the lifetime of the plant to decommissioning (ONR, 2016:8).

  The UK Nuclear Regulator thereby expects that the licensee has the following in place:

  - a formal process to understand and maintain the plant design;
  - sufficient technical capability to understand the analysis requirements;

- ownership for the safety analysis and a full understanding of the function and performance of the plant; and
- the ability to maintain the design basis and records for design changes, operating experience that could impact the design (ONR, 2016:7-8).

The ONR recognises the licensee may not carry all the specialised knowledge on systems and components, but may be able to demonstrate suitable Design Authority capability though the contractual appointment of Responsible Designers. The requirement for the Design Authority to be identified within the licensee organisation does not change. The ONR also makes mention of the concept of the 'Design Authority Intelligent Customer' to fully understand the results and implications to the plant design and safety functions of the work done by the Responsible Designers (ONR, 2016:7).

The principals detailing the ONRs expectations of the Design Authority capability is summarized below (ONR, 2016:8-14):

- **Principle 1-** The Design Authority should be a distinct function within a licensee's organization which is independent of plant operations and has a clear reporting line to the board of the licensee organisation.
- **Principal 2** – The Design Authority should have the responsibility and authority to approve or reject recommended design changes and concessions.
- **Principle 3** – The Design Authority should have the capability to understand the entirety of the design and nuclear safety analysis in the context of each phase of the plant life cycle.
- **Principle 4** – The Design Authority should have the resources, capability and processes to review changes to the plant's

performance, conditions and operating limits and hold the authority to recommend modification to or suspension of nuclear operations.

- **Principle 5** – The Design Authority should have current knowledge, expertise and resources.
- **Principle 6** – The Design Authority should periodically review and determine the continued adequacy of the plant's design and safety analysis and have the authority to address areas of concern.
- **Principle 7** – The licensee may choose to establish an agreement with a 'Responsible Designer' in areas where it does not carry the specialised knowledge of systems and components important to safety (ONR, 2016:8-14).

- **India – Atomic Energy Regulatory Board (AERB)**

The AERB in the publication of its Safety Code in 2014 (AERB, 2014:11) has a view that the applicant for the licence to construct or operate a nuclear power plant shall undertake the responsibility of ensuring that the submitted design meets the safety objectives. In order to fulfil the responsibility, the organisation shall establish a Design Authority with the responsibility for, and the knowledge required to maintain the design integrity and safety basis of the plant throughout its life (AERB, 2014:11).

Ownership for the safety analysis remains with the organisation with the primary responsibility for safety, the licensee, which requires the following:

- a complete understanding of the safety analysis including the applied standards and its assumptions leading to limits and conditions;
- the technical expertise to understand the safety analysis and work produced by supporting organisations; and
- participation in the development of the Safety Analysis to ensure that operational needs are met (AERB, 2014:11).

- **Canada – Canada Nuclear Safety Commission (CNSC)**

  The regulatory requirements for nuclear power plant designs in Canada have been published by the CNSC in the regulation document RD-337 "*Design of New Nuclear Plants*" (CNSC, 2008:1). This document establishes a set of comprehensive design expectations and offers examples of optimal design characteristics that are aligned to accepted international codes, standards and practices. All aspects of designs are considered and DID is promoted in design considerations (CNSC, 2008:1). The regulations set out the requirement that during the design phase, which is pre-construction, the Design Authority shall be within the organisation that has the overall responsibility for safety and that this responsibility may be transferred to the operating organisation prior to plant start-up. It further emphasises the allowance of assigning the responsibility for the design of specific sections of plant to Responsible Designers which is established as a formal documented agreement. The overall responsibility still resides with the Design Authority (CNSC, 2008:1).

  It is required of the Design Authority to achieve the following requirements in the design phase (CNSC, 2008:9):

  - Establishing the knowledge on the current plant design and sustaining this knowledge while considering operating experience.
  - Ensuring the availability of design information required for operation and establishing the security protocols to control access to classified information.
  - Establishing control necessary to review and approve design changes and for design configuration management.
  - Ensuring the required engineering and scientific knowledge and skills exists so that the impact to safety, as a result of proposed changes is fully understood (CNSC, 2008:9).

Regulatory requirements and international standards such as the IAEA Safety Standard SSR-2/1 have been consistent in requiring licensees to establish the knowledge and skills required to preserve the design integrity of the nuclear power plants as the Design Authority (IAEA, 2012:9).

In summary the legal framework existing in the nuclear industry holds the licensee solely responsible for the safety and integrity of the nuclear power plant design. From the extracts above certain regulators have the expectation that the Design Authority is established during the design phase of the project prior to plant construction. The design and construction of these plants involves many technical participants, design agencies, architect engineers, nuclear steam supply system (NSSS) and balance of plant designers. This specifically creates complex, massive and often unique infrastructure projects. This will be further explored in later sections of the study. In comparison to the aerospace industry, where the architect designer fulfils the role as the Design Authority for its section of the aircraft while the aircraft operator retains the responsibility for safety and reliability (WNA, 2012:4). This concept is also further explored later in the study.

2.5 Role of The Design Authority and Supporting Entities

The study has identified that there are various definitions of the Design Authority in many standards and documents on nuclear plant design and configuration management. The role of the Design Authority needs to be defined taking the roles of the supporting entities such as Design Agencies, the greater operating organisation and the regulatory body into consideration.

2.5.1 Role of the Design Authority

The WNA (2015:6) describes the role of the Design Authority as having to ensure that the knowledge of the plant design that is required for safe operation, maintenance and modifications are available and current so that the design requirements and configuration management may be maintained throughout the plant life (WNA, 2015:6). This requires the necessary engineering, scientific and technical expertise to be established and maintained within the operating organisation. The need to review, verify, document an approve all design changes implies that the design knowledge would have to be transferred from the vendor or plant designer to the operating organisation, even though more highly specialised information such as detailed design calculations, codes and method, may be challenging to acquire due to the protection of intellectual property (WNA, 2015:6). In a technical paper written in 2007 by nuclear specialists from four American Nuclear Utilities namely; Florida Power and Light, Duke Power, South Carolina Electric and Gas, and Carolina Power and Light, the following have been described as the key roles of the Design Authority. The efforts were in support of providing guidance on design configuration management to utilities considering and undertaking new nuclear construction projects, and to provide strategies for utility managers and suppliers during design, construction, testing and turnover of new plants (CDSV, 2007:2-4):

- The Design Authority is responsible for ensuring that plant configuration is established and maintained throughout the design, construction, commissioning and operating phases of plant life. This responsibility may be shared and may transition from one organization to another through the build project life cycle (CDSV, 2007:2-4).

- The Design Authority should be established through a formal appointment within the operating organisation. Where the Design Authority may be outside of the operating organisation the structure should be contractually established, fully defining roles and responsibilities, until the transfer to the operating organisation (CDSV, 2007:2-4).

- The Design Authority holds the responsibility for change control. Change control covers the full scope of design changes from the conceptual design phase to detailed system design requirements and the construction phase of the build project (CDSV, 2007:2-4).

- The Design Authority ensures that the potential transitioning of the authority through the construction phase to the operational phase of the project is established. The transition plan should include key milestones and deliverables such as, when transition occurs, that the transition of the required design information has been completed and verified and that transition shortfalls are documented and tracked to resolution (CDSV, 2007:2-4).
- After the transition from construction to operation, the Design Authority should clearly identify the "documents of record" which will be kept current as changes are implemented (CDSV, 2007:2-4).

Kilic (2014:27) argues that the role of the Design Authority entity is to ensure that the plant meets the acceptance criteria for safety, reliability and quality in accordance with laws, regulations, codes and standards. The detailed responsibilities are described in further detail by Kilic as follows (Kilic, 2014:27):

- Management of the design requirements and maintaining configuration management;
- Controlling the interfaces with suppliers and Responsible Designers;
- Establishing the required technical, engineering and scientific expertise;
- Reviewing and verifying, documenting and approving all design changes to the plant;
- Ensuring that documentation is maintained to facilitate future plant decommissioning;
- Ensuring that the plant design meets the requirements for optimising protection and safety by keeping radiations risks as low as reasonably possible;

- Verifying that that formal system includes the definition of codes and standards, provides construction and operational experience and maintains a safety culture;
- Ensures that the knowledge required for safe plant operation and maintenance is available and is kept current with operating experience and research findings;
- To identify any design and specification concerns during the design stage of a construction project;
- Review design changes with the full understanding of the design bases, the design intent and philosophy to ensure that plant is tested, validated and compliant with design and licensing requirements;
- Liaising with the regulatory bodies on plant design changes; and
- Ensuring the transfer of technical knowledge from the design and construction entities to the operational organisation (Kilic, 2014:27).

The World Nuclear Association in its report "Implementation of the Design Authority Within a Nuclear Operating Organization" (WNA, 2017:3) describes the role of the Design Authority as:

- Obtaining design basis information from all applicable organisations;
- Verifying the adequacy of the design assumptions in the design basis against new information from operating experience, research, safety standards and regulatory requirements;
- Establishing and ensuring compliance to the design change process;
- Reviewing and approving plant design changes;
- Ensuring that plant procedures are consistent with the plant design and licensing basis;
- Ensuring that plant changes do not inadvertently challenge the original design intent and design basis relied upon to manage and mitigate design and beyond design basis accidents (WNA, 2017:3).

The Indian Atomic Energy Regulatory Board in its Safety Code for the design of light water reactors sets out the roles and requirements for the Design Authority as the development of a management system for ensuring that all the safety requirements established for the design of the nuclear plant are reviewed and implemented in all phases of the operating life through the use of qualified and adequately trained staff (AERB, 2014:11).

The difference in this description from Kilic and the WNA is that the AERB describes the role for the phases, both prior to operation (during design and construction) and for the lifetime of the plant (post construction). The management system should ensure that the quality of the design for the structure, system and components of the nuclear power plant is maintained at all times. To accomplish this the following is required (AERB, 2014:11-14):

- Prior to plant operation
    - Procedures that call for specific reviews against design codes and standards should be established for the reviews of design change, modifications and safety improvements.
    - Independent verification should be performed on the adequacy of the plant design, which includes design tools and the relevant design inputs and outputs. This should be followed by the verification and validation of the documented plant design against the as built plant before plant operation (AERB, 2014:11-14).

- For the full lifetime of plant operation

  The Design Authority has the responsibility to ensure that the plant design complies to the criteria for safety, reliability and quality in accordance with the regulatory guidance, laws and the relevant national and international codes and standards. Through exercising its control, it ensures that (AERB, 2014:11-14):

- The plant design remains current and meets the requirements by keeping the radiation risks as low as reasonably achievable;
- The continued safety of the plant is maintained through the use of proven engineering practice, the review of applicable engineering documentation, maintaining a sound nuclear safety culture, by performing safety assessments;
- All proposed design changes are acceptable against requirements for operation, maintenance and future inspections;
- The knowledge of the design and safety analysis is maintained and current and that account is taken for operating experience and authenticated research findings;
- The plant configuration control is maintained;
- The required engineering, scientific and technical expertise is established and maintained within the operating organisation;
- The required agreements with the original designer and vendors are established and maintained;
- The integrity of design inputs such as functional requirements, safety goals, regulatory requirements, seismic loads, interface requirements, applicable codes and standard is maintained;
- The integrity of design outputs such as design limits, safety limits, specifications, operating limits are maintained;
- The required specialist knowledge of design calculations, stress analysis, hydraulic analysis which demonstrate the capability of the design is available;
- The records and understanding of testing, analysis, software code validation used to validate the design is available (AERB, 2014:11-14).

In summary the ability of the Design Authority to maintain the integrity of the plant design requires the establishment of the appropriate knowledge base, which is expanded with experience. The Design Authority would be responsible for recovering the knowledge base if it has been lost. It also ensures that needed information and skill of the plant design is available to safely operate and maintain the plant (WNA, 2015:7). The authority of the Design Authority to reject design changes with potentially adverse consequences to the safety and integrity of the nuclear power plant is vitally important for nuclear safety (IAEA, 2003:7). The elements of establishing a knowledge base, securing the required information and establishing a design control process is evident from all three bodies of literature.

2.5.2 Roles of the Responsible Designer / Design Agency

This study has shown that current safety and regulatory practice holds the operating organisation responsible for the design and the safe operation of the power plant. The legal stance in most countries holds the licensee liable for all costs resulting from damages in the event of a nuclear accident (IAEA, 2003:8). The operating organisation might not however hold all the specialist knowledge of all the safety related systems and components. It may therefore establish agreements with other entities, such as original vendors, as Responsible Designers or Design Agencies. These entities would adopt the responsibility to maintain their specialist knowledge of the plant design and support the operating organisation in developing and performing design changes to the plant design (IAEA, 2003:5). The agreements may vary over time as the operating organisation gains competence. It is imperative that the relationship be formally established so that roles, levels and areas of accountability and the process by which support may be granted, for the plant design is fully understood (WNA, 2017:8-12). Even though the Design Authority may appoint Responsible Designers it may not delegate the overall responsibility for the plant design. This relationship is illustrated in Figure 2.5 below (IAEA, 2003:5).

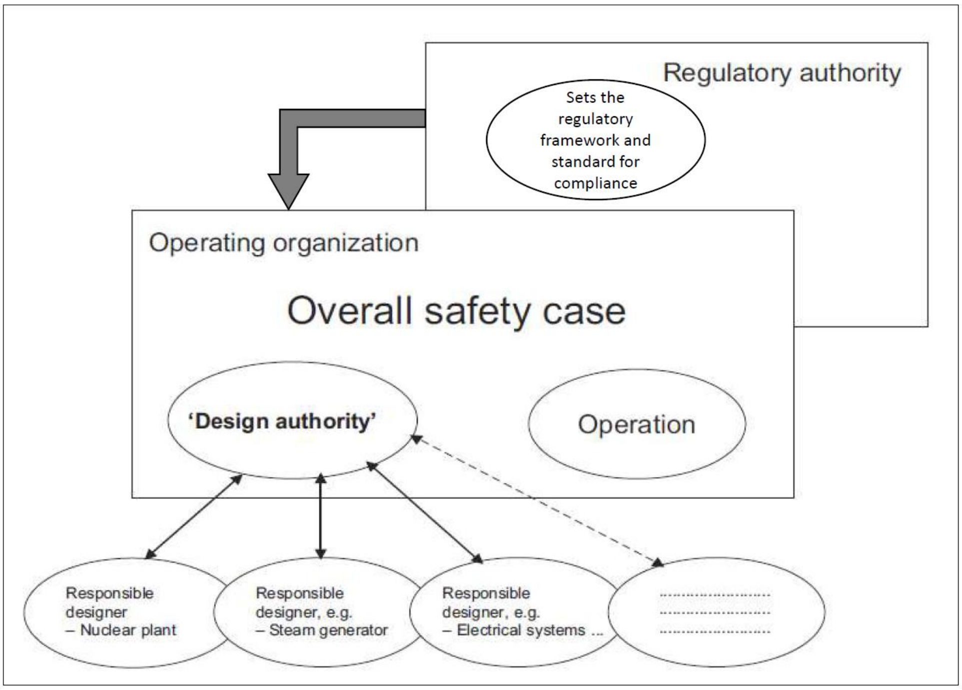

Figure 2.5: Relationship between Design Authorities and other entities (IAEA, 2003:5)

The Responsible designer is a representative of an organisation which has been formally contracted by the licensee to perform plant designs for proposed modifications. This concept is introduced in INSAG-19 (IAEA, 2003:5). In many cases operating organisations have opted to select the original plant or systems designers as the Responsible Design Agencies, that would continue supporting the Design Authority during operation. The concept of a Responsible Designer has also been captured in certain design and construction codes and standards. Section III of the ASME Boiler and Pressure Vessel Code (ASME, 2017:14), which many nuclear plants have been design and constructed to, recognises that all engineering expertise within the owner's organisation related to the design of pressure vessels will not always be sufficient. ASME defines the "designee" (Responsible Design Agency), as "*Any organisation that performs specific plant design related activities at the request of the owner*". The owner however retains the overall responsibility of the plant design.

