Nuclear Power Plant Life Management

Proceedings of an International Conference
Lyon, France, 23–26 October 2017

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International Atomic Energy Agency

NUCLEAR POWER PLANT
LIFE MANAGEMENT

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FOREWORD

Nuclear power plants (NPPs) provide secure and sustainable energy supplies. Safety should always be the prime consideration. Plant operators and regulators need to take the necessary steps to ensure that plant safety margins are maintained and, where possible, even enhanced throughout the plant's operating life. The world fleet of nuclear power plants is, on average, over 20 years old. Many of these plants may be allowed to operate for many more years. Such long term operation (LTO) requires that licensees demonstrate compliance with safety requirements through analysis, programmes for replacing equipment, system modernization, and advanced ageing monitoring and management techniques.

The ageing of structures, systems and components (SSCs) increases the probability of common cause functional degradation — the degradation of two or more physical barriers or redundant structures and components — which could result in the impairment of one or more levels of protection provided by the defence in depth concept. Effective ageing management of SSCs is a key element of the safe and reliable operation of NPPs. Ageing management covers all activities that aim to prevent or control ageing effects within acceptable limits through the entire lifetime of an NPP: from design, fabrication or construction, commissioning and operation including LTO to shutdown and decommissioning

LTO of an NPP is operation beyond an established time frame defined by the licence term, the original plant design, relevant standards or national regulations. The safety of NPPs during LTO has become more important owing to the steady increase in the number of operating organizations giving high priority to continuing the operation of NPPs beyond the time frame originally anticipated for their operation.

Plant life management (PLiM) is the integration of ageing management with economic planning to optimize the operation, maintenance and service life of SSCs; to maintain an acceptable level of performance and safety; and-to maximize the return on investment over the service life of the facility. A PLiM programme helps optimize when and how to repair, replace or modify SSCs, while at the same time ensuring that a reasonable level of safety is maintained. Given the excellent results already obtained and documented with advanced PLiM techniques applied to nuclear power facilities, an increasing number of operating NPPs have adopted these methodologies over the past decade, and these are leading to significant improvements in operational performance while also reducing operational costs.

The resulting plant upgrades aim to achieve better control over plant operation, deploy technologies that enhance safety system protection, deploy improved severe accident mitigation measures that address a wider range of design basis events, and provide strategies that more effectively deploy human resources utilized in plant operation. The aim is to obtain a workforce and the necessary supporting resources to be capable of controlling a reactor even under extreme circumstances that take the plant beyond its design basis envelope. In parallel, ageing management programmes are being updated to bring under the umbrella of PLiM programmes those additional accident mitigating features, systems, subsystems and services, and plant defences that may have been adopted in response to the Fukushima-driven stress test recommendations.

The IAEA has organized three previous PLiM conferences. The first International Conference on Nuclear Power Plant Life Management was held in 2002 in Budapest, and the second one was held in 2007 in Shanghai, China. Participants in the first and second conferences recognized the importance of PLiM. The third international conference on nuclear power PLiM was held in Salt Lake City, United States of America in 2012. The current conference was held from

23–27 October 2017 in Lyon, France, and was significantly larger than the previous three in terms of participation.

A major conclusion from this conference was that, given the limited financial and human resources available to be applied to PLiM, there is an increasing need to strengthen international cooperation and to ensure that knowledge and best practices are shared and adopted throughout the global NPP community. It was also agreed that LTO prepares for the future an energy mix combining nuclear and renewable energy to sustainably secure a safe, clean and competitive power output and contribute to the mitigation of climate change.

The IAEA gratefully acknowledges the work of the programme committee and the support and generous hospitality of the Government of France and, in particular, Électricité de France and the Sustainable Nuclear Energy Technology Platform in organizing this conference. The IAEA officers responsible for this publication were K.-S. Kang of the Division of Nuclear Power and R. Krivanek of the Division of Nuclear Installation Safety.

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1. BACKGROUND

The IAEA has continued to support countries with operating nuclear power plants, mainly by disseminating operational experience and good practices in technology, management and human resources, and by sharing new models, methods, tools and processes for efficient and reliable operation and construction. Increasing demand for electricity, coupled with pressures to meet global climate change targets, make convincing arguments for ensuring that NPPs can operate as long as technically possible taking into account the most up to date safety requirements.

The global generating capacity of nuclear energy reached 392 gigawatts (electrical) (GW(e)) at the end of 2017. Three new reactors were connected to the grid during the year, bringing the number of operational nuclear power reactors to 448. Construction started on 3 reactors, with a total of 59 reactors under construction around the world; 2 reactors were permanently shut down.

Out of 448 nuclear power reactors operating in the world, 267 or approximately 60%, have been operating for 30 years or more. Figure 1 shows the age distribution of operating reactors as of 31 December 2017. Before a reactor reaches the end of its design life, it undergoes a special safety review and an ageing assessment of its essential SSCs for the purpose of renewing its licence beyond the originally intended service period. The nuclear industry places very rigorous demands on the availability of competent, qualified and capable human resources. The complexity of the technology necessitates highly educated and trained staff who must meet high standards of performance and conduct. These requirements apply across the full range of nuclear activities and facilities, from nuclear new build programmes, facilities in operation, through to decommissioning and waste management.

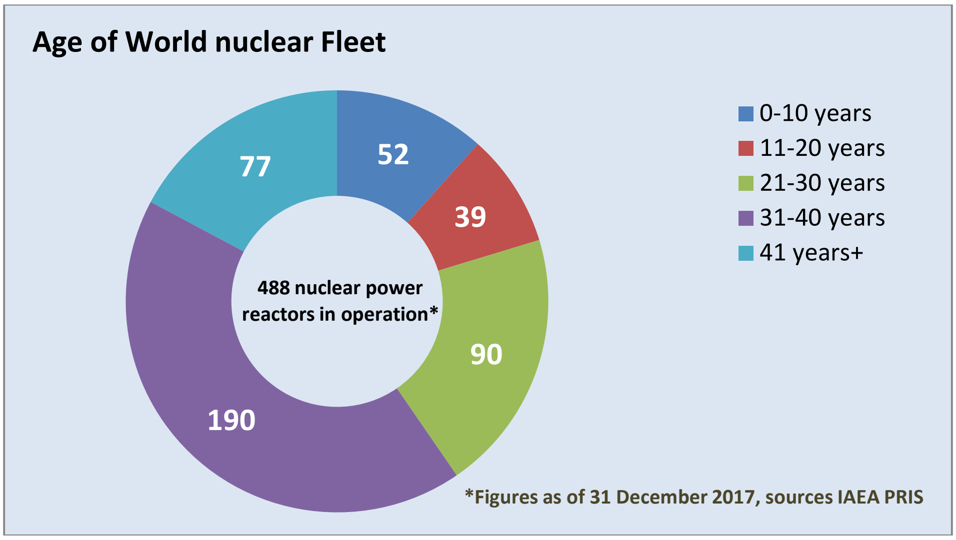

Fig.1. Age Distribution of Operating Reactors

The IAEA has periodically organized International Conferences on Nuclear Power Plant Life Management (PLiM), with the previous three being held in November 2002 in Budapest, Hungary, in October 2007 in Shanghai, China and in May 2012 in Salt Lake City, USA. This year's conference was held from 23-27 October 2017 in Lyon, France and was significantly larger than the previous three in terms of participation. More than 400 nuclear energy experts from over 38 countries and four international organizations gathered to discuss ways to safely and cost effectively operate NPPs beyond their design lifetime.

The IAEA has analysed the economic challenges, specific conditions, and cost drivers to identify optimized approaches for existing programmes, processes and procedures for operating facilities. Since the service life of NPPs spans a period beyond one generation, a large portion of the qualified workforce will retire before a plant is decommissioned. It is therefore essential that the industry addresses the issue of renewal of expertise and implements effective succession planning.