When considering the Design Authority element of knowledge and skill the concept of 'Responsible Designers' is significant in that it does not only include the original nuclear vendor of the NSSS (Nuclear Steam Supply System), but also other equipment suppliers, detailed designers for NSSS equipment as well as those balance of plant suppliers (WNA, 2015:4).

2.5.3 The roles of stakeholders

- **Vendor/designer role**

  The WNA (2012:7) explains that the role of the original plant designer and/or supplier is important as it is the designer who retains the detailed knowledge of the design intent and of how the design came to be as it is. Original designers are therefore often involved in processing enhancements to improve safety of the design during plant operation. For smaller utilities support from original designers is often imperative to the design change control process (WNA, 2012:7).

  The WNA (Cordell) report of 2015 (WNA, 2015) has shown a precedence for licensee ownership of the design basis especially where large fleets, in countries such as France and South Korea, have built plant of the same design and have adopted technology transfer agreements with the original design entities (WNA, 2015:16). In these cases, even though utilities have built significant internal capability, some level of contracted support is retained with the original designers and the degree of design ownership is aligned to the degree of capability of the utilities Design Authority (WNA:2015:15).

  Vendors also play a role in the sharing of operating experience with plants which have adopted their design which often supports design enhancements, understanding failure modes of systems and components and maintaining design knowledge. Most vendors have developed internal "Design

Authority" functions with the intent of keeping a history of various design changes they have performed or supported including the basis for these changes (WNA, 2012:8). The vendor also plays a role in staying current with new research findings and developments, understanding potential impact to the design basis of the plant (WNA, 2015:9).

In summary it should once again be re-iterated that even though vendors provide services from an historical base it remains the responsibility of the operating organisation to ensure that the professional competence, experience and qualifications of the contracted vendor complies to the standards in effect at the plant (IAEA, 2001:8).

- **Role of the operating organisation**

  The roles of the operating utilities have various ranges due to the structure of the organisations. These have ranged from small utilities running various plants, under the same regulations to larger utilities operating fleets in various countries with varying regulations. Smaller utilities have been unlikely to carry all the resources required to fully support every aspect of the plant design. They typically depend on supporting design organisations such as original designers, where the utility takes advantage of the vendors design capability while still maintaining formal accountability for design control (WNA, 2012:11). Utilities have therefore adopted the role of establishing contractual agreements with supporting design organisations on a long-term basis. This ensures the knowledge management of the design in both understanding the original design basis and evaluating the potential impacts of any proposed changes, even though the utility remains legally responsible for any decisions supporting change (WNA, 2012:12).

  The legal role of the licensee is emphasised in International standards in that the primacy of the licensee's role in nuclear safety remains: (IAEA, 2006:6) "*The licensee retains the prime responsibility for safety throughout the lifetime of facilities and activities, and this responsibility cannot be* *delegated. Other groups, such as designers, manufacturers and constructors, employers, contractors, and consignors and carriers, also have legal, professional or functional responsibilities with regard to safety*" (IAEA, 2006:6).

The key role of the operating organisation is therefore to establish the Design Authority with sufficient knowledge of the plant design to be an 'Intelligent Customer' and to know what is important to operate their plant safely (WNA, 2015:7).

In summary the operating organisation may opt to use Responsible Designers in support of its execution of the Design Authority function, at which point the concept of Knowledgeable or Intelligent Customer becomes a fundamental prerequisite. Some important attributes include: understanding the plants design and licensing basis (knowledge element), playing an active role and taking ownership for the plant change process including those changes performed by Responsible Design Agencies (process element), maintaining ties to NSSS vendors and architect engineering organisations who participated in the original plant design and staying abreast of operating experience from the same design plants and assessing applicability (WNA, 2017:3-4).

- **Role of the regulator**

The IAEA emphasises (IAEA, 2003:9) that inadequate management of the nuclear power plants design integrity could lead to a significant increase in nuclear safety risk. INSAG-19 therefore recommends that the establishment of the Design Authority and the related programmes be verified by regulatory bodies (IAEA, 2003:9). This requirement continues through regulatory oversight of the design integrity as changes are implemented, the establishment of design knowledge and competence and the effectiveness of the established configuration management process in preserving the margins to safety, over the operating lifetime of the plant (IAEA, 2003:9).

The IAEA (2001:7-8) states that the extent of regulatory body involvement in the configuration management process of a power plant depends on the regulatory regime adopted and varies from country to country (IAEA, 2001:7-8). Many regulatory bodies have established a graded approach to the level of involvement, based on the degree of potential safety significance a design change may present. The regulatory reviews of proposed design changes may therefore vary from a full review of the proposed modification and the associated safety analysis, prior to implementation, to a simple notification of minor non-safety significant changes (USNRC, 2015:3). The requirements for regulatory body reviews have typically been included into national regulations. The resultant regulatory reviews and inspections of design change projects are performed on the basis of compliance to the operating licence requirements (IAEA, 2001:7-8).

2.5.4 Roles when establishing the Design Authority

Build projects for nuclear power plants are often performed through joint ventures and consortia models. The question of which organisation holds the responsibility for the plant design through the different phases of the build project has come up in some cases. The WNA (2015:3) has a view that for many utilities this strategy has been dependant on the organisational structure and the ability to acquire the plant design information, and the specialist design knowledge of systems and components important to safety. For plants built on a turnkey basis, in countries with little or no nuclear power industry, it is even more challenging to properly establish the necessary requirements to assume the Design Authority role (WNA, 2015:3).

The establishment of a Design Authority, with the appropriate design knowledge and access to the plant design information is not trivial. INSAG-19 (IAEA, 2003:3) recognises the significance and states that: *"The operating organization must assure itself that a formal and rigorous design change process exists so that changes can be made with full knowledge of the original design intent, the design* *philosophy and of all the details of implementation of the design, and that this knowledge is maintained and added to throughout the lifetime of the plant".*

It further states that: (IAEA, 2003:5) *"the role and accountabilities of the 'Design Authority' within the operating organization, the specific roles that have been assigned to the Responsible Designers, the precise areas that the Responsible Designers are held accountable for, and the processes that must be followed for each of the parties to exercise their responsibilities properly, must be defined very clearly".*

2.6 Elements of the Design Authority Function

The key objective of this study is to identify the Design Authority elements to be considered in support of establishing the function prior to nuclear plant operation. The literature has noted various fundamental elements (prerequisites) that are important to a Design Authority being able to perform the required role effectively. Three dominant elements emanating from the review are therefore studied in more depth in this section of the report. These are the establishment of the required knowledge of the plants design basis, acquiring the plant design information, supporting basis and data and finally establishing a process for design control, referred to as the configuration management process.

2.6.1 Skills and knowledge

The WNA (2017:8-12) describes the ability to review and approve design changes as fundamental to the functioning of the Design Authority (WNA, 2017:8-12). To effectively perform this function, it must have sufficient knowledge of the design, the associated design intent and have the appropriate engineering, scientific and technical expertise (IAEA, 2003:3) This is often complicated by the fact that nuclear plant construction projects are typically a unique combination of nuclear island, balance of plant and auxiliary plant systems which could be from a consortium of different designers assembled for the specific project. This means that the operating organisation would often be the only entity with the consolidated view of the entire plant design (WNA, 2017:8-12).

Since licenced operating utilities, in many instances, would not be the original design or construction entity, they would not hold the level of technical design expertise within the organization needed to fully perform the required design engineering and safety analysis for proposed plant changes or modifications (WNA, 2017:8). In many instances detailed design and analysis documentation remains the intellectual property of the original design entity. Examples of specialist skills typically not held by operators for modifications to plant systems, structures and components are seismic analysis or the reanalysis of postulated accidents (WNA, 2017:8).

The WNA (2015:4) highlights the concern that the requirements to establish the Design Authority function within the operating organisation may introduce various challenges, considering that these organisations may be new to nuclear; may have a small staffing structure or may not carry the engineering skill to provide the required level of oversight. (WNA, 2015:4). These challenges may be exacerbated with turnkey build projects where operators would be required to develop and maintain the full design knowledge. To mitigate this risk operating organisations may opt to secure the services of external organisations with specialist skills and knowledge of the detailed design. These may include the original designer, subcontractors and equipment suppliers who hold the original design knowledge. In these types of agreements, the supporting organisations are referred to as Responsible Designers (WNA, 2015:4-6).

Modifications to plant systems and components at a nuclear plant could impact the design and licensing base and the operating procedures (WENRA, 2014:42). The Design Authority function should therefore be multi-disciplined and comprise of engineering expertise from all engineering disciplines, control and instrumentation, mechanical, electrical and civil engineering. This core compliment would be interfaced with plant systems engineers, safety engineers, licensing engineers and plant operating and maintenance staff (WNA, 2017:4).

The WNA explains that an important consideration is that since the plant operating lifetime is 60 years (WNA, 2012:6) or more it would exceed the working timeline for the plant's staff and the staff at the original designer and plant vendors who participated in the initial plant design and construction. The transfer of knowledge and a comprehensive plant document base is therefore imperative for sustaining the role over the lifetime of the plant (WNA, 2017:4).

The UK ONR (2016:17) have detailed the knowledge that the Design Authority is expected to hold and that must be available to fulfil the design control role as a minimum (ONR, 2016:17):

- A detailed understanding of the design basis (why the design is as it is);
- The research and experimental knowledge on which the design is based;
- The design inputs such as elementary functional requirements, performance requirements, safety principles, applicable codes and standards, regulatory requirements, design conditions, seismic loads and design interface requirements;
- The design outputs such as design, operating and safety limits including specifications;
- Design calculations which prove the adequacy of the design and the ability to replicate the design calculation if needed to support design change reviews;
- An understanding of the analysis, testing, inspections, computer code validation with the associated acceptance criteria used by design organisations to confirm that the design output meets the design requirements;
- The design assumptions made in all of the above including those related to plant operating modes and procedures (ONR, 2016:17).

The IAEA has developed guidance, for establishing and maintaining the required training to achieve high levels of competence and staff qualifications at nuclear power plants (IAEA, 2002:1). Qualification is stated to be the formal declaration that the candidate has met the required competence assessment to perform the duties, whereas competence is defined as the ability to apply the skills and knowledge to a specified standard (IAEA, 2002:8).

The training methodology proposed by the IAEA in the Safety Guide: NS-G-2.8 - *Recruitment, Qualification and Training of Personnel for Nuclear Power Plants,* refers to a Systematic Approach to Training (SAT). The SAT approach provides a logical evolution, from the identification of required competences to perform a specific task, to the development of the training material, delivery methodology and the process of evaluation (IAEA, 2002:19). The IAEA argues that this approach has shown advantages in the reliability of training results, efficiency and management control (IAEA, 1999:1).

The systematic approach to training consists of five phases:

- Analysis: This identifies the training needs and competences required to perform a particular task.
- Design: The required competences are converted into specific training objectives.
- Development: Training materials is prepared to achieve the training objectives.
- Implementation: Training should be delivered using the training materials.
- Evaluation. In this phase, all facets of the training is evaluated and informs improvements in the training development and delivery (IAEA, 2002:19).

If Responsible Designers are appointed by the Design Authority for specific plant systems or components, the designer should be expected to have the knowledge base consistent with the above list (IAEA, 2003:6). The IAEA (2010) further specifies that one key factor to maintaining the required design knowledge within the Design Authority, is the ability to identify the key competencies supporting the function and identifying holders or owners of undocumented information which is considered valuable. This should be supported by pre-retirement programmes with a process for skill and knowledge transfer from one employee to another (IAEA, 2010-1:36).

2.6.2 Documents and data

The Electric Power Research Institute (EPRI) in its 2011 report (EPRI, 2011:1-3), *Elements of Pre-Operational and Operational Configuration Management for a New Nuclear Facility,* states that it is important for nuclear power plants to consider contractual agreements regarding the Design Authority roles and responsibilities; the design configuration management standards at the various phases of the project and the transfer of data, records, documents and information systems as a deliverable at the formation stages of the nuclear construction project (EPRI, 2011:1-3).

The WNA (2012:4) recognises that accessing and maintaining nuclear power plant design knowledge is not a trivial matter; that the volume of information is substantial considering knowledge of the original design intent, the detailed design implementation and the design philosophy (WNA, 2012:4). EPRI (2011) states that to effectively maintain the design configuration of the plant the Design Authority would require the plant information that describes, certifies, reports or provides data related to the design requirements of the plant (EPRI, 2011:1-3). The information should therefore also be consistent with the physical plant configuration including documents for operating and maintaining the plant and training staff (IAEA, 2010-2:7).

With new build projects, during the design and construction phases, prior to operation, the operator needs to obtain sufficient information and documentation on the plant systems, structures and components necessary to understand the design basis and beyond design basis of the plant. Beyond design basis conditions are potential plant conditions which may arise from events or accidents which that plant has not been designed to cope with. Typical information required could include drawings, design calculations and any specialised technical studies (WNA, 2012:12). It further expands to normal and emergency operating procedures, equipment qualification reports, calculation models, pre-service test results and the criteria. Operating plants have experienced challenges in obtaining such information after construction completion due to contractual shortfalls and original design entities considering the information proprietary (WNA, 2017:11).

In light of increased nuclear construction projects and new contractual agreements being established, EPRI (2011:4-6) highlights that of the information created during the design phase of the nuclear power plant, some is only useful for construction, however almost all would be required to ensure that the information exists when required for long term plant operation (EPRI, 2011:4-6). It is therefore important for the operating company, supported by its Design Authority, to define the precise information required to support decisions, plant processes and programmes and regulatory requirements. As an example, it might not be important for the construction company to know the reserve capacity of the cooling system, but this would be of critical consideration if the operating organisation were to consider a power uprate at some point (EPRI, 2011:4-6). This study concludes that current industry guidance for “new to nuclear countries” on design information transfer from construction to operation is insufficient. The absence of industry guidance on design information transfer is further discussed in section 4.3.2 of this report.
An additional consideration is that the advancements in technology in the design, procurement and construction of new nuclear power plants depends heavily on the exchange of electronic information when compared to previously build plants. Multidimensional modelling and intelligent technology including significant amounts of data and electronic documents are used during these projects (EPRI, 2016:2-1). Paper as the traditional medium has been replaced by electronic documents in formats such as text searchable PDF files. Document centric

databases, such as these, introduces complexity in the information turnover process. It becomes imperative for the Design Authority to understand the documents, data and the specific format they should be delivered in, allowing them to be usable to fulfil the design control function (EPRI, 2016:2-1).

- **Plant documents**

  EPRI has developed high level industry guidance in its 2016 Technical Report titled: *Advanced Nuclear Technology: New Nuclear Power Plant Information Turnover Guide*. The guidance given for the turnover of each plant system from the constructor to the operating organisation establishes a needs lists which refers to the following documentation as a minimum (EPRI, 2016:5/2-7/2):

  - System and Component Design Information, drawings, specifications, calculations, and analyses;
  - Vendor information by component function and design;
  - Information needed to support the engineering programmes, including baseline test reports and results;
  - Operating and maintenance procedures;
  - Setpoint lists identifying levels of criticality;
  - Complete list of data needed to support engineering programmes and the preventative maintenance programme. This includes a Master Equipment List, line lists, and Instrument lists generated by the constructor;
  - Engineering analysis supporting the design with input/output data (EPRI, 2016: 5/2 – 7/2).

  The guide further states that even though the required documentation is delivered to the operating organisation, continued assistance and support from the original designer and the constructor would be required in the following areas (EPRI, 2016: 5/2 - 7/2):

- Support the commissioning, inspection, testing, acceptance, and compliance process;
- Development of the materials management system including, critical stock holding, warehousing, and inventory management;
- Preparation and the review of maintenance and operating procedures;
- Development of engineering inspection, integrity and testing programme;
- Support of the design and installation of a full scope control room simulator;
- Development of training material;
- Maintenance workshop facilities and the storage of tools and equipment
- Development of a bill of material and spare parts list;
- Development of storage and environmental requirements for warehouse equipment (EPRI, 2016: 5/2 – 7/2).

The US NRC states that, prior to operation, the operating organisation should aim at developing a computerized system for the identification and retrieval of design bases documents, drawings and calculations which should include the following (USNRC, 1988:12):

- The Final Plant Safety Analysis Report;
- Regulatory commitments and requirements;
- Design requirements and criteria;
- System design requirements;
- Calculations, analysis reports and specifications;
- Design drawings, as build equipment drawings, schematics and logic diagrams;
- Construction test and commissioning reports;
- Interface documents;
- Technical, operating and maintenance manuals (USNRC, 1988:12).

- **Plant data**

  The IAEA (2003:3) states that the generation of nuclear power plant data, supported by current technology, starts from the initial design requirements, through to information collected during construction and commissioning tests. Plant data is vital to plant operation as it provides the data and meta-data to the operator to identify plant components and the information related to the plant components to establish operational processes. Because the sources of plant data are so diverse, early development of a data repository is critical to the success of a construction project and future plant operation. (IAEA, 2003:3). EPRI (2016) goes further in describing that nuclear power plant construction projects typically develop (or adopt) naming conventions so that unique identifiers are assigned to plant systems, components and plant documents of standard formats. Data transferred to the operating organisation should therefore be aligned to the unique identifiers to allow future retrieval (EPRI, 2016:4-10).

Figure 2.6 (EPRI, 2011:7-1) describes the sources of nuclear power plant data and a typical repository structure to facilitate the management of the data through the design, construction and operations phases.

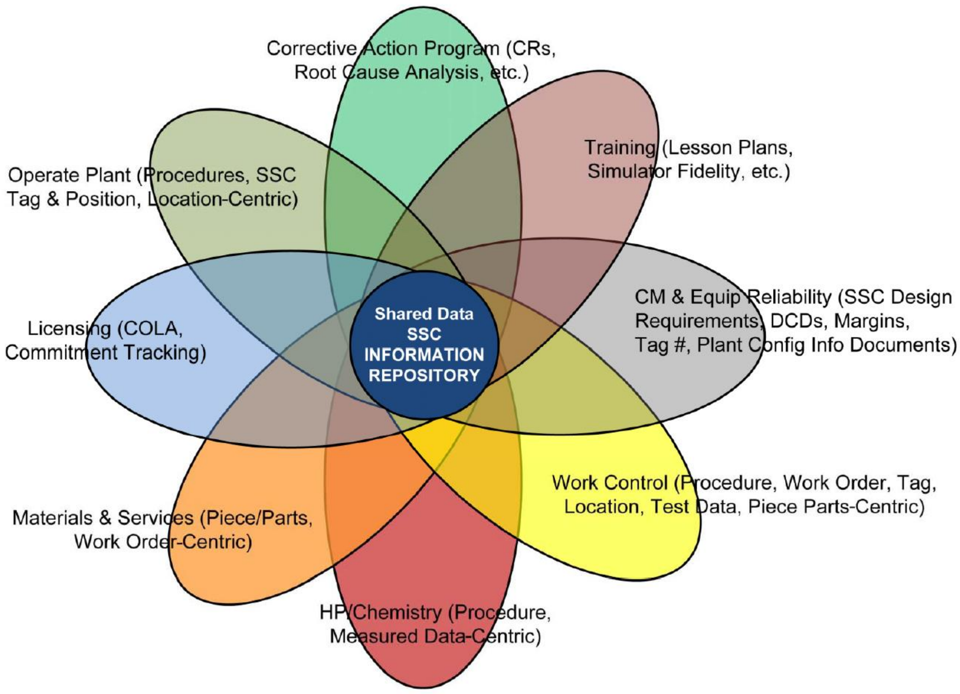

Figure 2.6: SSC Data Repository (EPRI, 2011:7-1)

2.6.3 Plant configuration management process

The IAEA states that configuration management is an organisational concept that provides technical and administrative direction to the development, establishment, support and plant life-cycle of an item for which an accurate status needs to be maintained (IAEA, 2010-1:1). This process is applicable to all plant equipment and components including all supporting technical documentation, processed materials, hardware, software and services. The risk of degraded configuration management and design knowledge could lead to changes to plant systems, structures and components which could challenge the design intent, and plant safety functions ultimately increasing the risk of a nuclear incident or accident (IAEA, 2003-1:3), (IAEA, 2010:10).

The joint IAEA and NEA report, *International Reporting System for Operating Experience,* for the period of 2015-2017 captures 246 event reports from 35 member countries (IAEA, 2020-1:7). The reporting system was designed to support the sharing of operating experience amongst member countries. The reports are assessed by the IAEA, and sent back out to member countries as learning from event occurrences. The ultimate objective is to assist in preventing similar safety-significant occurrences in member states, by pre-emptively addressing similar vulnerabilities which may have caused the event (IAEA, 2020-1:10).

Three main categories of events were highlighted as significant contributors: human performance, equipment issues and management and oversight. Equipment issues focused on the availability and reliability of SSC's and events which may have adversely affected the intent of the design to ensure safe plant operation. A total of 63 events related directly to deficiencies in design and modifications (IAEA, 2020-1:32). These included issues related to inaccurate calculations, the erosion of safety margin and a lack of understanding of the design requirements, all of which falls within the responsibility of the Design Authority (IAEA, 2020-1:33).

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Plant safety and production could also be severely impacted by not having the right information available at the right time and in the right format for the plant's engineering and operations staff. Nuclear plant history has shown that efforts required to correct the loss of configuration control is considerably greater than the effort required to establish and maintain plant configuration (IAEA, 2010-1:1).

The IAEA (2010:1-4) considers the concept of plant configuration management as critical to the safety and life cycle management of the plant as it ensures that the construction, operation, maintenance and testing of the physical plant are in accordance with the design requirements as documented in the design basis (IAEA, 2010-1:4). It therefore ensures that the consistency is maintained between the physical plant, the paper plant and the design requirements. It provides the plant owner, operator and regulator the assurance that that the plant is designed, operated and maintained in accordance with the actual design and licensing basis. The commitments for the safety of the public and the protection of the environment is thereby kept intact and valid (IAEA, 2010-1:4).

Permanent and temporary modifications to the plant present a particular challenge to plant configuration management and may be initiated by equipment obsolescence, operating experience, safety upgrades and changes in operating limits or controls amongst others. These are required to be rigorously controlled to ensure that the plant documentation is timeously updated. The WENRA Safety Reference Levels for Existing Reactors (WENRA, 2014:42) mentions the following stipulations related to the plants configuration management process: "*The licensee shall ensure that no modification to a nuclear power plant, whatever the reason for it, degrades the plant's ability to be operated safely" and that "The licensee shall establish a process to ensure that all permanent and temporary modifications are properly designed, reviewed, controlled, and implemented, and that all relevant safety requirements are met.*". It should also be noted that a rigorous regulatory framework is applied to design changes of the nuclear facility during which the regulatory body determines the level of regulatory oversight required (WENRA, 2014:42).

The IAEA (2003-1:4) states that the Design Authority in accepting responsibility for the configuration management programme ensures that accurate information, which is consistent with the physical plant and operation requirements, is available in a timely manner to support safe, knowledgeable and cost-effective decisions with a high degree of confidence (IAEA, 2003-1:4). The element of design information availability therefore supports the implementation of the design control function. The confidence provided through the configuration management process is based on the presumption that sufficient design documentation is available, to verify the implementation of the design basis and to provide justification that the critical design parameters are accurately accounted for and are preserved even with modifications being implemented on the plant (USNRC, 1991:7).

Over the life of plant several plant modifications may be implemented. An ineffective configuration management process may result in the facility documentation no longer reflecting the actual plant status. Further, the cumulative effect of plant changes may cause a misalignment in the conformance, as described in Figure 2.7, between the design requirements, the facility documentation and the physical plant. Maintaining this conformance is the essence of an effective process (IAEA, 2010-1:1).

The process of configuration management recognises three elements that should be in conformance in support of nuclear and industrial safety at the power plant as illustrated in Figure 2.7 (CMBG. 2009: 3):

- The Design Requirements – The technical design requirements from regulatory requirements, codes and standards, and the design process which stipulates limits on the final design and includes the consideration of design margin which gets reflected within the design documentation.
- The Facility Configuration Information – The set of documentation that that contains information defining how the plant is designed, operated and maintained. These would include but are not limited to system description manuals, plant drawings, maintenance and training procedures.
- Physical Configuration – The actual plant structures, systems and components and the operational configuration of these (IAEA, 2010-1:5).

To preserve the plant design basis and nuclear safety, the conformance needs to be maintained and becomes the key priority of the Design Authority.

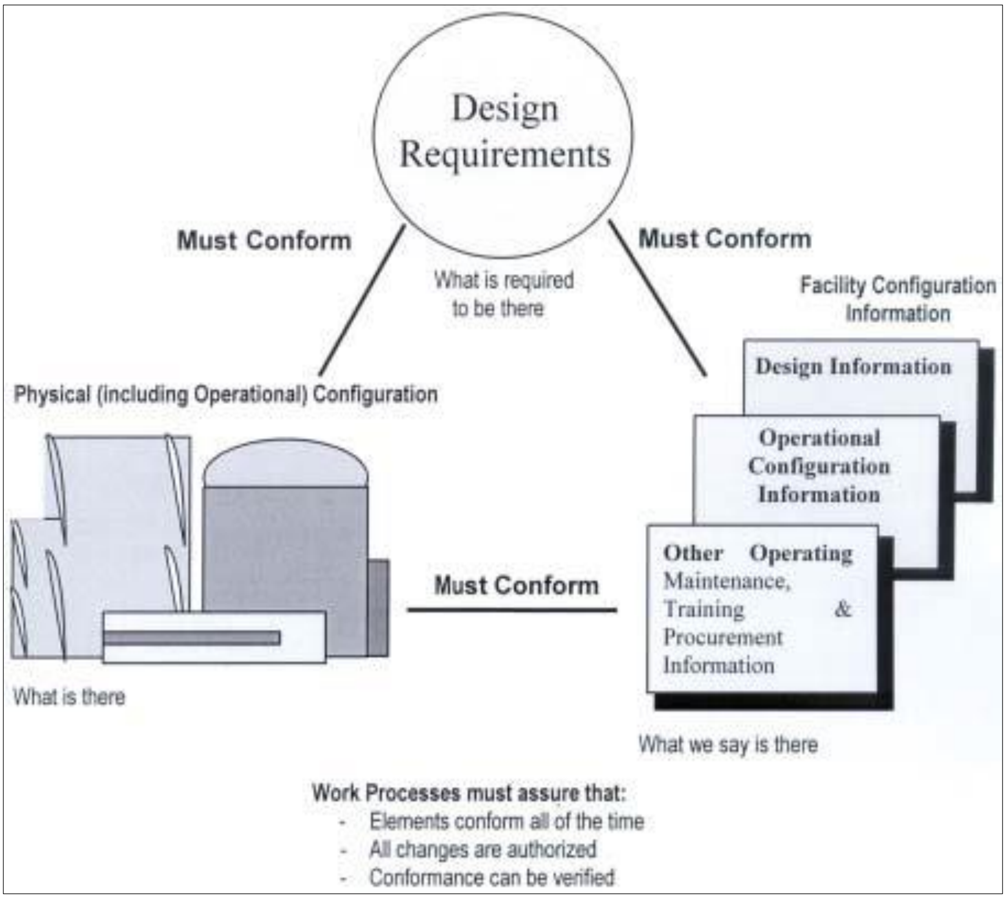


Figure 2.7: Relationship between the Design, Physical Plant and Plant Documentation (CMBG. 2009: 3)

A successful configuration management process at an operating facility normally includes six elements. Each should be adopted to the specific strategy and unique circumstances of the power plant (IAEA, 2003-1:5):

- **Programme management**
  The key objective is focused on directing the development of the CM programme as a priority and providing oversight on its implementation.
- **Design requirements**
  The objective is to establish, formally document, communicate and maintain the plants design requirements for the structures, systems and components.

- **Information control**

  The objective is to obtain, and manage the plants configuration information which includes required documents and electronic data related to the design requirements and the physical plant.

- **Change control**

  The objective is to maintain the conformance between the design requirements, the facility documentation and the physical plant. This element requires the greatest attention as it introduces the most risk. Effective processes have adopted a graded approach whereby the degree of scrutiny and required assurance is proportional to the safety significance, complexity and potential economic impact of configuration errors (IAEA, 2003-1:5).

- **Assessment**

  The objective is to comprehensively define the CM needs of the plant and to monitor the effectiveness of maintaining the basic relationships between the design requirements, the facility documentation and the physical plant (IAEA, 2003-1:5).