A total of 170 papers were registered, 110 were presented orally in 6 sessions, and the remaining displayed as poster presentations. There were 10 keynote speeches, 3 panel discussions, 17 technical exhibitors and 3 side events. Technical tours to visit an operating nuclear power plant and a power plant that was undergoing decommissioning were also organized.

2. SUMMARY OF THE CONFERENCE

The objectives for the fourth international conference on plant life management (PLiM) were to emphasize the role of PLiM programmes in ensuring safe and reliable nuclear power plant (NPP) operation; to provide a forum for information exchange on national and international policies, regulatory practices and the safety culture; and to have participants report on demonstration strategies, including the application of ageing management and PLiM programmes.

The Conference provided a forum for presentation of reports of the key elements within ageing management and PLiM programmes and good practices that related to the safety aspects of LTO; the identification of the economic impact of PLiM programmes and methodologies used for their evaluation; and a summary of the help available to IAEA Member States from the IAEA that can enable them to further develop their own PLiM programmes, including taking advantage of the latest available technology.

Opening addresses were made by a senior management representative of the IAEA, a representative of the Government of France, a vice president of EDF group, and the Chairperson of the Conference. This session defined the conference objectives and provided background information on the status and trends in the field of PLiM. Keynote presentations reported the development of PLiM approaches which have helped implement increased reliance, within the NPP community, on a systematic and highly effective approach to life management that is capable of enhancing the safe and economic operation of existing plants.

Following the opening plenary session and keynote presentations a total of six technical sessions were conducted during the conference:

Session 1: Approaches to PLiM. The aim of this session was to share information on, and best practices in the application of PLiM for LTO from the safety and economic point of view. Participants indicated that ageing management programmes of NPPs are developed and regularly updated to account for the latest technical information and new regulatory requirements. The harvesting of aged material from decommissioned plants, operating experience and other technical means (setup & expansion of databases, e.g. equipment qualification) are used.

Session 2: Economics of PLiM. The aim of this session was to discuss the methods to improve the economic performance of NPPs through PLiM. Participants reported and exchanged experience. This included examples of the successes achieved in the improvement of plant economic performance through the use of PLiM methods. It was noted that economic conditions impacting energy prices are an immediate and long-term challenge to the success of LTO, and it is important that those countries concerned identify a pathway to success in improving economic conditions to allow for LTO.

Session 3: Ageing management and preparation of LTO. The aim of this session was to share technical updates on ageing management issues for mechanical, electrical/instrumentation and control (I&C) components and civil structures. Participants shared technical updates on ageing management issues, and preparation of LTO. It was recognized as essential to perform environmentally-assisted fatigue testing on real-scale components to identify the margins incorporated in the codified approach covering environmental fatigue. The need to continue information exchange on material and structural integrity issues and share it through IGALL and Member States was noted.

Session 4: Configuration and modification management for safety enhancement. The aim of this session was to share information on safety enhancements, design modernization, refurbishment and replacement programmes for ageing SSCs, to discuss methods to address obsolescence and additional safety requirements. Participants shared information on SSC design modernization, refurbishments and major component replacement programmes to meet additional safety requirements.

Session 5: Human factors and managerial aspects. The aim of this session was to share experiences and lessons learned in relation to system management and the successful resolution of the technical issues and challenges presented in the previous sessions, and to identify outstanding human factors and managerial aspects in the field. It was noted that research is needed to develop human factors methods and technical bases to enable design, development, and deployment of new digital technologies.

Session 6: Regulatory approaches to ageing management and LTO. The aim of this session was to exchange information about regulatory requirements in different Member States (MS), to discuss the distribution of roles and responsibilities among the parties involved, and to address regulatory policy considerations. Important issues identified in this Session include public acceptance, openness between the regulator and the operator, and transparent regulator. The important role of the IAEA in facilitating the exchange of information and co-operation in this area was highlighted (Safety Standards, SALTO Peer Reviews, IGALL).

The closing session included short presentations by the technical session chairs, reporting the key messages from their respective areas. This was followed by a panel discussion on the current national approaches to PLiM. Successful achievements of ageing management and PLiM applications were reported in support of LTO in both technical and economic fields.

A major conclusion from the conference was to optimize the financial and human resources available to LTO. To optimize these resources, it is essential to strengthen international cooperation, preserve knowledge, and share best practices throughout the global NPP community. In addition it was concluded that LTO prepares for the future energy mix that combines nuclear and renewables to secure safe, sustainable, clean and competitive power output and to contribute to addressing the climate change challenges.

3. OBJECTIVES OF CONFERENCE

The objectives of the conference were to:

- Emphasize the role of PLiM programmes in assuring safety and improving reliable NPP operation;
- Identify the economic impacts of PLiM and LTO programmes, as well as methodologies for their evaluation;
- Provide key elements and good practices related to the safety aspects of ageing, ageing management and LTO;
- Provide a forum for information exchange on national and international policies, as well as on regulatory practices, and for the demonstration of strategies, including their application in ageing management and PLiM programmes for operating and new NPPs;
- Assist Member States in further developing their PLiM programmes taking into consideration lessons learned and impacts from the Fukushima Daiichi accident.

4. OPENING PLENARY SESSION

4.1. MIKHAIL CHUDAKOV, DEPUTY DIRECTOR GENERAL, DEPARTMENT OF NUCLEAR ENERGY, IAEA

Mr. Chudakov formally opened the conference by welcoming the participants and expressing appreciation to all the parties that planned and hosted the conference. He explained the role of LTO of NPPs to make a bridge between the current fleet and future reactors, ensuring their safety, while remaining economical.

The IAEA has been organizing major conferences on PLiM since 2002. This year's conference is significantly larger than the previous three held in Budapest in 2002, Shanghai on 2007 and Salt Lake City in 2012. This is a clear indication of the growing importance of this area. And in that sense, he appreciated partners, the European Commission's Joint Research Centre, the Electric Power Research Institute for their support in organizing this event. He also expressed his sincere appreciation to the government of France, to EDF and to NUGENIA, for their strong commitment in hosting this conference. His other comments were as follows

The IAEA projection shows that nuclear power will continue to grow in the coming decades. Many Member States look at nuclear as a possible source to address development, energy security, and climate change issues. Nuclear, hydro, and wind based electricity are the lowest CO_2 emitters, when emissions over the entire life cycle are considered. Direct greenhouse gas emissions from NPPs are negligible. And nuclear power is the key low carbon technology that is available today in large capacities, and that can be deployed on a wide-scale basis to help meet the climate–energy challenge. Today, nuclear energy produces 11% of the world's electricity but actually 1/3 of the low-carbon electricity.

The IAEA can support Member States through development of Safety Standards, Safety Aspect of Long Term Operation (SALTO) Peer Review Service, Energy Planning and Integrated Engineering Support for Operating NPPs. Over 50 % of today's 448 operational reactors are over 30 years of age; so LTO is becoming a large human and technical challenge.

The IAEA has been supporting operating countries. The IAEA has disseminated operational experience and good practices in technology, management and human resources. The IAEA helps share new or advanced models, tools and processes for efficient and reliable operation and construction. The IAEA has expanded our activities to analyse the economic challenges, specific conditions, and cost drivers and to identify optimized approaches for existing operation programmes, processes and procedures. Safer NPPs always show high performance.

PLiM must also address non-hardware ageing issues. Since the service life of NPPs spans a period beyond one generation, a large portion of the qualified workforce will retire before a plant is decommissioned. It is therefore essential that the industry addresses the issue of renewal of expertise and implements effective succession planning. Member States should define how they can maintain and enhance the operational infrastructure at national and regional levels to adequately support long term operation. The more operating experience is shared, the better resilience to events will become. Fukushima has demonstrated to us that we need to be joined up when responding to significant events in our industry, we can do this by facilitating our exchange of technical information about our plants.

During this conference, we will discuss the issues on material degradation and ageing management and international experience for beyond 60 years of operation, and approaches of

PLiM to maintain and enhance the operational infrastructure at national and regional levels. Also we will share and communicate our information with stakeholders to reinforce the positive social and economic benefits of the nuclear industry.

I am confident that this conference will demonstrate the value of an open exchange of information between experts from different countries and different organizations. The information collected in the various venues of this conference, the key note speeches, the oral and poster presentations and the panel discussions will play a critical role in the development of new and effective approaches to PLiM. I also expect that through this conference, international co-operation will be strengthened, and a culture of active sharing and learning will be encouraged.

4.2.DOMINIQUE MINIÈRE, VICE PRESIDENT, EDF, FRANCE

EDF group in France operates 58 nuclear reactors with three standardized series ranging from 900 MW up to 1500 MW units. The first connection to the grid took place 40 years ago and the average age of our reactors is 30 years. We cumulate 1600 years of operating experience. EDF believes that its experience in design, building and operation is unique in the world.

EDF’s industrial strategy is to operate the existing nuclear fleet well after 40 years under the best industrially possible conditions of nuclear safety (integrating the lessons learned for the past incidents and accidents: Fukushima-Daichi, in particular). We also intend to operate under the optimum conditions of environmental safety and protection, which requires continuing improvement of maintenance and control during the whole life time or our installations.

While there is no pre-determined service life, a ten-year review process and continuous nuclear safety enhancement are enshrined in the French law and as matter of fact in our processes: EDF is eager to take into account all the lessons learned from the few incidents and accidents that our industry has unfortunately experienced such as TMI, Chernobyl and Fukushima. EDF also integrates in its industrial strategy the progress of knowledge and last but not least the changes in the environment as a whole. Continued operation of each individual reactor is an asset to be approved for a ten-year period.

Work and its qualification are conducted upon completion of each ten-year inspection outage. Consequently, every ten years, the safety level of the French nuclear fleet is constantly advancing, as attested by the continuous improvement of its safety records.

To meet these challenges, involving the entire nuclear power industry on the short term, a programme called the “Grand Carénage: the big refurbishment” was initiated back in 2014 for a duration of 10 years. This programme was implemented in order to be able to perform in an integrated way the significant amount of work to be done on the fleet, jointly with the Group’s industrial partners being national or international.

In fact to continue operating after 40 years as safe and as efficient as possible, it is mandatory to address three complementary issues:

1. To comply with French regulations, improved safety requirements must be implemented taking into account the operational experience of existing plants, at each ten-year safety review;
2. To demonstrate that the ageing of non-replaceable equipment does not compromise their ability to fulfil the safety objectives;

3. As appropriate, a large maintenance programme should be implemented in addition to the replacement of some major equipment components (steam generators, transformers, et).

The Grand Carénage refurbishment programme responds to three combined goals:

— enable NPPs to continue operating after 40 years;
— generate around 400 TWh of annual output in full safety;
— secure and optimize the financial path of the programme.

The refurbishment programme is structured around 22 projects covering 7 key areas (10-year inspections, post-Fukushima upgrades, steam generators, nuclear island components, internal, external and other risks regarding environmental chemistry, civil engineering and fleet performance). The projects are specifically defined and managed in an integrated manner.

The programme is structured around three key design challenges

The first one is reinforcing the safety of our facilities

Component ageing management and nuclear safety enhancements are prerequisites for a life extension after 40 years of operation. For some components and some aspects, the initial design of the PWR fleet was based on 40 years of plant service life. An extension of this initial postulate is subject to an in-depth demonstration of these components robustness, as well as ongoing measures to maintain the qualification of the relevant components to withstand accident conditions.

Over and above major component refurbishments, licensees in most European countries and more specifically in France are required to raise their safety standards above their initial safety standards, along with design modifications. According to the French nuclear regulatory authority (9 April 2010, parliamentary office): “Over 40-years of operation is a new chapter in terms of nuclear safety” for two reasons:

Firstly, because the initial design was based on 40 years of plant operation;
Secondly, because when the first reactor reaches 40 years of operation in 2019, the first third generation reactors will be connected to the grid. Consequently, the safety level of our existing fleet will be looked at in comparison with third- generation reactors.

In summary, the Grand Carénage programme incorporates:

— The refurbishment and replacement of the main components to operate after 40 years;
— The integration of post-Fukushima learnings;
— Preparation of the next periodic safety reviews.

The second challenge is to secure the financial path of EDF Group.

An extension of the operation period of the fleet past 40 years offers a high profitability potential, which is essential for our Group and our customers and therefore our country. Today, the cash cost of existing nuclear power output is 32 euros per MWh, including the cost of the Grand Carénage programme. The existing nuclear power fleet therefore supplies and guarantees competitive price and low carbon source of electricity for France over decades.

Lastly, the third challenge is to invest massively in our skills.

Throughout its history, EDF has successfully focused on the development of its employees' skills to support its industrial project. The professionalism of the Group's men and women proved decisive to deliver its public service missions, guarantee the safety and performance of its facilities, develop customer satisfaction, and make EDF a global leader in energy and low-carbon growth.

The Grand Carénage programme has been initiated in a context where we invest massively to renew and bolster the skills of our employees and of our industrial partners.

- In an effort to renew the generation of workers who contributed to build the fleet, substantial recruitments made over the past few years have contributed both to rejuvenate the workforce and to launch large-scale knowledge management programmes. As in example, In 2016, we hired over 4,500 people across the Group in France, of which 1105 specifically in the nuclear sector.
- EDF is investing massively in the training of our employees and our subcontractors' employees, while focusing in priority on the development and strengthening of new skills with life-long learning.
    - in 2016, EDF invested 663 million euros in training, of which 60 % in the nuclear sector.
    - EDF have launched several initiatives, such as the "chantiers-écoles" on-the-job training sites, coaching mock-ups and simulators on nuclear sites.
    - training is also provided to support career paths, for instance in the field of nuclear safety or facility operation.

In summary, the Grand Carénage programme enables us to prepare for the future, towards an energy mix combining nuclear power and renewables, and to secure sustainably a safe, clean and competitive power output. During the next technical sessions, my wish is that we can engage all together with a strong bias in favour of commitment and action:

- To identify areas for improvement;
- To define some key actions to the success of our industry;
- To share the key learnings gained from a huge collective experience; and
- To make sure that we are on the best path to deliver safe, efficient, competitive and low carbon nuclear energy worldwide.

4.3.ETIENNE BLANC, MAYOR OF DIVONNE-LES-BAINS AND 1ST VICE PRESIDENT OF THE REGIONAL COUNCIL OF AUVERGNE-RHONE-ALPES

Auvergne Rhone Alpes is made up of almost 8 million inhabitants, a GDP (gross domestic product) of more than 240 billion Euros, a surface area comparable to Switzerland, almost 70,000 km2. It is a region known for it enormous tourist attractions and for its mountain infrastructure. It is also a large agricultural region, but also a very large industrial region which supports high tech sectors in pharmaceuticals combining production, research, and innovation.

Auvergne Rhone Alpes (AURA) is an emblematic region with an energy mix that is up to the call of the energy transition, because we produce 30 Terawatts/hour of electricity from renewable sources (50% of our regional consumption), that its production of electricity is totally without carbon, thanks to the mix between nuclear and hydroelectricity.

From a more general point of view, it is about 1/4 of the nation’s electricity which is produced by our territory. And it is here that the hydroelectric industry was born, with the massive of the Alpes, the Rhone and the Central Mountain Range - 187 dams in operation by EDF and the CNR (Rhone National Company)-.

It is in this territory, along the Rhone River, that 14 of the 58 operational reactors in France are found today, total 90,000 Gigawatts/hours, representing almost one quarter of the electric production from French nuclear sources.

Expertise from EDF’s operational nuclear plants has come to help in these sites in the domains of setting up technical modifications and outage. The technical division of EDF (SEPTEN) is located in this city to study engineering of NPPs.