- **Training**

  The objective is to provide acceptable assurance that the plant and vendor personnel are fully aware of the operator organisation's configuration management process, terminology, definitions and procedures and are able to execute their duties with full compliance to the CM process (IAEA, 2003-1:5).

In summary the effective implementation of the Design Authority function is highly dependent on establishing the elements of knowledge and skills, the full series of the required plant information and the establishment of a robust configuration management process. The configuration management programme may provide the tools and information required for integrating and coordinating design related activities within the operational plant, but needs to be supported by many other plant related processes and functional departments to ensure design integrity (IAEA, 2003-1:5). This may not be achieved without the full support from the top plant management and by developing a comprehensive set of organisational roles and responsibilities in support of the configuration management process and ultimately the Design Authority function (IAEA, 2003-1:5).

2.7 Design Authority Structure within the Operating Organisation

The literature study has previously highlighted the requirement that the operating company has the overall responsibility for safe operation, maintenance and design integrity of the power plant. The architect designer, in most cases, fulfils the role of the Design Authority during the original design, licensing, construction and commissioning phases of the nuclear build project. The IAEA cautions that the establishment of Design Authority in the operating organisation and the transfer of design information, might not be in the best interest of the vendors as it often represents their commercial advantage. The process of transfer may therefore become challenging if not contractually secured (IAEA, 2003:8).

The IAEA (2003:8) recognises that it is incumbent on the operating organisation to establish the Design Authority prior to plant operation in the following way:

- Developing and implementing the complete Design Authority structure within the operating organisation;
- Contracting and assigning original designers and selected vendors, the formal responsibility as Responsible Designers;
- Ensuring an effective transition from the architect Design Authority to the operating organisation Design Authority (IAEA, 2003:8).

The IAEA (2003:8-9) provides further guidance that these agreements should be formalised prior to the completion of the plant construction and the transferal of the Design Authority role, noting that the operating company retains the responsibility for the effectiveness of the programme. It also carries the responsibility to maintain the programme over the life of plant and make provision in the anticipation of losing the capability of Responsible Designers (IAEA, 2003:8-9). WNA (2017:4) studies have shown that operating companies with multi-plant operations have established the Design Authority at a corporate level rather than at a plant level especially where the operator runs several plants of the same design (WNA, 2017:4). This comes with the additional requirement of maintaining consistency among the designs of the various plants, which allows generic safety issues to be addressed. Furthermore, it provides opportunity to share the organisations specialised skills while ensuring consistency (in design standards, and configuration management) across multiple units (WNA, 2017:4).

The considerations in establishing the Design Authority organisational structure within the operating entity therefore varies within different organisation and project structures. The key organisational considerations include (WNA, 2017:18):

- A licensed operating organisation that operates a single unit;
- A licensed operating organisation that operates multiple units at a common plant site or at multiple plant sites;
- A licensed operating organisation that operates different design units at a single plant site or at multiple plant sites.

The WNA has a view that it is possible to group the Design Authority structures based on the specific organisational context which could support some level of economies of scale. One Design Authority structure introduces notable complications especially when units are not identical. The greater the difference in units the more likely the divergence in the design and licensing bases (WNA, 2017:18). Certain differences are inherent to the different projects. These would include differences in site-related design basis, such as seismic studies and risks or the design for the available ultimate heat sink (ocean, dams, river, or cooling towers) This could further be complicated as multiunit sites with the same design may be different if these units are constructed over a long time period, as vendors, component suppliers and constructors change, introducing additional complexity.

When units are identical the design of a centralised Design Authority is easier. The greater the similarity in units the greater the tendency to maintain a single Design Authority for multiple unit (WNA, 2017:18).

2.8 The International Approach to Design Authority

The WNA (2012:14) states that the principle of the operator maintaining the ultimate responsibility for the safe operation, maintenance and design integrity of the plant infers that the operator is the "final decision-making authority" (WNA, 2012:14). It however also implies that the operator holds the knowledge and capability to fulfil the role. Many operators do not hold the specialist design knowledge which comes with original designers, vendors and architect engineering companies and have opted to enter into commercial contracts to secure the support services required through plant operation. There are however examples of where original designers and vendors no longer exist as commercial entities which complicates issues further (WNA, 2012:14).

The World Nuclear Association's Working Group on Cooperation in Reactor Design Evaluation and Licensing (CORDEL) released its report on *Design Change Management in Regulation of Nuclear Fleets* in 2015. This study included a survey to understand how different operators have approached the subject of the Design Authority in nuclear power plant operations. The study covered five countries, South Korea, USA, Canada, UK and France (WNA, 2015).

The key focus areas of the study included (WNA, 2015:16):

- How design knowledge was transferred and maintained over life of plant?
- How the Design Authority function was executed?
- What role the original designer played?
- What the role of the Design Authority in the configuration management process was?
- How fleet wide design conformance was attained?

- How many staff were in the Design Authority structure?

The results of the study are summarised as follows:

France:

Electricite de France (EDF) is the architect engineer and the operator of its nuclear plant fleet. Its senior level division called the Nuclear Engineering Division (DIN), although not formally established, fulfils the role of the Design Authority. DIN coordinates the design related activities across the utilities engineering centres and maintains a close link to the original vender Framatome (previously AREVA), even though it has developed a significant internal design expertise (EDF, 2014:5-9). International experience and feedback are incorporated through Periodic Safety Assessments. EDF has shown consistent safe plant operation through its structure which has been developed over decades. Challenges are however experienced in the consistency of the design change management implementation across its fleet (WNA, 2012:16).

USA:

In the USA the original designers retain the intellectual property of the NSSS design. It is also widely accepted that Original Equipment Manufacturers (OEM) sometimes implement modifications resulting in design changes to older plants. These are implemented differently based on the operator's responsibility. The industry is however working towards a "joint ownership" model between designers and operators potentially based on Probability Risk Assessment (WNA, 2015:17).

UK:

In the UK, the original nuclear plant designers no longer exist for some of the plants which were built decades ago. Processes have been developed for the transfer of knowledge to the current organisations (DTI, 2002:7-11). The Design Authority is typically assigned to an individual supported by an engineering team. Challenges have been experienced in areas which have been supported by additional contractual agreements with Responsible Designers (WNA, 2015:17).

Canada:

In Canada the Design Authority is assigned to the Chief Nuclear Officer within the operating organisation. He in turn delegates certain aspects of the function to the plant engineering team and others to Responsible Designers but maintains overall accountability. This arrangement, defining the process and roles, is formally captured within the operating license (CNSC, 2008:8). For the potential new build projects in Canada the roles of the vendor, the operator and the transition of the Design Authority after construction is being reviewed (WNA, 2015:17).

South Korea:

In South Korea the Design Authority for its operating plants is assigned to the operating organisation, Korea Hydro and Nuclear Power (KHNP). The Design Authority within KHNP is formally designated to its Central Research Institute Division. KHNP as a subsidiary of the government entity Korea Electric Power Company and has close links to the original designer Korea Electric Power Company Engineering and Construction System Design Division (KEPCO E&C – SD), which is also subsidiary of KEPCO (WNA, 2015:16). KHNP has delegated areas of the overall design to KEPCO SD and continuously improves its Design Authority capability as more plants are being constructed (NEI-1, 2014). The South Korean approach has been for the Responsible Designer to maintain the Design Authority during construction and handover until commercial operation of the unit and then to transfer the Design Authority to the operating organisation. The South Korean model of the operator and the original designer being part of the same company has shown to be very successful (WNA, 2015:16).

In summary even though there are many common strategies in different organisations there are many subtle differences as well due to the context and maturity levels of the organisations. Age of the units plays a role in the UK; private ownership influences the strategy in the US and France and South Korea have fleets of similar designs. (WNA, 2015:17).

2.9 Design Authority Strategies in the Aviation Industry

In 2013 the WNA mandated a study by its, Cooperation in Reactor Design Evaluation and Licensing (CORDEL) working group, on the methods in which designs were managed in the Aviation industry in comparison with the nuclear industry (WNA, 2013). The report produces evidence that the aviation and nuclear industries have many similarities in that both are highly regulated, operating in global regimes and have common goals of achieving records of excellence in safety and reliability (WNA, 2013:3). International regulatory framework has been developed in the nuclear arena due to the potential cross border effect of a nuclear accident and the resultant radiological and social consequences. Aviation faces similar risks as aircraft cross international borders (WNA, 2013:3).

The WNA highlighted two specific aspects of the aviation regulatory system worth noting (WNA, 2013:4):

- Individual states and their national regulator hold the ultimate authority and is not undermined by the international framework;
- Aircraft designers, manufacturers and operators support a system of design and the allocation of risk and liabilities in a common response to events, operating experience and the implementation of design changes (WNA, 2013:4).

One difference to note is that aircrafts are certified for airworthiness which becomes the aircrafts “passport” to fly across borders. A ‘type certificate’ is issued to the aircraft designer confirming that the aircraft complies to the safety requirements (ICAO, 2006:9-10). The international framework for aviation regulation, set out by the 1944 Convention on International Civil Aviation and the International Civil Aviation Organization, describes a framework for each regulator to fully execute its duties and does not involve the transfer of those duties (ICAO, 1944:3). Each country does however have its own airworthiness codes and its own national aviation authority with differences not being significant. It is therefore possible for aircraft designers to 'envelope' a design encompassing a number of relevant national or regional standards applicable in many countries, but the 'type certificate' only remains valid, as issued, in the country in which the designer is based (WNA, 2013:4-5).

The EASA (2011:43-61) explains that that all other parties associated with the aircraft would have a legal obligation to report events that may impact the design and have clearly defined roles (EASA, 2011: 43-61):

- Aircraft operator: Has the responsibility that the aircraft is operated and maintained in accordance with the manual and remains complaint to the design. The national aviation authorities should be notified of any safety related findings and problems found during maintenance.
- Manufacturers and Designers: Have the responsibility to collect and analyse information related to defects and failures and should make the safety relevant results available to all operators and authorities. This includes the risk analysis and the technical solution to retain airworthiness.
- Regulators: Issues airworthiness directives, based on risks identified by designers which required operators to take specific action to address safety issues within a maximum reaction time (EASA, 2011: 43-61).

When the production of an aircraft type stops the designer remains obligated to keep the type certificate valid. If the designer exits the market methods should be found to continue the duties or the type certificate would become invalid for the aircraft design thereby revoking airworthiness of the aircraft. For very old designs, with limited numbers of aircrafts still in operation, the operator could assume the responsibilities of the designer under certain conditions. In nuclear the role of the designer is different as the operator takes on the Design Authority role and the designer has no ongoing design responsibility (WNA, 2013:12).

Within the aircraft industry most of the significant changes to an aircraft's design are made by the original designer. When a different entity wishes to make a significant change, it would apply for a supplemental type certificate from the state of registry. In most cases the authority would seek the opinion of the original designer who holds the original type certificate and design competence. Original designers frequently introduce design changes to improve safety and performance and publish many service bulletins to operators. Major design changes have to be approved by the competent authority which issued the 'type certificate'. This guarantees that the aircraft design developed under regulatory control is not compromised on the premise that implementation of the design change is in full compliance with the authorised design (WNA, 2013:14).

The similarities exist in the sharing of operating experience and information exchanges, but mandatory responses from events and safety related experiences are less organised in the nuclear industry. Through time various 'owner groups' have been established to facilitate closer collaboration between owners of the same designed plants, however participation and resultant actions are not mandatory (WNA, 2013:14). The WNA (2013:13) however highlights that the National Nuclear Regulatory bodies similarly do not have institutionalised systems for mutual exchange and do not have systems to implement mandatory design changes proposed by the original designer, based on designer risk and technical proposals, as these are typically requested from the side of the operating organisation (WNA, 2013:13).

In summary due to the fundamental differences the Design Authority function in the nuclear industry is not comparable with that of the aviation industry in both the continued responsibility for the design and the licensing (airworthiness) of the design.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Research Approaches and Design

Leedy (2015:24) describes research as the systematic way of collecting, analysing and interpreting information from various sources to explain or establish an understanding of a phenomenon or subject of interest. The process of carrying out research is categorised into quantitative and qualitative research (Leedy, 2015:24). Research is also considered a scientific method being applied to problem solving. It is formal, systematic and requires analysis which may be done through the logical manipulation of assumptions, observation and reasoning by analogy (Pandey, 2015:8).

3.2 Quantitative Research

Quantitative research looks at quantities and attempts to measure variables in a numerical or statistical way. It asks questions such as 'to what degree', 'how many', 'how long' and looks to quantify the general outcome for sample or aggregate results (MacDonald, 2008:9). The research designs used to collect quantitative information which can be used for statistical analysis are observation studies, correlation research, developmental designs and survey research. These are further defined (Leedy, 2015:98):

- Observation study – These studies in quantitative research could be performed on plants, non-living objects or physical phenomenon such as the weather with a limited focus. Behaviours are typically counted and evaluated (Leedy, 2015:154).
- Correlation study – These typically examines the extent of differences in characteristics and how it relates to differences in other characteristics. The correlation exists when one characteristic change together with a predictable change in another variable (Leedy, 2015:156).
- Survey Research - Deals with present events or incidences and is quantitative in nature. It may further be divided into; exploratory

discretional, and correlational type of research. (Pandey, 2015:12) The information may be obtained through face -to- face or telephonic interviews or paper-and-pencil or electronic questionnaires (Leedy, 2015: 159).

When performing quantitative research, the ‘Statistical significance’ becomes an important aspect, as understanding the sample size and the projected response rate is required to support a result which are considered an accurate reflection of the target population (MacDonald, 2008:13-14).

3.3 Qualitative Research

Qualitative research, in contrast, looks at characteristics through observation and people’s perspectives on particular issues. The approach utilizes a number of different methodologies which have two common factors: its focused on a phenomenon that is occurring or has actually occurred and secondly it involves studying the complexity of the phenomena. In studies where, little information exists or when the supporting theory doesn’t exist or is inadequate the qualitative research approach assists in defining the important aspects (Leedy, 2015:269). Qualitative research provides insights into the context and setting of problems and allows ideas and hypotheses to be generated (MacDonald, 2008:35).

Qualitative research has the advantage in facilitating the following purposes:

- Exploration - It assists in gaining an initial and further understanding of a topic or phenomenon which may or may have been studied in-depth previously;
- Multifaceted description – It describes the complexity of certain situations systems or people;
- Verification – It focuses on the validity of assumptions, postulations or theories to be tested in a practical context;
- Theory development – It allows the development of new theories or concepts related to a topic or phenomenon;

- Problem identification – It facilitates the discovery of key challenges, problems or shortfalls within the phenomenon;
- Evaluation – It allows judgment to be drawn on the effectiveness of policies, methods or ideas (Leedy, 2015:271).