From Lyon, the specialized services of EDF manage the decommissioning of 9 French nuclear plants or outage ensure the current construction of the installation for conditioning and storage of radioactive waste (ICEDA), that is a transitory storage facility for radioactive waste, follow the studies of the impact on the environment and put in place the measures to reinstate the land back to their original state after the end of operation.

At the side of the historic operator, EDF, we find the essential partners in the nuclear industry, such as AREVA or the CEA. The combination of resources, whether it be in production, engineering, or know how in decommissioning makes AURA the leading region worldwide in the nuclear industry.

France reached a CO_2 emission rate of 15g per kilowatt/hour produced, which is remarkable if we compare the rate of our main neighbours, which are about 400g per kilowatt/hour. We are proud in Auvergne Rhone Alpes to be a region totally de-carboned concerning the production of electricity. This nice result is possible thanks to the nature of the sources of electrical production: nuclear and hydroelectric.

The new region AURA, with its president, has decided to actively and efficiently support the local economy in a general way and in matters of innovation, in particular. It is also true in matters of energy. It has also launched an ambitious programme of development for the uses of hydrogen in public transportation “Zero emission Valley” associating the researchers, the producers, and the citizens in the elaboration of a participatory approach. In the nuclear domain, this eagerness is transformational, thanks to a deep collaboration with the industrials of nuclear by the creation the competitive cluster “Nuclear Valley”, supported by the region.

It is the only cluster labelled by the state dedicated to civil nuclear in France and assembles 200 members - of the small and middle sized companies with the large corporations - located all over the French territory (companies, industrials, study offices, education, and the laboratories) around a common goal: unite all actors in the French nuclear industry.

The region also promoted the creation of a work/study training centre for careers in the energy industry, in collaboration with the industrial of the electric industry, including those of the nuclear industry in order to respond to the needs of the entire nuclear industry in the coming years.

In AURA, we are sensitive to maintaining and developing the nuclear activity in our country and above all in our region for many reasons. It is, most importantly, a safe industry and one of excellence, very closely controlled by an independent safety agency.

It is an industry which generates employment: 225,000 jobs in France and 40,000 in the Auvergne Rhone Alpes Region. It is a responsible industry:

- It emits almost no CO_2
- It respects the environment until decommissioning
- It employs young people with difficulties in the education system or people in difficult situations with companies of insertion and adaptation - 35,000 hours of work dedicated to said companies per year
- It welcomes 500 students in a work/study programme in its workforce
- It invests 5 billion Euros in the next 10 years in the region, of which 1.7 billion for local economic fabric

This industry permits the region to be also, from the base of nuclear and hydraulic production, a land of development of renewable energy.

The subject of the conference which brings us together is crucial: operate in the long term and in total safety with efficient NPPs and this conference will be an opportunity to discover the strengths of the Auvergne Rhone Alpes Region, a region up to the challenge of the energy transition, a positive energy region.

4.4.MICHEL MASCHI, DIRECTOR OF EDF R&D PRODUCTION AND ENGINEERING , PRESIDENT OF NUGENIA

The division of nuclear production of EDF has the duty to ensure high performance and safe energy production and more especially the implementation of the project Grand Carénage, mentioned by Mr. Dominique Minière and will be explained in some details by Philippe right after the break

At the engineering and new nuclear projects branch of EDF, the mission is to contribute to the success of the new projects initiated under optimum conditions, support EDF operating fleet performance and extended operating lifetime, promote abroad EDF know-how in the nuclear power sector and prepare the future of the nuclear power sector in France.

The main goal of the EDF group's research and development (R&D) division is to contribute to the improvement in the performance of the operational units. We identify and prepare mid and long-term growth vectors and help anticipate the major challenges facing the Group in the global energy context.

In nuclear power generation, EDF R&D develops tools and methods to improve the safety of generation methods, to optimize their operating life and to increase their generation and environmental performance. EDF R&D proposes also innovative solutions for the new reactors

As it was said the goal of this conference is to learn from each other the best practices related to PLiM. At EDF, our experts and engineers are having this exercise daily and this conference is the occasion to confront, benchmark, challenge our way of doing. Our teams have also worked together in a very complementary way with the IAEA secretariat to provide smooth organization of this important event.

This conference would not have been possible without the engagement of our teams, but also the help of the European commission through the joint research centre of Petten and also the involvement of NUGENIA. NUGENIA for which I have the honour to act as president, is a young association (launched in 2012) dedicated to the R&D for safe, efficient and competitive R&D in Europe and around the world.

As usual, this kind of event is not possible as well without the involvement of our strategic partners such as our material ageing institute, AREVA and CEA but also all our partners and guests present in the exhibition hall. Last but not least, do not hesitate to consult the IAEA-event application to share your remarks and comments, but also seek for personal contacts to improve your network and engage collaboration and why not business.

5. KEYNOTE SPEAKERS PLENARY SESSION

5.1.KI SIG KANG, TECHNICAL HEAD PLIM AND ROBET KRIVANEK, LTO PROGRAMME MANAGER, IAEA

THE IAEA recently organized two technical working group meetings, one is life management of NPPs (TWG-LMNPP) in February to provide a forum for the exchange of information in the field of PLiM for LTO of NPPs and support to THE IAEA's programme. 31 TWG members and observers from 19 MSs and one international organization attended. Another technical working group meeting on instrumentation and control system of NPPs (TWG-NPPIC) in May was held to provide the IAEA's I&C programme with planning and implementation advice for 2018-2021. 36 TWG members and observers from 20 MSs and one international organization attended that meeting.

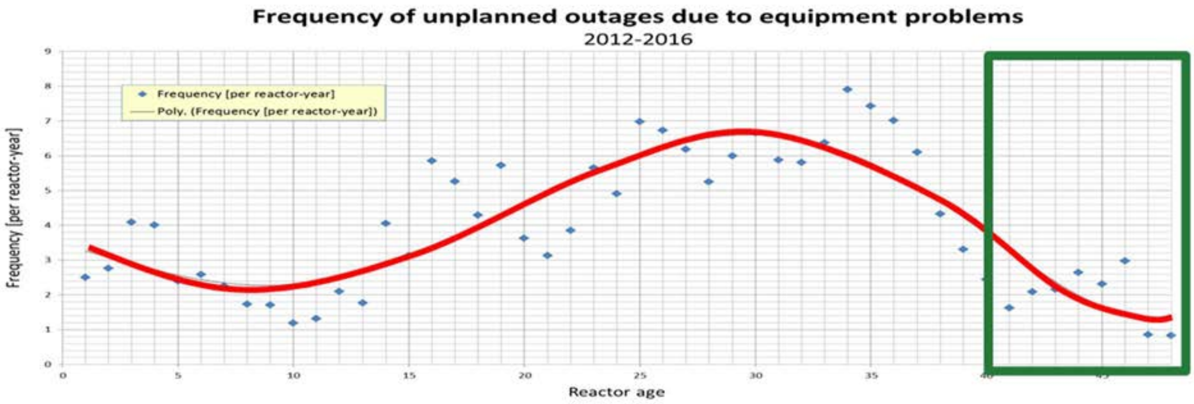

Fig. 2. Frequency of unplanned outages due to equipment problems based on reactor operating age

As shown on Fig. 2, more than 40 years old operating NPPs is less failure rate than 30 years operating NPPs. This means 40 years operating NPPs are more safety than 30 years operating NPPs. The main reasons are 1) grand modernization and replacement of heavy components like steam generator, reactor vessel head or main control room modernization to get the extended operating license, and 2) matured operation experiences.

THE IAEA issued four publications and two pamphlets on operating nuclear power in the IAEA Nuclear Energy Series. A handbook of ageing management for NPPs (IAEA Nuclear Energy Series No. NP-T-3.24) provides information on ageing mechanisms, effects on SSCs, the regulatory framework as well as some details on innovative techniques and research and development in the area. A benchmark analysis on condition monitoring of low voltage (IAEA TECDOC–1825) describes the fundamentals of cable performance and condition monitoring techniques.

Plant Life Management Models for Long Term Operation of Nuclear Power Plants (IAEA Nuclear Energy Series No. NP-T-3.18)

PLiM integrates ageing management and economic planning to optimize NPP investment. The aim is to maintain a high level of safety, commercial profitability and competitiveness, all while providing a reliable supply of electric power. The report showcases life management models of 10 Member States to help others to build the most appropriate model for their needs.

This publication:

- Describes and discusses the three approaches to PLiM for LTO used by the Member States;
- Compares differences, and highlights equivalencies between periodic safety review and licensing renewal approaches;
- Highlights pitfalls, and draws conclusions and recommendations based on the LTO experience from Member States.

Requirements for a successful LTO process are:

- Demonstrating a good understanding of the plant condition;
- The capability to operate safely after extended lifetime (after designed lifetime).
- Critical SSCs are effectively managed, so that all required safety functions can be maintained through the LTO period.

Nuclear power plant outage optimization strategy (IAEA TECDOC No. 1806) and maintenance optimization programme for nuclear power plants (IAEA Nuclear Energy Series No. NP-T-3.8)

The goal of maintenance at a nuclear power plant is to ensure that nuclear operators have the use of all systems necessary for safe and reliable power production and are able to keep these systems available and reliable. Traditionally, most maintenance activities are performed during refuelling and maintenance outages, which already require a great deal of attention and planning as they are the main cause of NPP unavailability and a large portion of the operational and maintenance costs.

In recent years, there have been significant changes in the electricity production industry and the electricity market itself. This has prompted plant managers to manage NPPs more effectively to optimize the operational and maintenance costs and increase availability. Outage management is a very complex task, involving many aspects of plant policy. These include the coordination of available resources, plant safety, the regulatory body, technical requirements and all activities and work before and during an outage.

The duration and costs of an outage should be optimized to achieve the best possible result, without compromising personal, operational, or environmental safety. The best possible result is in an overall reduction in the cost of electricity generation over the life, or the remaining life, of the plant. This requires balancing the best possible capacity factor against the cost required to achieve an optimal level of performance given the expected payback period for investments. Optimization of outages is a continuous process. It is driven by corporate and plant goals as well as regulatory requirements.

Maintenance and outage optimization are key factors for good, safe and economic power plant performance. Maintenance optimization is vital to asset management.

Procurement engineering and supply chain guidelines in support of operation and maintenance of nuclear facilities (IAEA Nuclear Energy Series No. NP-T-3.21)

In recent years, nuclear facilities have been impacted by significant procurement related events and concerns. There is an increasing need for nuclear facility procurement organizations to address obsolescence and component ageing issues. This has led to new actions by facility operators and regulators. Procurement for nuclear facilities plays a key role in nuclear safety. Beyond ensuring that the required parts are available when needed for operation and maintenance activities, the procurement function helps to ensure that the correct equipment and components are installed in the correct locations in the plant, to maintain proper configuration management and safety functions.

This publication provides an overview of nuclear equipment procurement processes and issues of special concern, as well as guidance for good practices to set up and manage a high-quality procurement organization. Lessons learned for organizations considering new nuclear power plant projects are also included.

Ageing Management and Development of a Programme for Long Term Operation for Nuclear Power Plants

This Safety Guides provide recommendations to meet the Requirement 14: Ageing management and the Requirement 16: Programme for long term operation of SSR 2/2, Rev.1, as well as the Requirement 31: Ageing management of SSR-2/1, Rev.1. This Safety Guide provides guidance for operating organizations on implementing and improving ageing management and on developing a programme for safe LTO for NPPs, which, among other aspects, takes due account of ageing management. The Safety Guide may also be used by the regulatory body in preparing regulatory requirements, codes and standards, and in verifying effective ageing management in NPPs.

International Generic Ageing Lessons Learned (IGALL) Programme

The IGALL Safety Report No. 82 was published as a result of the IGALL Programme Phase 1 (2010-2013). The publication provides a technical basis and practical guidance on managing ageing of mechanical, electrical and instrumentation and control (I&C) components and civil structures of NPPs important safety to provide support in application of the IAEA requirements on ageing management and LTO and Safety Guide SSG-48 on Ageing Management and LTO.

The publication and its database contains:

- A generic sample of ageing management review (AMR) tables;
- A collection of proven AMPs;
- A collection of typical time limited ageing analysis(TLAAs).

Phase 2 (2014-2015) and Phase 3 (2016-2017) of the IGALL Programme were aimed at:

- Providing a forum for exchanging experiences, while supporting Member States in applying IGALL as a tool to address ageing management and safe LTO;
- Enhancing the completeness and quality of IGALL;
- Preparing the IGALL Safety Report, version 2018.

The IGALL Safety Report is supported by the IGALL database which contains 84 AMPs, 28 TLAAs, technological obsolescence programme and more than 2000 consolidated line items in AMR tables. The IGALL database is updated twice per five years.

SALTO Peer Review Service

Recognizing the need to assist MS in dealing with the unique challenges associated with LTO, the IAEA developed a Safety Aspects of Long Term Operation (SALTO) Peer Review Service.

The SALTO service is a comprehensive safety review directly addressing strategy and key elements for safe LTO of NPPs, which complements OSART reviews. The evaluation of programmes and performance is made on the basis of the IAEA Safety Standards and other IAEA publications, and of the combined expertise of the international review team. The SALTO peer review is conducted in line with the Guidelines for Peer Review of Safety Aspects of Long Term Operation of Nuclear Power Plants (IAEA Services Series No. 26). The review is a technical exchange of experiences and practices at the working level aimed at strengthening the programmes, procedures and practices implemented at the plant. The key objectives of the SALTO peer review are to provide:

— The host organization with an objective assessment of the status of the preparedness for LTO with respect to international nuclear safety standards, and with recommendations and suggestions for improvement in areas where performance falls short of international best practices;
— Key staff at the host organization with an opportunity to discuss their practices with experts who have experience with related practices in the same field;
— Member States with information regarding good practices identified in the course of the review;
— Reviewers and observers from Member States and the IAEA staff with opportunities to broaden their experience and knowledge of their own field.

The guidelines (IAEA Services Series No. 26) provide a basic structure and common reference across the various areas covered by a SALTO peer review. As such, they are addressed principally to SALTO peer review teams, but they also provide guidance to operating organizations for preparation for a SALTO peer review.

The SALTO service is available to all MS with NPPs considering LTO. By 2017, 32 SALTO peer review missions (including eight pilot missions) have been conducted at 19 NPPs in 15 Member States. A further nine follow-up missions reviewed the implementation of previous SALTO results (refer to Fig. 3). For nine plants, the LTO module was included in the OSART mission including the follow-up missions.

Fig.3. SALTO missions 2008 - 2018

5.2.EDF LTO PROGRAMME LESSONS LEARNED FROM FUKUSHIMA DAIICHI ACCIDENT

Philippe Coïc, Technical Director , Programme Grand Carénage presented EDF LTO programme including the lessons learned from Fukushima Daiichi accident. The purpose of this major refurbishment programme (so called Grand Carénage) is to extend the operating lifetime of the operating EDF nuclear fleet. The on-going programme involves the following three types of activities:

- exceptional refurbishment of large components (i.e. heavy components' replacement etc.);
- modifications resulting from PSR;
- structure and component qualification for LTO under design basis and severe accident conditions.

Consideration of the French and international feedback is an integral part of the periodic safety reviews. Therefore the post Fukushima programme is naturally included in the EDF LTO program.

The cause of the Fukushima accident was the flooding of the site including emergency diesel generators by a high water wave following an earthquake of very strong intensity. The immediate consequences were a loss of electric power supply and of the ultimate heat sink leading to core melt, hydrogen explosion of containment and release of radioactivity into the environment.