The five commonly used qualitative research designs are (Leedy, 2015:272-275):

- Case Studies – A specific person, programme or event is studied for a period of time and data is collected based on the focus of the investigation. Case studies are effective where a little knowledge exists of a topic or phenomenon;
- Ethnography – in contrast to case studies focuses on a group of events, people or programmes in its natural setting for a certain period of time;
- Phenomenological studies – Attempts to comprehend peoples understanding or perspective related to a certain situation;
- Grounded theory – Begins with the data collected in the field which is used to develop a theory and focuses on the process related to a topic;
- Content analysis – Refers to an analysis of the contents of a body of literature to identify common patterns, themes or preferences (Leedy, 2015:272-275).

3.4 Mixed-Methods Research

Mixed-method research involves integrating findings from collecting, analysing and interpreting information from both quantitative and qualitative research into a cohesive conclusion. This method of research is mostly effective when the researcher has the skills to: develop focused research questions; to create a measurement instrument that is valid and reliable; to conduct structured, semi-structured or open-ended interviews and to draw persuasive arguments for reasonable conclusions. The method allows one type of information to inform the collection of another type of information as an example, conclusions drawn from literature studies may guide the construction of interview questions for a survey (Leedy, 2015:329).

Five general types of mixed-method designs are described below (Leedy, 2015:331):

- Convergent designs – A parallel approach is taken for the collection of quantitative and qualitative data. Similar weight is given to the two sets of data with the hope that similar conclusions are drawn on the research topic.
- Embedded Design – Both quantitative and qualitative data is collected however the one method is selected as the primary and the other as the secondary within the design of the research tools.
- Exploratory Design – This design has two phases, firstly the researcher uses qualitative methods to get a general idea of the phenomena and then uses a quantitative study to observe the phenomena in a real-world setting.
- Explanatory Design – This is also a two-phase process but the quantitative data is collected first and the qualitative research follows to further elaborate on the data collected in the first phase.
- Multiphase Iterative Designs – These designs have three or more phases. The first creates a platform for the phases which follow and the researcher may move between qualitative and quantitative methods with the one phase and method informing the next (Leedy, 2015:331).

3.5 The Research Design for this Study

A Mixed-Method Research Methodology has been selected for this study for the following reasons:

- The subject of the "Nuclear Design Authority" in operating nuclear power plants or nuclear construction projects has not been widely studied or published. The study therefore depended on limited publications from international nuclear organisations and associations as well as governmental regulatory guidance, as core literature on the subject. Due to the limited literature actual industry information on current practices was sought through conducting an industry survey.

- It is important to note that the literary guidance developed for the functioning of a Design Authority within the nuclear industry differs between Industry Organisations, National Nuclear Regulatory bodies and Nuclear Utilities.
- This study aimed to determine the extent to which existing industry guidance is applied in different Nuclear Power Plant Projects and Operations.

For these reasons, conclusions drawn from the literature study is further explored through engagement in a real-world context with actual industry experience.

An Exploratory Design was adopted with the first phase using a qualitative – content analysis method to study the existing nuclear industry guidance, for the establishment of a Nuclear Design Authority with second phase being a quantitative method – survey research, to source information within a real-life nuclear project and operations context.

3.5.1 Content analysis

The Content Analysis methodology used in this study is to interpret and identify common themes from information related to the establishment of a Design Authority Function for a nuclear power plant project. Content Analysis is defined as "*A detailed and systematic examination of the content of a particular body of material (e.g. television shows, magazine advertisements, internet websites, works of art) for the purpose of identifying patterns, themes, or biases within that material*" (Leedy, 2015:102).

The discussions in the literature review would be used to further define the concept of Design Authority, to identify the critical elements of establishing the Design Authority function and to document the various approaches to its establishment.

The research study will employ qualitative data to explore various approaches through the limited number of construction projects, published industry guidance and accessible subject matter experts. This study captured literature reviews from international standards and guidance developed by regulatory bodies, expert authorities and safety bodies within the nuclear industry.

A systematic approach will be followed, through identifying common themes, in firstly extracting and analysing from existing industry guidance, the definition of the Design Authority function; followed by common requirements for the Design Authority. The critical elements for the establishment of the Design Authority will then be analysed in further detail and finally, the Design Authority strategies which have been selected by various countries will be analysed.

The detailed approach and aim are as follows:

- Extracting the definitions of the Design Authority from the various industry guidance captured in the literature review with the aim of identifying the key characteristics embedded in these definitions.
- Analysing the regulatory and safety requirements which have been published by various international bodies to extract and re-affirm the critical elements to be considered in establishing the Design Authority function.
- Reviewing these critical elements to establishing a Design Authority function as captured in the literature, highlighting pertinent information from the guidance.
- Analysing the different approaches adopted by countries in selecting a Design Authority strategy. The subject countries are: France, UK, USA, South Korea and Canada. The aim is to identify common considerations or reasons for deviations in selected these organisational strategies.

3.5.2 Industry survey

Current practices and approaches to the concept of Design Authority will be reviewed for existing nuclear construction projects and ongoing plant operations through developing and administering a questionnaire and follow-up unstructured clarification interviews.

The sample of participants will be selected to provide an international perspective of the Design Authority approach and establishing elements. These will include industry experts in the areas of nuclear design, nuclear systems engineering, nuclear power plant construction, existing Design Authority leads and nuclear power plant configuration management. The sample is designed to cover existing power plant operations within the countries scoped into the research study namely; United States of America, France, United Kingdom, South Korea and Canada, but also expanded to countries such as the United Arab Emirates, China, Romania and South Africa. The nuclear power plant engineering and construction experience among projected participants ranges from 20 to 38 years.

The questionnaire, attached as Appendix B, consists of 10 questions, most of which require an explanation substantiating the selected answer. The questions are structured to cover the key focus areas which include:

- The strategy selected by the operating company in using Responsible Designers and the structure through construction;
- The regulatory requirements which exists for the Design Authority;
- Design knowledge and information (securing and maintaining) and what is considered critical information;
- The implementation of the configuration management process and the roles of the Design Authority.

The survey will be administered through an online application called "Survey Monkey". Participants will be given two weeks for completion, after which a 1 hr clarification and follow-up telephonic discussion will be scheduled. The survey results will then be extracted and the answers will be analysed for common conclusions, varying insights and for deviations from the common approach.

A key consideration in performing the survey is that nuclear utility related information, in most cases, is considered proprietary and confidential. The identities of the participating industry experts and the resultant utilities and nuclear build projects will therefore be protected as committed to in the letter of participation captured as Appendix A.

It is considered that minimal statistical meaningfulness will be drawn through quantitative research methods due to the restricted industry sample, however the research performed will support a review against the content analysis conclusions in the real-world context and is deemed to be accurate and reliable from credible sources with resultant conclusions which are warranted.

3.5.3 Analysis

The analysis of both the content and the survey results would require a degree of "deductive logic". Deductive logic starts with certain assumptions, in the case of this study, it would be that nuclear operators have adopted the guidance, as member states, of agencies such as the IAEA and that regulatory requirements for the establishment of a Design Authority is consistent among National Nuclear Regulatory Bodies. Reasoning then proceeds through the material, logically towards a conclusion, which in the case of this study, would be supported by expert information derived from the industry survey.

CHAPTER FOUR
ANALYSIS OF RESULTS

The research performed during this study has focused on the main elements required to establish a Design Authority function in an operating organisation after completion of the nuclear power plant construction. The literature review has captured a body of work consisting of industry guidance, standards and regulations, followed by a survey completed by industry experts. The formal industry content and the results from the survey will be discussed in this section of the study.

4.1 Common understanding of the Design Authority Role

The definition of the Design Authority has been drawn from several industry guidelines and although differences exists a common thread could be drawn through the key characteristics.

Table 4.1: Definition of the Design Authority

Source	Definition
IAEA	*"The designated entity that takes the **overall responsibility** for the design process, **approval of design changes**, and for ensuring that **the requisite knowledge is established**, preserved and extended with experience."*
ASME NQA-1	"*The organization having the **responsibility and authority for approving the design bases,** the configuration, and changes thereto*"
USNRC	"*The organization having **responsibility** for **maintaining the design bases** and ensuring that design output documents accurately reflect the design bases*"
ONR	"*the defined function of a licensee's organisation with the **responsibility** for, and the **requisite knowledge** to maintain the **design integrity** and the overall basis for safety of its nuclear*

	facilities throughout the full lifecycle of those facilities. ***<u>Design Authority relates to the attributes of an organisation rather than the capabilities of individual post holders</u>***"
IAEA-SSR	"*the design organization with* ***<u>appropriate knowledge</u>*** *of the design basis that is* ***<u>responsible</u>*** *for establishing the design requirements and ensuring that design documentation (document and/or data) appropriately and accurately reflect the design. The Design Authority is responsible for* ***<u>design control</u>*** *and the technical adequacy of the* ***design process*** *throughout the lifetime of the nuclear facility*"
AERB	"*The defined function of a licensee's organisation with* ***<u>requisite knowledge</u>*** *and with* ***<u>responsibility</u>*** *for maintaining the* ***<u>design integrity</u>*** *and the overall basis for safety of its nuclear facilities throughout the full lifecycle of those facilities.* ***<u>Design authority relates to the attributes of an organisation rather than the capabilities of individual post holders</u>***"

From the literature extracts the following attributes are common to the various definitions:

"The Design Authority: has the overall responsibility and authority over design changes, possesses the requisite knowledge and manages the design control process to ensure the integrity of the Nuclear Power Plant Design".

The ONR and AERB raises a pertinent point in that the Design Authority does not reside with a particular individual, but within an organisation. Effectively fulfilling the Design Authority function requires a host of diverse engineering knowledge and skill and experience which comes with a multidisciplinary engineering organisation.

4.2 Regulatory and Safety Standard Requirements

International Safety Authorities and National Nuclear Regulatory Bodies have developed requirements for safe nuclear plant operation. In understanding the key elements to establishing a Nuclear Design Authority analysing the industry requirements is critical.

Table 4.2: Design Authority Requirements from Regulatory Bodies and Safety Agencies.

Regulatory or Safety Body	Design Authority Requirements
IAEA	*"The prime responsibility for safety must rest with the person or organisation responsible for facilities and activities that give rise to radiation risks."* • This is further clarified in that the responsibility may not be delegated by the licensee. • The responsibility for establishing and maintaining the required **competencies and processes**, is the direct obligation of the licensee.
IAEA	"*The operating organization must also assure itself that a formal and rigorous* ***design change process*** *exists so that the actual configuration of the plant throughout its life is consistent with changes to the design, that changes can be made with* ***full knowledge of the original design intent****, the design philosophy and of all the details of implementation of the design, and that this* ***knowledge is maintained*** *or improved throughout the lifetime of the plant*"
ONR	It is expected that the licensee has a **formal process** to understand and maintain the plant design; **sufficient technical capability** to understand that analysis requirements; ownership

	for the safety analysis and a **<u>full understanding of the function and performance</u>** of the plant; the ability to **<u>maintain the design basis and records</u>** for design changes, operating experience that could impact the design.
AERB	In order to fulfil the responsibility, the organisation shall establish from the beginning a Design Authority with responsibility for and the **<u>required knowledge</u>** to **<u>maintain the design integrity</u>** and safety basis of the plant throughout its life.
CNSC	It is required of the Design Authority to achieve the following requirements: **<u>establishing the knowledge</u>** on the current plant design; ensuring the **<u>availability of design information</u>**; establishing **<u>control necessary to review and approve design change</u>**; ensuring the required engineering and scientific **<u>knowledge and skills exists</u>**.

The extracts from the various safety guidelines and regulatory requirement documents have highlighted common elements required by the Design Authority to effectively maintain the integrity of the plant design and thereby ensure safe plant operation. The key elements are:

- Establishing and maintaining the **technical skills and knowledge** to manage design changes and maintain the design integrity of the plant;
- To ensure the **availability of the design information** to support the full understanding of the design and the original design intent;
- The **establishment of a configuration / change management process** to facilitate changes to the plant design and execute the control of the Design Authority.

4.3 Critical Elements to Establishing the Design Authority

The previous section highlighted the key elements to the establishment of the Design Authority which is most comprehensively described by the ONR as – "*It is expected that the licensee has a **formal process** to understand and maintain the plant design; **sufficient technical capability** to understand that analysis requirements; ownership for the safety analysis and a **full understanding of the function and performance** of the plant; the ability to **maintain the design basis and records** for design changes, operating experience that could impact the design*" (ONR, 2016).

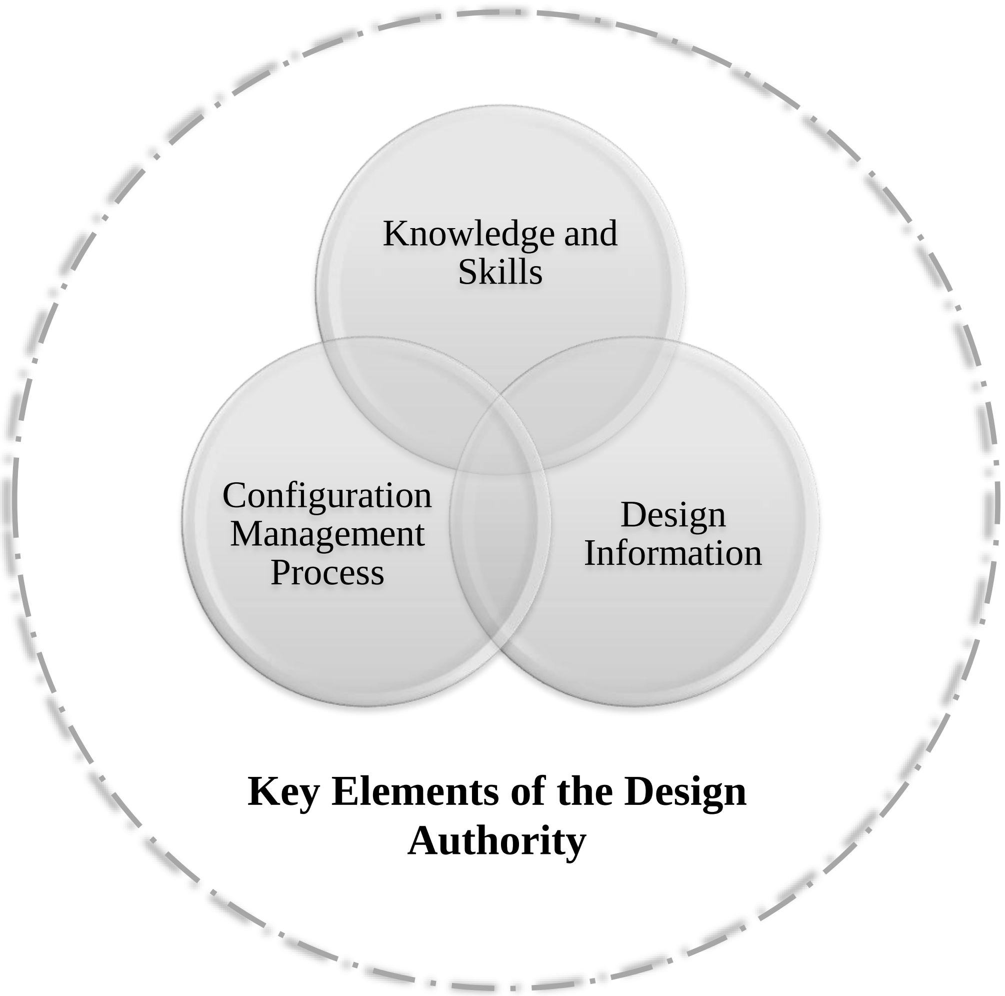


Figure 4.1: Key Elements to Establishing a Nuclear Design Authority (Source: Author)

4.3.1 Knowledge and skills

The IAEA (IAEA, 2003:2) describes nuclear power plants as: "*Nuclear power plants are complex machines. They are composed of many interdependent systems which must operate in a manner that meets the design intent over a period of many decades*".