The accident emphasised the following:

- the need to have an initial robust design with a high level requirements in order to avoid a cliff edge effect in case exteranl hazards on NPPs are higher than initially expected. ;
- the provision of a PSR, taking into account the improved knowledgebase;
- the need for crisis management and plan involving fixed or mobile means, initial team training and regular training, several levels of crisis management, and adapted communication devices.

The French supplementary safety assessments carried out in 2011 showed a satisfactory level of the requirements of the dimensioning domain (according to structural analysis) and highlighted the contribution of the periodic reviews process (reassessment of the levels of aggression and post-TMI and Chernobyl modifications). Finally, a set of complementary modifications were identified:

- to reinforce reactor autonomy, in terms of internal electrical power supply and water resources;
- to reinforce earthquake resistance and mitigation means for accidents with core meltdown;
- to improve provisions of crisis management in terms of organization and complementary means.

In January 2012, ASN required the establishment of (i) a "hard core" of physical and organizational arrangements for mastering fundamental safety functions in extreme situations, (ii) a gradual implementation of the nuclear rapid action force (NRAF) and (iii) reinforcements of spent nuclear fuel pools to reduce the risk of fuel assemblies running dry. In June 2012 these requests were complemented by a set of technical prescriptions specifying the expectations, particularly in the definition of the “hard core” and in the realization of modifications.

In response to this decision, EDF implemented a significant industrial programme articulated in different phases aimed in the first stage at deploying "mobile" provisions and setting up the NRAF and, secondly to install a set of fixed equipment resistant to levels significantly higher than the sizing domain requirements, as these new devices represent the first elements of the Hard Core. The main equipment in these phases includes:

- The installation of a diesel of ultimate relief (Fig.4) for each reactor of a power with 3 MWe and resistant to earthquakes, floods and tornados of very high level;
- THE installation of a water supply which makes it possible to permanently provide water to mitigate residual fuel power;
- The construction of a building on each site, robust to extreme conditions, to control the crisis and to communicate with the different levels of crisis management;
- The implementation of the programme is planned to be completed within ten years after the Fukushima accident.

Within a period of ten years, EDF will have implemented the modifications mentioned in the French stress tests reports of September 2012, throughout its nuclear fleet, allowing a gradual and significant improvement in reactor safety based on the feedback from the Fukushima accident.

At a later stage, in response to the requirements issued by ASN in January 2014, these measures will be supplemented with additional ones to prevent an accident with core meltdown and limitation of molten core without necessity to open the containment building.

Fig. 4. Installation of a diesel of ultimate relief (reproduced with permission courtesy of EDF)

5.3.FRENCH LICENSING APPROACHES FOR LTO

Sylvie Cadet-Mercier, commissioner of France’s Nuclear Safety Authority (ASN), introduced French licensing approaches for LTO. In France, as in many European countries, there is no operating life limit for NPPs under current regulation, even if lifetime assumptions were made at the design stage. The operators have to carry out PSR of their plants every ten years (Nuclear Security and Transparency Act, 13th June 2006). This PSR, which is performed for each nuclear installation, addresses the drawbacks due to normal operation as well as all the risks (non-radiological, malicious acts and radiological). The PSR covers two topics:

- Compliance with the applicable requirements (conformity check, accounting for ageing management);
- Safety re-evaluation, in order to identify safety improvements taking into account international best practices, knowledge improvement resulting from most recent research, operational experience.

Both topics are covered by the PSR report transmitted to the safety authority. Due to the standardized fleet (for example 900 MWe) in France, the safety re-evaluation is performed several years before the first-off plant of this fleet and is generic for the whole fleet. Concerning LTO (4th PSR of the 900 MWe fleet), the reactors in operation would function alongside new EPRs or equivalent type reactors, meeting considerably strengthened safety requirements. The continued operation of the current reactors beyond 40 years must therefore be examined taking account of the existence of safer technology and their level of safety must be improved with respect to the requirements applicable to the new reactors. The achievement of these goals requires numerous modifications which are typically implemented during the 4th ten-year outage.

In view of the 4th PSR of the 900 MWe fleet, ASN issued a position statement in 2013 on the list of topics to be examined more closely and the generic studies to be carried out in the run-up to the fourth periodic safety reviews for the 900 MWe reactors. Early 2016, ASN gave its expectations on the objectives adopted by EDF for the study and verification programmes associated with these reviews. After the safety re-evaluation studies assessment, ASN will issue a generic opinion on the continued operation of the 900 MWe reactors beyond forty years. Fig. 5 shows the France regulatory framework to apply LTO using PSR approach.

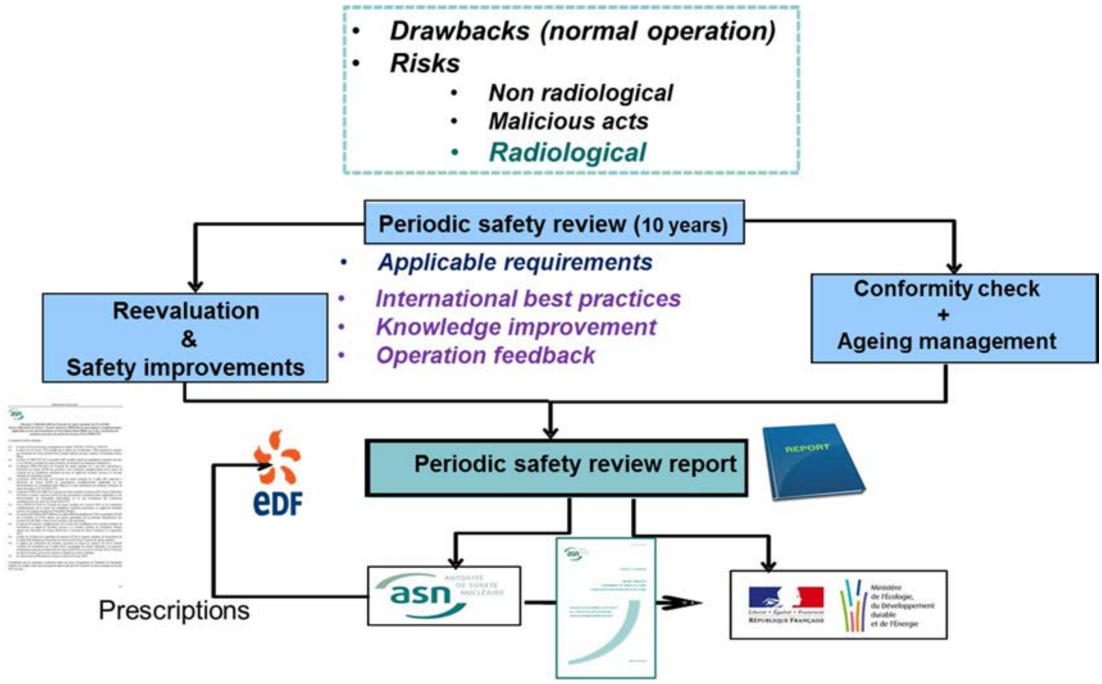

Fig. 5. Regulatory framework in France

As specified by the French energy transition for green growth act (TECV), the 4th periodic review of each reactor will entail a public inquiry. Due to the standardized fleet and the generic process for safety re-evaluation, ASN has decided to involve the public at an earlier stage, that means even as part of its generic opinion.

Finally, after each ten-yearly outage and the analysis of each specific reactor PSR report, ASN will edict the requirements that the licensee must fulfil for the continuation of its operation.

5.4.CHALLENGES AND OPPORTUNITIES IN CONSTRUCTION TECHNOLOGY AND MANAGEMENT FOR ADVANCED NUCLEAR POWER PLANTS

Yikang Dou, director of Shanghai Nuclear Engineering Research and Design Institute (SNERDI) presented the current situation of nuclear power generation in China. China has 38 units in operation and 19 units under construction. This year alone, it plans to bring five units into commercial operation and start constructing another eight units. By 2030, China plans to build 30 additional reactors overseas.