To effectively perform the Design Authority function within an operating organisation the required skills and knowledge should be established as early as possible by the Design Authority Organisation. The guidance documents are mostly silent to the specific engineering skills, the number of resources required or the project phase in by which the capability should be established. The World Nuclear Association has documented the following as a core complement: control and instrumentation, mechanical, electrical and civil / structural engineers. With more plants being built with digital control and protection systems and complexed man machine interface capability, information technology related skills are being seen to play a bigger role.

The minimum knowledge statements collated from the literature is as follow:

- An understanding of the design basis;
- The technical analysis on which the design is based;
- The requirements informing the design basis: safety principles, applicable codes and standards, regulatory requirements and design conditions;
- The resultant operating and safety limits for the particular design;
- Design calculations which supports the final plant design and the Safety Analysis;
- Analysis, testing, inspections and computer code validation used to confirm that the design requirements are met;
- Functional understanding of Plant systems, components in support of plant operating and safety;
- An understanding of the suit of data and documentation developed for the project.

The literary sources have however highlighted the need to establish formal links to the original design entities, as Responsible Designers / Design Agencies, as part of the Design Authority capability. The overall authority may not be delegated from the operating organisation, but certain design related responsibilities may and should be captured in formal agreements. It is proposed that these links be maintained with a long-term vision, so that a wider operating experience of the specific design is shared. It is also accepted that the Design Authority will most likely not hold all the specialist skills required to analyse and maintain the plant design over its full life, with a specific reference to skills such as accident analysis or complexed technical modelling. These skills should however be secured through formal agreements ensuring availability as required to support the evaluation of design changes and impact on plant operation.

The type of technical skills required and the degree of contractual arrangements with support organisations has been explored through interviews with the survey participants.

4.3.2 Design information

The availability of the plant documentation and data is of critical importance to the function of the Design Authority as most of the detailed information supporting the knowledge base as referenced in 4.3.1 would be captured in formal documents and data.

From the current industry guidance, it is concluded that the array of data and documents differ from project to project and that that the variables which influence the final information set comes from, contractual arrangements, regulatory requirements, design and construction methodologies and codes and standards. It could therefore be hugely different for various build projects. The study considers this a shortfall in the industry approach. A comprehensive guideline could be developed for new nuclear power plants based on previous build experience in not only specifying the information turnover requirements during the project design and build phase, but also from an operating plant perspective where many years of Design Authority practice exists.

The Electric Power Research Institute (EPRI) has developed high level industry guidance in its 2016 Technical Report titled: *Advanced Nuclear Technology: New Nuclear Power Plant Information Turnover Guide*. This guide describes a detailed process of handing over information to the operating organisation from the construction and design organisations, but falls short in providing a basic guide of the actual information required. The subject of a design documentation listing was explored further during the industry survey.

4.3.3 Configuration management process

The approach to establishing and maintaining a configuration management process has been widely published within industry. International agencies such as the IAEA, WANO and INPO; Nuclear Regulatory Bodies in various countries and Industry Peer Groups have recognised the risk that the loss of configuration management poses to nuclear safety and have elevated the focus over many years of nuclear power operation. Certain nuclear plants have been forced to cease operations through regulatory enforcement, as a result of configuration management concerns. In contrast with the first two elements, it is clear that guidance has been developed, industry best practice has been identified and sufficient information exists to support a new nuclear plant Design Authority in establishing and maintaining a robust configuration management process.

4.4 Industry Approach to Selecting a Design Authority Strategy

The study has shown that various strategies have been adopted by utilities in different countries. The key variable has been whether the core capability for the Design Authority is kept internal to the operating organisation or whether the core capability is outsourced to a Responsible Designer or Design Agencies.

The strategies have been influenced by the following as a minimum:

- The maturity of the operating organisation;
- The size of the utility – one plant or many – one plant of the same design or many;
- The experience within the country to operate nuclear power plants and the existence of a skills base;
- The contractual agreement EPC vs EPCO;
- The utility strategy to simply operate nuclear power plants or to build greater infrastructure and expand its nuclear programme.

The analysis of the literature as yielded the following:

Table 4.3: Country Strategies in Establishing a Nuclear Design Authority

Country	Design Authority Strategy
France	• EDF is the architect engineer and the operator. • Its senior level division called the Nuclear Engineering Division, fulfils the role of the Design Authority. • Maintains a close link to the original vender Framatome.
UK	• Original plant designers no longer exist for some of the plants • The Design Authority is assigned to an individual supported by an engineering team. • Challenging areas have been supported by additional contractual agreements with Responsible Designers
South Korea	• Design Authority for its operating plants is assign to the operating organisation to KHNP – CRI Division. • KHNP as a government entity has close links to the original designer KEPCO E&C. • KHNP has delegated areas of the overall design to KEPCO

USA	• Original designers retain the intellectual property of the NSSS design • The operating organisation however retains the Design Authority
Canada	• The Design Authority is assigned to the Chief Nuclear Officer within the operating organisation • In turn certain aspects of the function are delegated to the plant engineering team and others to Responsible Designers.

Insights drawn from the comparison Table 4.3:

- In countries such as South Korea and France, nuclear utilities are government owned and these countries have multiple nuclear power plants in operation. Their nuclear programmes are built on the transfer of the base technology from original designers such as Westinghouse Electric, in the case of South Korea, or from the development of the country's own technology, in the case of France. Due to these utilities operating multiple nuclear sites the Design Authority is established and centralised at a corporate level rather than within the individual nuclear plant structures. After establishing successful domestic nuclear programmes, both South Korea and France have exported nuclear technology and are currently constructing nuclear plants in other countries.
- In countries such as the UK and Canada the Design Authority function is assigned to a single operating plant individual, supported by engineering teams at the plant. These countries typically have smaller fleets which are not owned by the government. Even though the majority Canadian plant are of a similar design they are owned by different utilities.
- The USA has a diverse range of nuclear power plant designs which are operated and owned by independent utilities. What is unique is that the intellectual property remains with the architect designers whereas many utilities in other countries have opted for a technology transfer approach.

The comparison reinforces that the strategy adopted by various countries and utilities has been based on the strategy of its nuclear programme and the specific circumstances of the operating utilities.

4.5 Industry Survey Results

The industry survey was completed by 12 industry experts. These participants currently fulfil senior engineering roles in nuclear operating plants or nuclear power plant construction project organisations. Their experience has been drawn from nine countries, and eight nuclear build projects. Responses to the survey therefore included experience beyond the five selected countries and expanded to the United Arab Emirates, China, Romania and South Africa.

It is considered that minimal statistical meaningfulness will be drawn due to the restricted industry sample. 30 Countries are currently operating commercial nuclear power plants with 440 nuclear reactors in operation.

The survey consisted of 10 questions and was administered through an online survey application. The utilities and individual identities have been kept anonymous for the purposes of the study.

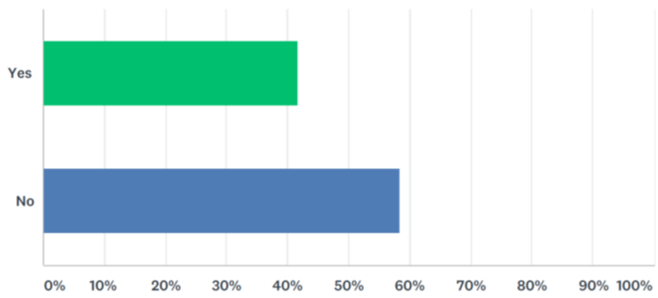
It should be noted that the survey questions have not been documented in chronological order and have been sequenced to support responses to five main sub-topics; Design Authority knowledge and skills; Design Information; Configuration Management Process; Regulatory Requirements; Critical Considerations for the establishment of a Design Authority Function.

4.5.1 Design Authority knowledge and skills

The following questions were focused on the Operating Organisations strategy in building the full or partial capability within its structure in support of the Design Authority function.

Question 1: Has the operating organisation taken the full role as Design authority and how has the architect / original design organisation been incorporated into the strategy?

Answered: 12 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes	42%	5
No	58%	7
TOTAL		12

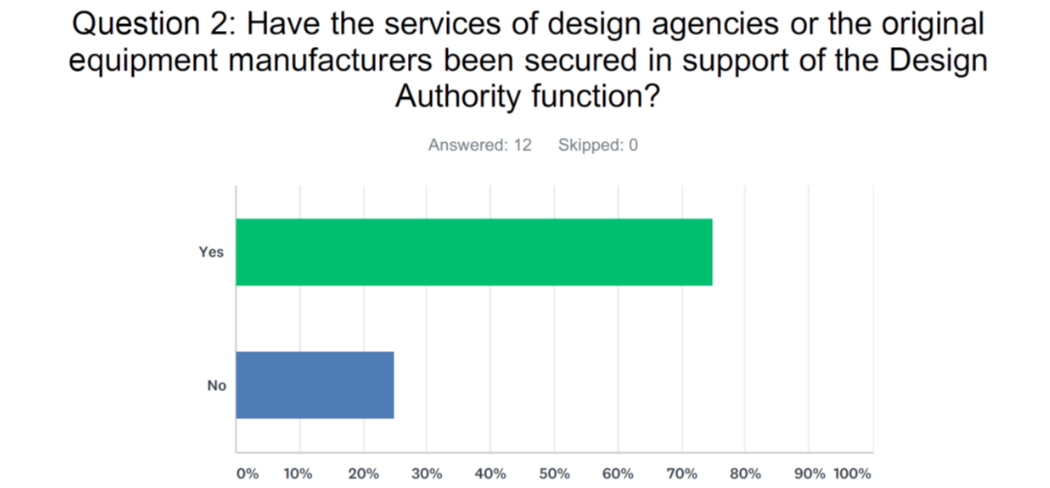
Figure 4.2: Operating organisation assuming the full role of the Design Authority

Figure 4.2 shows a split survey result which supports the understanding that certain utilities may take on the full role of the Design Authority and build the capability international to its organisation. This is evidenced in countries such as France (EDF) and South Korea (KHNP), with larger utilities who operate a number of nuclear plants, where full capability has been built to support the nuclear programme and the fleet of nuclear plants.

The key insights drawn from the written survey answers are:

- Projects in “new to nuclear’ countries have opted to support its Design Authority with capability from Architect Engineering companies until in-house capability has matured.

- Operating organisations have taken the full accountability for fulfilling the role of the Design Authority, but have retained links to the original designers as they do not intend to carry all the specialist capability.
- The Design Authority should retain the capability to understand the totality of the plant design. It should therefore build a knowledge base of qualified staff. The capability should be in the form of record and expertise. Original designers should be used to transfer knowledge to the Design Authority.
- The Design Authority is established during the plant design phase in UK new build projects. This allows competency to be built, through providing design oversight from an early stage. Where all the in-house capability does not exist, consultants are contracted, which often creates concerns with priority information.



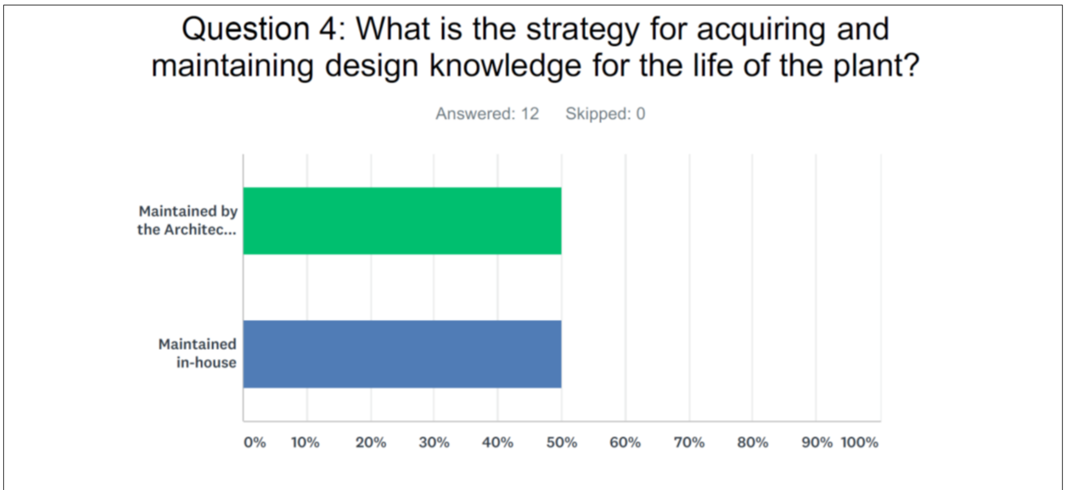
ANSWER CHOICES	RESPONSES	
Yes	75%	9
No	25%	3
TOTAL		12

Figure 4.3: Securing the services of "Responsible Designers"

The results have shown a greater propensity for securing the services of Responsible Designers in support of the Design Authority function.

The key insights drawn from the written survey answers are:

- Utilities have established long term agreements with original designers and original equipment manufacturers for design related support. These have not only included original suppliers but also main equipment sub-suppliers for systems and equipment such as, turbine - generators systems, nuclear steam supply systems, primary system pumps, man machine interface systems and diesel engines.
- A respondent stated that in South Korea the Korean Nuclear Regulator requires all design information to be available to the Design Authority to ensure that they can effectively execute the function. This has not been the case in other projects internationally.



ANSWER CHOICES	RESPONSES	
Maintained by the Architect Designer / Constructor	50%	6
Maintained in-house	50%	6
TOTAL		12

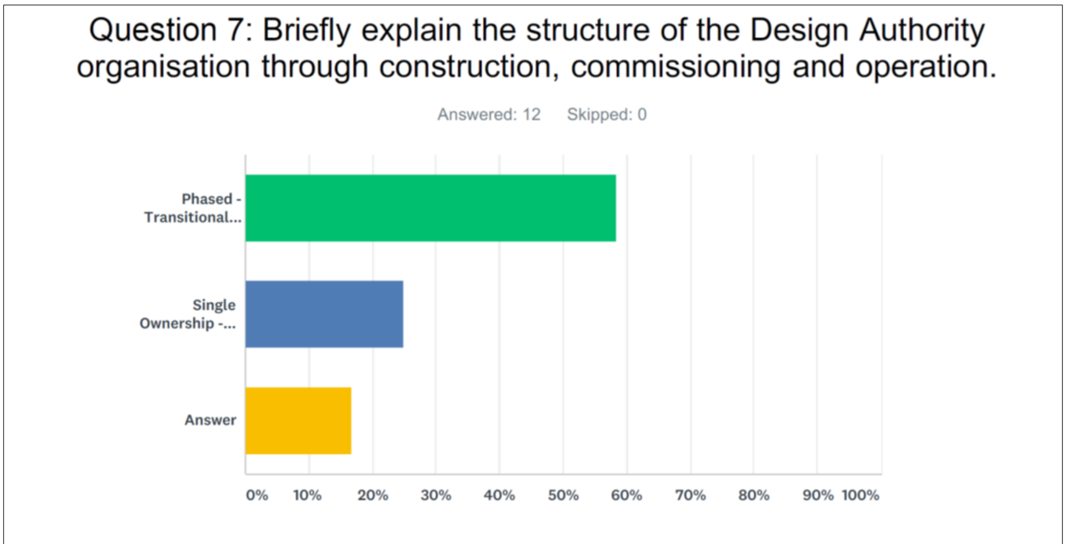
Figure 4.4: Establishing and maintaining design knowledge over the life of plant

The survey results have indicated a split result with 50% of the knowledge being retained in-house and 50 % being maintained by original designers. The answers provided in the written survey were insufficient to draw insights into the aspect of how design data is acquired.

The key insights drawn from the written survey answers are:

- Operating organisations strive to carry design expertise in-house but often the final plant design has been a culmination of many years of design architecture. The analysis supporting the final design are not always available with the related design history. The embedded history often remains with the original design organisation. An example would by the South Korean APR 1400 plant design which was originally based on the Westinghouse AP 1000 plant design.

- The context for each nuclear plant and utility needs to be assessed as a single unit station that would have a different approach to a multi-unit operator. Original Designers market their design based on the unique safety features and this information is considered highly proprietary, hence the reluctance to make information, such as safety analysis calculations, available to plant operators. Design Authorities have often found themselves securing as much knowledge through the build process, but having to continue building internal capability over time.



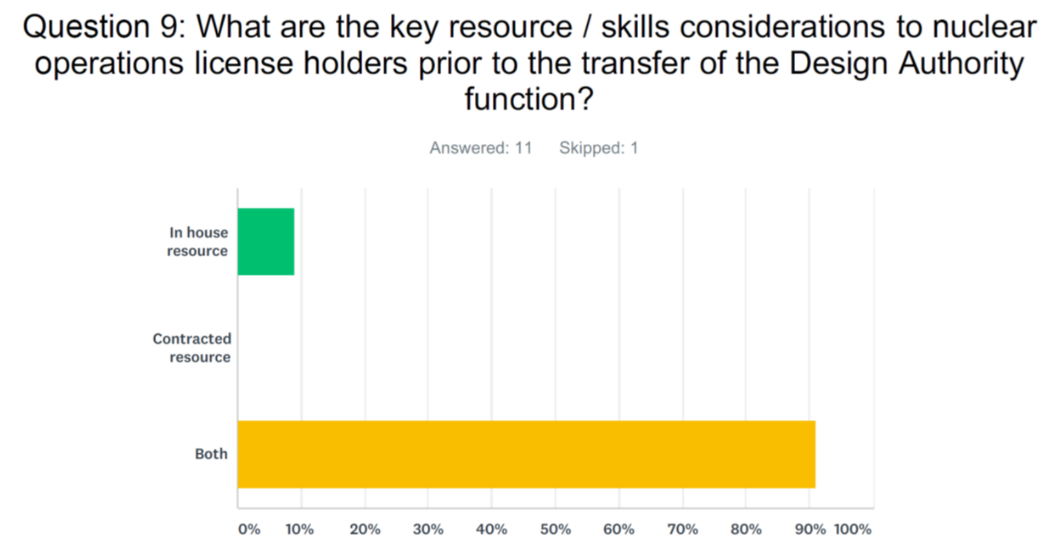
ANSWER CHOICES	RESPONSES	
Phased - Transitional Design Authority	58%	7
Single Ownership - From construction to operation	25%	3
Answer	17%	2
TOTAL		12

Figure 4.5: Design Authority through construction, commissioning and operation

The survey results have leaned towards a "phased or transition" of the Design Authority function through the project phases of construction, commissioning into operation.

The key insights drawn from the written survey answers are:

- It is essential that the Design Authority retains the capability to understand the totality of the design and nuclear safety case over the full lifetime of the plant. The lifetime (construction, commissioning, operation and decommissioning) of nuclear plants means that a plant will undergo changes throughout its life. Changes can include physical ageing of the plant's systems, structures and components, software and hardware obsolescence, feedback from operating experience or research and development, changing engineering or regulatory standards, changes in plant performance, change of lifecycle phase and changes in the licensee organization or operating practices.



ANSWER CHOICES	RESPONSES	
In house resource	9%	1
Contracted resource	0%	0
Both	91%	10
TOTAL		11

Figure 4.6: Key Resources required to Establish the Design Authority

The results indicate that a combination of in-house resources and contracted resources would be required to establish the design authority prior to the transition from construction to operation.

The key insights drawn from the written survey answers are:

- In the UK setting, as noted above, both are considered. The Design Authority function aims to hold the "intelligent customer" capability in-house as a minimum, supported by designers and consultancies as required.
- The Design Authority should have knowledge of:
    - The **design inputs** such as basic functional requirements, performance requirements, safety goals and safety principles, applicable codes, standards and regulatory requirements, design conditions, loads such as seismic loads and interface requirements;

    - The **design outputs** such as specifications, design limits, operating limits, safety limits, failure or fitness for service criteria. Support might be contracted initially but ultimately the Design Authority should develop in-house capability.

- A detailed knowledge of the design calculations, which demonstrate the adequacy of the design, and the ability to reproduce the design calculation is needed. A detailed understanding of why the design is as it is and the implication of operating experience on the design are fundamental requirements.

- New build projects have taken different approaches in the case of South Korea. The Design Authority in South Korea remains with KHNP throughout the build process and does not transition. This is the same strategy for the UK new build programme. In the case of the UAE build project, the Design Authority remains with the constructor until post construction and the issuance of the operating license.

4.5.2 Design information

Question: From the list below - which are the key turnover documents required, as a minimum, by the Design Authority to perform its function after Design Authority transfer?

ANSWER CHOICES	RESPONSES	
2 P&ID Drawings	92%	11
7 Design Criteria	92%	11
15 Fire Hazard Analysis	92%	11
30 System Design Requirements	92%	11
33 Component Specifications	92%	11
38 System Functional Descriptions	92%	11
4 Wiring Diagrams	83%	10
5 Operating Procedures	83%	10
22 Single Line Diagrams	83%	10
25 Logic diagrams	83%	10
26 PRA report	83%	10
43 Component design drawings (NSSS)	83%	10
8 Instrument loop diagrams	75%	9
10 Test and Commissioning documents	75%	9
11 Valve list	75%	9
13 RCS component design analysis	75%	9
18 Design Calculations	75%	9
20 Fire Barrier Penetration List	75%	9
27 Data Sheets	75%	9
29 HVAC configuration	75%	9
35 Safety Analysis Containment	75%	9
39 Cable tray and conduit layout	75%	9
40 Pre-service performance and test reports ISI/ MOV/ IST/ FAC	75%	9
41 Internal flood analysis	75%	9
44 Severe Accident Analysis	75%	9

Figure 4.7: Selection of the Key Design Information Required to Support the Design Authority Function.

Of the 45 information types listed in the survey at least 40 documents were identified as required by at least seven of the 12 participants. The insight is that operational demands would identify the plant and design information required at a point in time. To provide reasonable assurance that sufficient critical information is available to the operating organisation prior to the issuance of the operating license, the Design Authority should be fully aware of what information exists and how this will be accessible.

4.5.3 Configuration management process

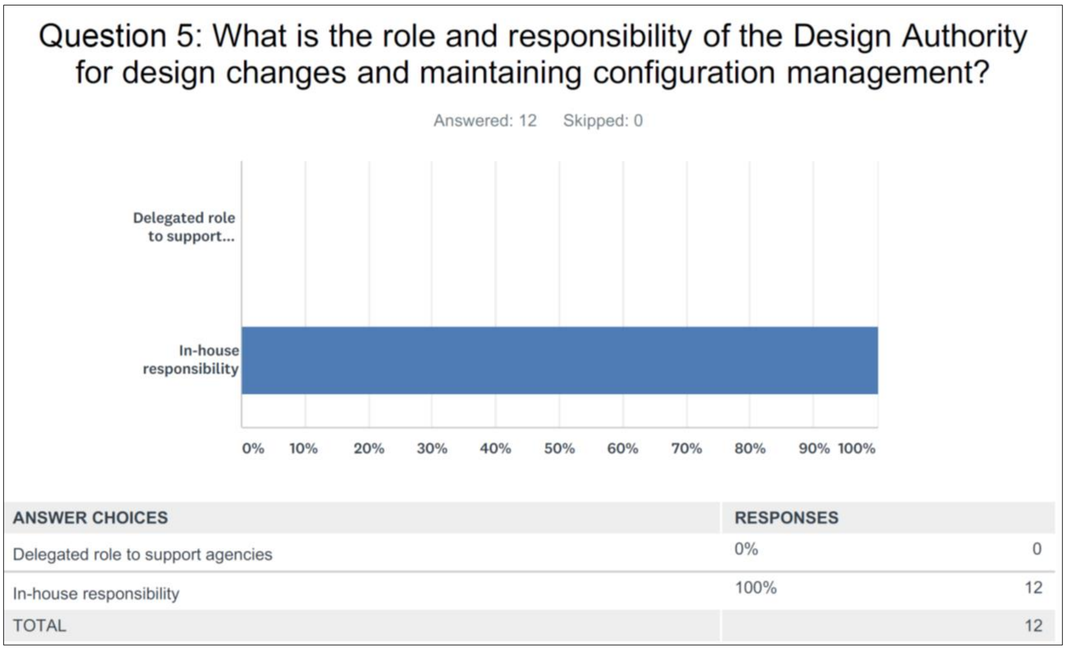


Figure 4.8: Design Authority Control of the Plant’s Configuration

The results have indicated that all participants believed that the role of the Design Authority in managing the plant configuration remains in-house and is not delegated to a support organisation.

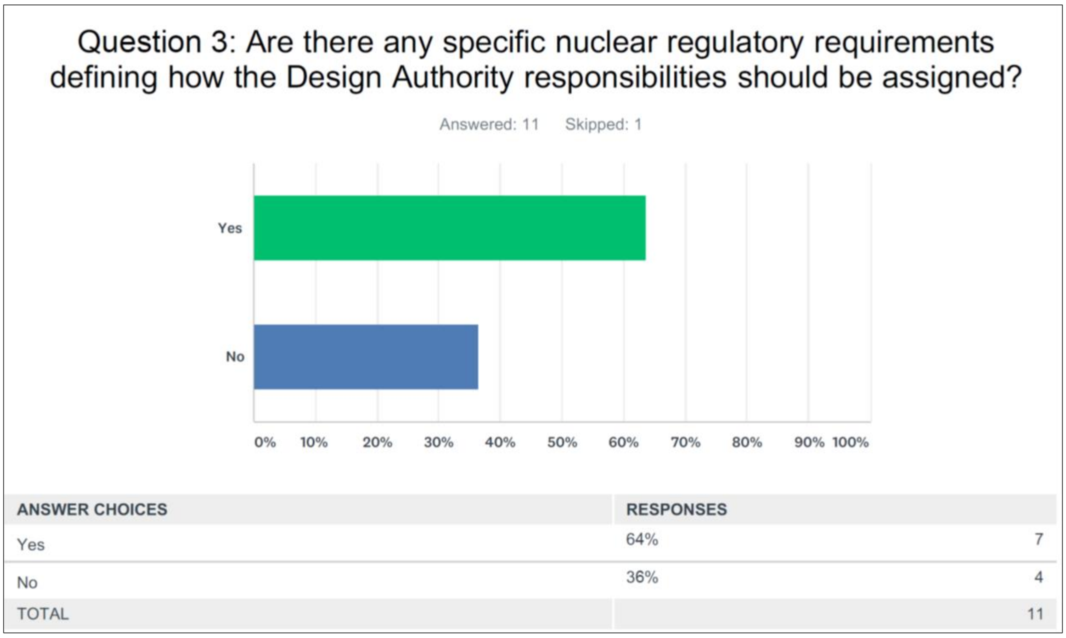
The key insights drawn from the written survey answers are:

- The Design Authority should maintain a formal and rigorous design change process which ensures that the actual configuration of the plant throughout its life is consistent with the design, and that changes are made with the full knowledge of the design intent. Design Authority maintain the plant’s design basis and control the plant's configuration. This becomes the formal role of the Design Authority as soon as the function is transferred from the construction phase to the operations phase of the project.

- The operator is responsible for safety. The decision to modify the plant to deal with an emerging issue is in the hands of the operator. Having the complete plant configuration available is within the responsibilities of the operator. The operator needs to have enough in-house capability to determine which of the external design entities are sufficiently qualified and capable to provide services. The operator establishes the highest level of the Design Authority and is responsible for ensuring that the design processes used are robust and that the required background knowledge is available for use.

- In the UK – the responsibility is 'required' to be in-house by the regulator. In theory it could be delegated out but it is assumed that the ONR wouldn't be particularly comfortable with that. Whilst the preparation of design change packages may be carried out by external agencies, the acceptance and configuration control will be managed in-house.