Given the current sluggish global economy, rapid development of the renewable energy as well as high safety demand from the public, the nuclear power industry is facing external and internal challenges. In particular, for the development of the Gen III NPPs, the engineering cost and risks have been raised due to new standards and requirements, new technologies, new process, new equipment, new materials and new cooperation modes. The CAP1400 is a Chinese national brand with independent interlectual property right. To improve the economy of the CAP1400, the capacity is increased, systems are simplified and structures are modularized. In addition, safety margin is increased and severe accident prevention and mitigation are comprehensively considered for the CAP1400. Following lessons learned from the Fukushima accident, Safety of CAP1400 has enhanced against extreme hazards. Moreover, technologies are developed to minimize radioactive waste as well as increasing flexibility. CAP1400 will better meet future requirements for new build.

The design of the CAP1400 is completed and ready to be built. Due to modularization, construction of the CAP1400 is optimized. The construction time for the nuclear island is expected to be considerably shortened, while improving the quality of the construction process and mitigating potential safety risks.

The good practice of CAP1400 construction indicates that design plays a key role for project success. Design changes leading to construction delays usually come from new requirements, experience feedback and interface mismatches. Synchronized with design and balanced between localization and international procurement, the reliability and effectiveness of supply chain will increase, which contributes to reducing construction risk.

Last but not least, a successful project is contributed by standardization, supply chain building, project management optimization, license application and government support. Furthermore, a full life cycle digitalized design model is essential to decrease the risk of costly design changes and to enhance the supply chain, which helps to control budget and construction duration.

5.5.ASSURING SAFE SUBSEQUENT LICENSE RENEWAL FOR COMMERCIAL NUCLEAR POWER REACTORS IN THE USA

George A. Wilson, U.S. Nuclear Regulatory Commission introduced the renewal of licenses for operating NPPs in the United States. The License Renewal Application (LRA) process is a mature, stable process, with 86 reactors possessing renewed licenses for operation to 60 years.

Using the same regulatory process as initial license renewal, the U.S. Nuclear Regulatory Commission issued guidance documents to address subsequent license renewal, for plant operation to 80 years, in July 2017.

Although the license renewal (and subsequent license renewal) review is a limited scope review that focuses on managing the effects of ageing for long-lived, passive structures and components in NPPs during the period of extended operation, the U.S. Nuclear Regulatory Commission has in place a number of regulatory programmes (e.g., the analysis of the operating experience, the reactor oversight process, the generic upgrades and regulatory changes, and the use of risk informed regulation) that are integrated to ensure safe plant operation at all stages, including the initial operating license period, the period of extend operation, and the subsequent period of extended operation. The combination of the existing, on-going NRC regulatory processes with the detailed license renewal and subsequent license renewal reviews will continue to ensure safe plant operation through the 80 year operating period. See Fig. 6.

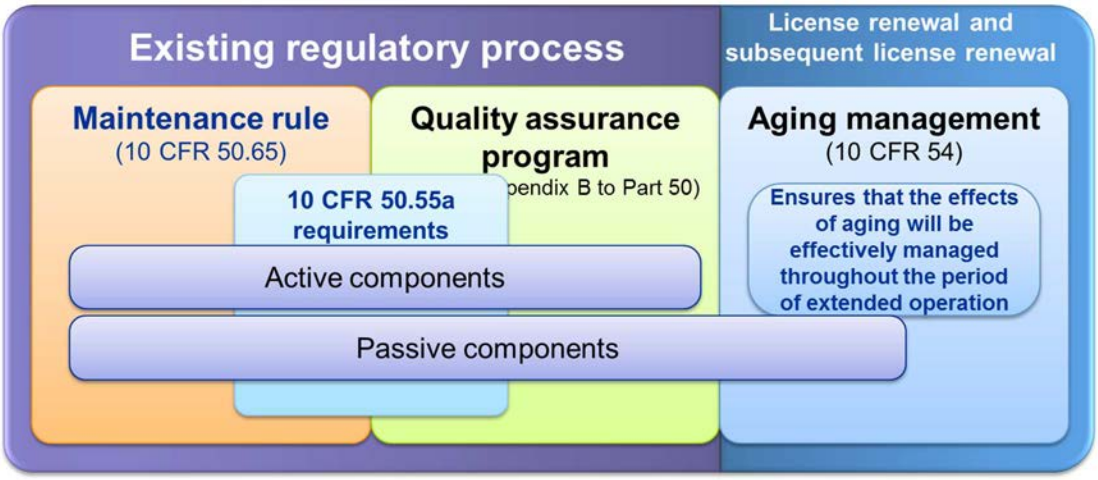

Fig. 6. Licensing renewal application based on 10 CFR 54

5.6.LICENSING APPROACHES BASED ON INTENSIVE PSR

Sung Yup Lee, Korea Hydro Nuclear Power Company (KHNP), Republic of Korea, presented the intensive PSR approach of the Republic of Korea as it is laid down in the Nuclear Energy Safety Act from January 2001. According to this act, PSR needs to be carried out for each operating reactor in the Republic of Korea. In July 2004, the government decided to establish a legal basis for continued operation of existing NPPs and a legal article for continued operation was introduced to the Nuclear Energy Safety Act in September 2005.

There are 24 reactors operating in Republic of Korea, and the design life is 30 years for PHWR, 40 years for Gen II PWRs except Kori 1(which is PWR, and it has 30 years design life) and 60 years for Gen III PWRs (APR-1400) from the date of the first criticality. In June 2007, Kori unit 1 reached 30 years of operation and its license was renewed for an additional 10 years. In June 2017 it was permanently shutdown without a second 10 years extension. The operating license for Wolsong unit 1 (PHWR) was renewed in 2012 after completing a 62-month regulatory review. The Fukushima accident occurred during the regulatory review of Wolsong unit 1, which led to additional follow-up measures and strengthened regulatory review, resulting in delayed license renewal approval.

After the Fukushima accident, a joint inspection team composed of government, academia, research institutes and industry conducted safety reviews for all NPPs from March to May in

2011. As a result, a total of 56 follow-up measures were identified and implemented (except 7) in the entire fleet. Major measures include installation of a sea wall, watertight doors, containment vented filter system, waterproof drain pumps (diesel driven), securing mobile generator vehicles, installing an external injection loop for reactor emergency cooling water and injection loops for spent fuel pool and passive autocatalytic recombiner.

When the licensee seeks for the continued operation, they need to prepare the intensive PSR report. The licensee first needs to prepare the intensive PSR report that contained 14 safety elements and time limited ageing analysis, and radiological environmental impact report. A safety assessment for LR must follow IAEA PSR guidelines and in addition US NRC’s LRA. Based on these assessment reports, the decision whether to apply for a LR is made considering facility improvement requirements, economics and public acceptance.

At this point, public hearing is also required. The licensee submits the LR application to Nuclear Safety and Security Commission (NSSC) within five to two years before the expiration of the licensed operating life and the regulatory body performs the review for 18 months including site inspection. Based on the result of a review, NSSC issues a new license for continued operation. Refurbishments for LR are carried out reflecting the result of safety assessment, Fukushima follow-up measures, stress test, etc., which ensures enhanced safety.

As Korea went through two LRs so far, it is facing challenges such as the controversy on the up-front investment, public acceptance issues, and moves to amend related laws to limit LR. Korea is expected to reach the end of the design life of 11 NPPs by 2030, and the current government has announced a policy opposing LRs. Such an environment will bring many difficulties for the Licensee and also a big change in Korea’s future energy policy (refer to Fig. 7.)

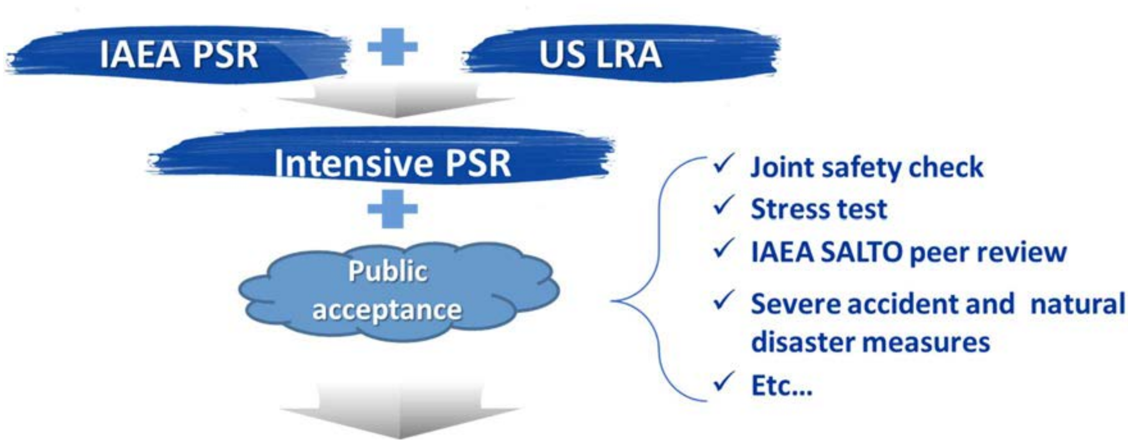

Fig. 7. Intensive periodic safety review (IAEA’s periodic safety review + NRC’s license renewal)

5.7.PLIM AND R&D ACTIVITIES IN JAPAN AFTER THE FUKUSHIMA DAIICHI ACCIDENT

Naoto Sekimura, the University of Tokyo, presented the situation concerning PLiM for Japanese NPPs after the Fukushima Daiichi accident. The Japanese Government issued its 4th Strategic Energy Plan on April 11, 2014 that provides the basic energy policy with a view to an energy supply-demand structure after the Fukushima Daiichi accident for the mid to long term for 20 years. The Strategic Energy Plan states that "nuclear power is an important baseload electricity source". A long term energy plan was also issued on April 27, 2015, which stated that the contribution of nuclear power should be 20-22% of the total electricity source in 2030. However, the environment of the utilization of nuclear energy in Japan includes many issues to be solved in the future, including fuel debris removal and decommissioning of the Fukushima Daiichi nuclear power station, response to the new regulatory standards to restart nuclear reactors, nuclear fuel cycle policy and decommission of some reactors by regulatory requirements of operation periods, in addition to electric market reform.

Current Japanese regulatory requirements to restart the reactors and to extend their operation beyond 40 years are so strict that some licensees have made decisions to shut-down some reactors before 40 years of operation. Additional inspections and replacements of important components are currently performed for continuous operation beyond 40 years (refer to Fig.8).

Knowledge management for all the aspects of nuclear technology has been effectively performed through the construction of a Strategic Research Roadmap which includes human capacity building after the Fukushima Accident. Utilization of materials and components from decommissioning reactors in Japan is one of the major topics for international research collaboration. Knowledge management and knowledge transfer for safety of huge complicated systems like NPPs requires additional basis for knowledge-base.

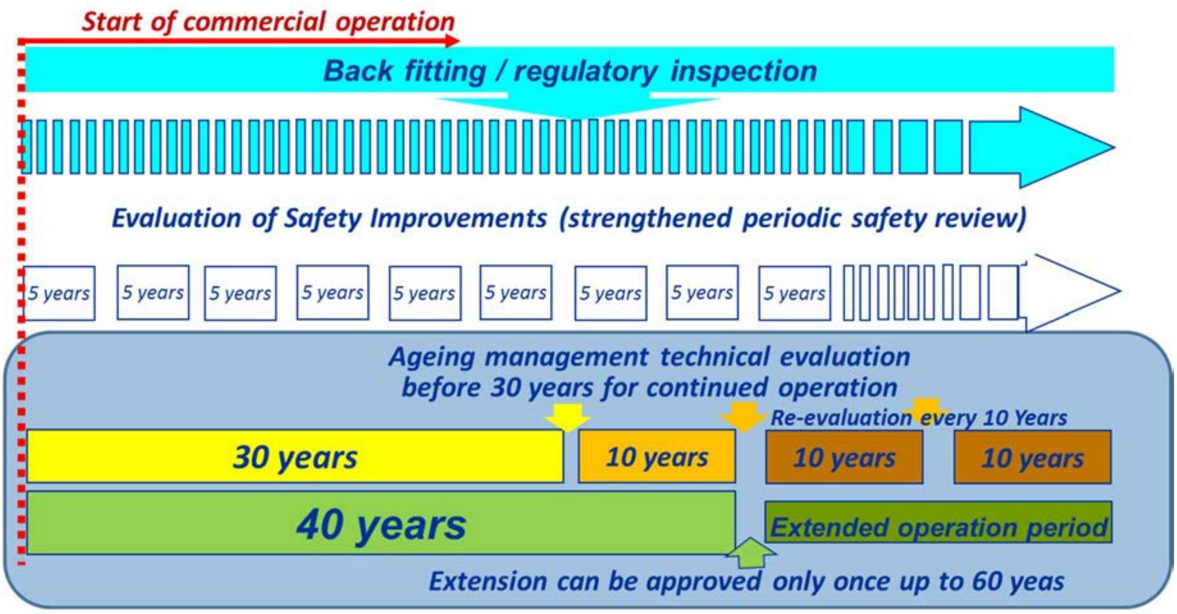

Fig.8. Regulatory systems for inspection, periodic safety review and ageing management in Japan

5.8. CANADIAN REGULATORY APPROACHES FOR LTO AND RELATED CHALLENGES

A. Viktorov, Canadian Nuclear Safety Commission introduced Canadian regulatory approaches for LTO and related challenges. The Canadian regulatory philosophy calls for continuous improvement in safety in order to meet changing expectations of the society. This general approach is also applied in regulatory decision-making related to older operating NPPs, which were built in accordance with the standards those days. It is acknowledged that there are economic and physical limits to improvements of existing facilities. Nevertheless, the advances in science, accumulation of experimental evidence, more powerful computational methods, proven design features of newer reactor designs and better understanding of key risks arising from nuclear facilities allow enhancing the safety of facilities built to earlier standards.

All operating power reactors in Canada are of CANDU design which has matured and demonstrated safe and reliable operation. However the path towards good performance was not without difficulties. Attention to operating experience and the ability to detect and correct the early signs of reduction in safety margins is essential in maintaining a good operational record. In the aftermath of the Fukushima accident, Canadian licensees have implemented multiple physical and procedural enhancements. Some of these enhancements are expected to be standard features in advanced reactors. In particular, design extension conditions have been evaluated using modern approaches and, where feasible, backfitting measures have been put in place. These measures have predominantly strengthened the fourth and fifth levels of defence in depth.

At this time, all of Canadian power reactors have undertaken or are in the process of conducting a Periodic Safety Review (PSR), as recommended by the IAEA. This practice has proved itself to be an efficient tool in identifying, in a systematic way, the practicable safety enhancements. The PSR outcomes, combined with the lessons learned from operational experience, provide crucial support for the safety case for extended operation. The current Canadian regulatory practice requires renewal of operating licences at relatively short intervals. This allows public to provide input and identify societal concerns when dealing with complex issues of nuclear safety. The public input enriches the context in which major licensing decisions are made and helps the regulator to focus its attention in the areas of public concern. The presentation elaborates on the developments and challenges related to long term operation of Canadian NPPs.

6. PARALLEL TECHNICAL SESSIONS

Below is a summary of the key points and recommendations made in this session. The detailed papers of the discussion that followed are in the proceedings.

6.1.SESSION 1