4.5.4 Regulatory requirements



ANSWER CHOICES	RESPONSES	
Yes	64%	7
No	36%	4
TOTAL		11

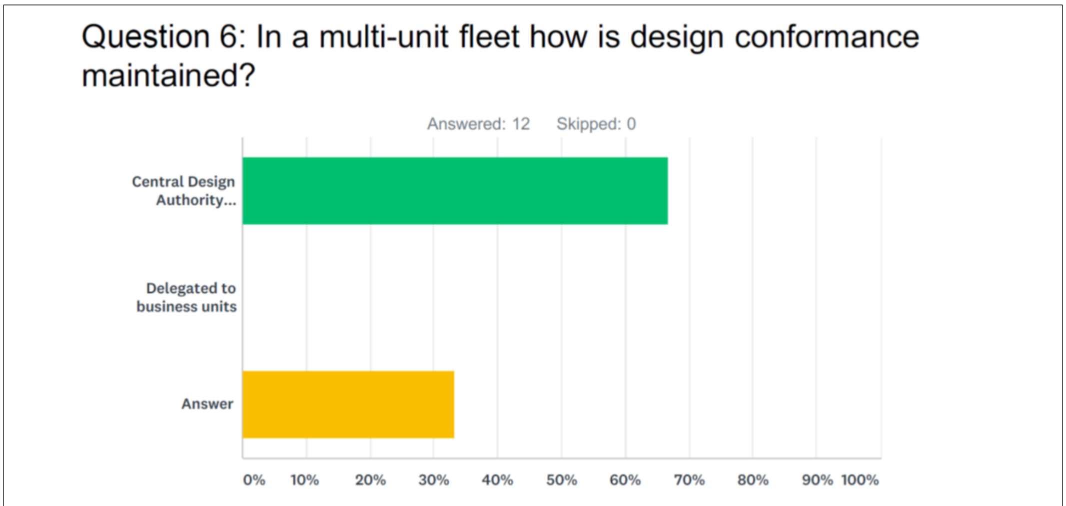
Figure 4.9: Regulatory requirements for assigning the Design Authority

The results show that seven participants have indicated that regulatory requirements exist for the assigning of the Design Authority function.

The key insights drawn from the written survey answers are:

- The South Korean Nuclear Regulator (KINS) have not set regulatory requirements for the appointment of the Design Authority.
- For the UAE – The requirements have been specified in federal regulation by the Nuclear Authority.
- In the case of Canada, the regulator allows the Design Authority to remain with the OEM provided that the operator confirms their capabilities. The INSAG-19 document from the IAEA implies that the Design Authority should be with the operator but acknowledges the challenges with respect to having sufficient capability and access to detailed enough design documentation.

- The UK regulator has adopted a goal setting approach and so does not set 'requirements' as such. The ONR has safety assessment principles and technical assessment guides which provide guidance to the ONR inspectors as to what they should be looking for from the operator to demonstrate adequacy of arrangements. In the case of Design Authority, the operating organisation should have the capability to provide sufficient oversight if the function is supported by an external entity.



ANSWER CHOICES	RESPONSES	
Central Design Authority Function	67%	8
Delegated to business units	0%	0
Answer	33%	4
TOTAL		12

Figure 4.10: Multi-unit Fleet Design Conformance

The majority of the participants have indicated that the function is performed by a central Design Authority.

The key insights drawn from the written survey answers are:

- In the case of France (EDF), for a multiple unit fleet where units are sufficiently similar, it is possible to have a centralized Design Authority. For maintaining design conformance, a major modification is typically performed as a generic modification that can be implemented for units as required.

- EDF Energy (UK) - there is a central Design Authority who manage some design changes, but generally it's up to the individual sites to manage design control, with oversight from the Design Authority. The new build projects have aimed for a central function.

4.5.5 Critical considerations for the establishment of a Design Authority function

Survey Question 10:

What are the three key lessons learnt / experiences you would like to share with utilities entering the operational phase which they could benefit from?

The following responses have been drawn directly from the written survey answers:

- *"The Operating Organisation must exercise strict configuration control management practices to ensure safety and reliability of plants"*
- *"The plant staff shall understand the actions that can place the plant under non-compliance. For example:*
    - *operator cannot leave drain hoses attached to the valve as this will be considered design change;*
    - *plant staff cannot leave test equipment attached to the plant as this will be considered design change;*
    - *all staff must strictly follow temporary change process for short term configuration change;*
    - *operators must always be in control of plant and should have logs of all temporary changes;*
    - *The Operating Organisation must implement strict documentation retention programme to remains in control of plant design changes";*

- *"All design basis documentation and other critical design calculations and analysis* <u>*are to be transferred*</u> *to the Operating Organisation to effectively implement the design change control process";*
- *"Configuration management, especially related to field changes during commissioning is usually not well controlled.* <u>*Turnover of design documents*</u> *including commissioning reports, factory acceptance tests, vendor design manuals, etc should be completed satisfactorily prior to turnover. In-house capabilities should be developed for long term protection and defence of design basis";*
- *"Contractual arrangements should ensure adequate security of, and accessibility to,* <u>*knowledge and support*</u> *and ensure that Responsible Designers do not have a conflict of interest with the operations function. Implement adequate arrangements for suitable training of all those on site who have responsibility for any operations which may affect safety. Staff fulfilling Responsible Designer roles, as roles which may affect safety, must be suitably trained to fulfil those roles";*
- *"Start building the* <u>*in-house capability*</u> *early and if possible, embed the System Engineers in the Start-up organization from Day-1. Understand the limitations of a new plant Operating Organization and consider a contract with the OEM to support a portion of the Design Authority role for the first few fuel-cycles. The Design Authority is about approving the need for a design change and* <u>*ensuring the design processes followed*</u> *are adequately performed by qualified persons, it is not about approving the design outputs";*
- *"Target* <u>*skills/knowledge*</u> *required, not people when designing the organisation, grouping skills effectively gives the 'bare minimum' organisation required to be effective (i.e. capability). Then look at capacity where you can be flexible on how you deliver the capacity aspect using in-house and external support - Start early, particularly with* <u>*configuration control*</u>*, information is very important - Good relationship with designer is*

vital; managing the need to ask deeper questions into proprietary information, not to take it, but to understand the basis";

- *"It is unlikely that an operating organisation can staff up adequately to take over the design role of the OEM. You need a strong Quality Assurance function to ensure qualifications of contractors and their sub-contractors performing designs on your behalf. <u>Rigorous adherence to process</u> and standardized design change package templates are required".*

In summary the critical considerations captured by the participants have again highlighted the fundamental requirements of developing and securing the knowledge and skills to execute the Design Authority function; to secure agreements with Responsible Designers in support roles; to secure technical and design information; to establish and ensure compliance to the configuration management process.

The basic strategies for operating organisations to consider includes:

- Securing all the Design Authority capability internally – which breaks ties with the original designer and loses access to its specialist knowledge and skills;
- The development of the Design Authority capability internally with support from Responsible Designers – which comes at an additional operational cost and oversight requirements or
- Retain a core capability to be an Intelligent Customer but outsource most of the Design Authority function – which creates a long-term reliance on external entities which might require significant oversight, introduce sustainability risk or even be costly.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATIONS

The importance of the Design Authority Function within the Nuclear Power Plant industry has been highlighted throughout this study. In the backdrop of major nuclear disasters such as Chernobyl and Fukushima, which highlighted fundamental shortfalls in the plants design and operation, it is clear that Nuclear Safety and continuously improving nuclear plant designs are increasingly critical to the operation of nuclear power plants. This study has shown that the role of the Design Authority is key in enhancing nuclear safety through design and maintaining nuclear safety by preserving the plants design integrity.

As a foundation to safe nuclear operation, significant emphasis is placed on the ability of the Design Authority to ensure that the plant design meets all applicable safety requirements and in particular that the plant's design bases remains valid for the entire plant life. Nuclear energy regulatory bodies internationally, require operating organisations to have a formally appointed entity to own the design knowledge and control. The responsibility for establishing and maintaining the required competencies, establishing procedures and processes, verifying the design safety features and preserving the overall integrity of the plant design in line with its design intent which is the direct obligation of the licensee, as stipulated in its operating license.

The objective of the study was to define the role of a Design Authority within a nuclear utility and identify the critical elements required for establishment of the Design Authority to support safe plant operation.

The conclusion has been written in answer to the research question:
What elements should be considered for the effective establishment of the Design Authority function at commercial operation of a New Nuclear Power Plant Construction project?

5.1 Summary and Conclusion

The following conclusions can be drawn:

The operating organisation is required to have an officially appointed entity to own the design knowledge and control changes to the plant design. This entity is called the Design Authority.

The role of the Design Authority has been defined as follows:

"The Design Authority: has the overall responsibility and authority over design changes, possesses the requisite knowledge and manages the design control process to ensure the integrity of the Nuclear Power Plant Design".

The common elements required by the Design Authority to perform its function is the establishment of the design knowledge and skills; obtaining the required plant design information and developing and implementing a robust configuration management process.

Acquiring the design knowledge and skill is fundamental to the Design Authority who are in most cases not the original design entity. The ability of the Design Authority to maintain the integrity of the plant design requires the establishment of the appropriate knowledge base, which is expanded with experience.

The concept of the Intelligent Customer re-enforces the need for the establishment of the Design Authority internal to the operating organisation, but also allows for certain portions of the Design Authority functions to be assigned to Responsible Designers, without delegating the overall responsibility for the design.

The availability of sufficient critical design information is a prerequisite to providing reasonable assurance to regulatory bodies that the Design Authority has the ability to fulfil its function.

Challenges with original designers may arise on issues relating to propriety of information and the final information set comes from, contractual arrangements, regulatory requirements, design and construction methodologies, codes and standards which should be clearly defined.

The Design Authority maintains the plant’s design basis and controls the plant’s configuration. Configuration management ensures consistency among design requirements, plant configuration documentation and the physical plant.

Fundamental differences exist in the execution of the Design Authority function in the aerospace industry as the original designer retains the Design Authority for their aircraft design and the aircraft operator retains the responsibility for safety and reliability.

The strategy adopted for the Design Authority is often dependant on the strategy of the country’s nuclear programme and the specific circumstances of the operating utilities. The key variable has been whether the core capability for the Design Authority is kept internal to the operating organisation or whether the core capability is outsourced to Responsible Designer or Design Agencies. For new nuclear countries the support of the original designer is critical as design capability and experience is developed within the Design Authority.

5.2 Recommendation for Future Work

The study identified that industry experience sharing and guidance to “new to nuclear” countries and utilities on design information transfer and resource requirements in support of the Design Authority function is lacking in detail. Further to this no internationally agreed standards exists which ensures that the original designer guarantees that design knowledge is applied to all its international builds as that responsibility lies with the Design Authority of the power plant. The sharing of Design related information between Design Authorities may continue to be challenged as a result of political, legal, commercial and intellectual property restrictions and regulations. The study considers this a shortfall in the industry approach as a comprehensive guideline could be developed for new nuclear power plants based on previous build experience.

It is recommended that more detailed guidelines be developed for new nuclear plants that details the advantages and disadvantages and the extent to which internal Design Authority capability is established within the operating organisation. The guidance should include a comprehensive listing of the design information required to perform the Design Authority function and mechanisms which has shown positive results in securing this information in commercial build contracts.

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Appendix A – Introduction letter

(Source: Author)

Nuclear Design Authority Research

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

To whom it may concern 1st August 2018

Re: Participation in Research on Design Authority Strategies for Nuclear New Build Projects.

I am a part-time MSc student in the School of Engineering and the Build Environment at the University of the Witwatersrand, under the supervision of Dr Tim Hutton. My MSc title is: Defining Design Authority elements in Nuclear Power Plant Construction Projects.

The study aims to define the role of a Design Authority within a nuclear utility. It will then identify the critical aspects required for the Design Authority to be effective and develop guidance for managing plant design basis to support safe plant operation during and after nuclear power plant construction. The study will further explore functional elements in support of the Design Authority function, such as the configuration management process, design capability, engineering skills requirements and the required design data.

I would like to formally invite you to participate in this study a professional nuclear engineer. Your experience, lessons learnt, technical insights and judgment would contribute significantly.

The study will be conducted during October / November 2018 and would involve the completion of a survey document on the online on the Survey Monkey application. It consists of 10 questions which could be completed within 1 hour.

The Survey may now be completed at the following link:
https://www.surveymonkey.com/r/JDQLQ6Q

Participation in the study is voluntary, and you may withdraw at any time. No personal or sensitive company related information is required as part of the answers to the study. Anonymity, regarding your name, and confidentiality of information provided will be assured and respected.

The results of the study will form part of my MSc dissertation report, and may also be reported in academic papers and at conferences. A summary of the results of the research will be made available to you on request.

Please contact me if you have any questions regarding the research and participation in the study.

Yours faithfully

Warren James Whittaker

Appendix B – Questionnaire

(Source: Author)

School of Engineering and the Build Environment - University of the Witwatersrand

Research Survey: Nuclear Design Authority Research

Question 1:

Has the Operating Organisation taken the full role as Design Authority and how has the Architect / Original Design Organisation been incorporated into the strategy?

( ) Yes ( ) No

Answer:

Question 2:

Have the services of design agencies or the Original Equipment Manufacturers been secured in support of the Design Authority function?

( ) Yes ( ) No

Answer:

Question 3:

Are there any specific Nuclear Regulatory requirements defining how the Design Authority responsibilities should be assigned?

( ) Yes ( ) No

Answer:

Question 4:

What is the strategy for acquiring and maintaining design knowledge for the life of the plant?

○ Maintained by the Architect Designer / Constructor ○ Maintained in-house

Answer:

Question 5:

What is the role and responsibility of the Design Authority for design changes and maintaining configuration management?

○ Delegated role to support agencies ○ In-house responsibility

Answer:

Question 6:

In a multi-unit fleet how is design conformance maintained?

○ Central Design Authority Function ○ Delegated to business units

Answer:

Question 7:

Briefly explain the structure of the Design Authority organisation through construction, commissioning and operation.

- Phased - Transitional Design Authority
- Single Ownership - From construction to operation

Answer:

Question 8:

From the list below - which are the key turnover documents required, as a minimum, by the Design Authority to perform its function after DA transfer?

1) Civil structural design criteria
2) P&ID Drawings
3) Instrument rack arrangement
4) Wiring Diagrams
5) Operating Procedures
6) Structural steel drawings
7) Design Criteria
8) Instrument loop diagrams
9) Maintenance Procedures
10) Test and Commissioning documents
11) Valve list
12) 3-line diagrams
13) RCS component design analysis
14) Field changes
15) Fire Hazard Analysis
16) Electrical grounding grid layout
17) In Service Inspection Isometrics
18) Design Calculations
19) Structural Diagrams
20) Fire Barrier Penetration List
21) Schematic diagrams
22) Single Line Diagrams
23) Safe shutdown accident analysis
24) Annunciator arrangements
25) Logic diagrams
26) PRA report
27) Data Sheets
28) Class 1 Stress Analysis isometrics

29) HVAC configuration	30) System Design Requirements
31) Cable diagrams	32) Instrument Valve list
33) Component Specifications	34) Motor control centers
35) Safety Analysis Containment	36) General instrumentation arrangement
37) Architectural building drawings	38) System Functional Descriptions
39) Cable tray and conduit layout	40) Pre-service performance and test reports
41) Internal flood analysis	42) Fluid System Hydraulic Analysis
43) Component design drawings	44) Severe Accident Analysis
45) Piping Class sheets	46) Vendor manuals

Question 9:

What is the key resource / skills considerations to Nuclear Operations License Holders prior to the transfer of the Design Authority function?

In house resource   Contracted resource   Both

Answer:

Question 10:

What are the three key lessons learnt / experiences you would like to share with utilities entering the operational phase which they could benefit from?

Lessons Learnt   Critical Considerations

Answer: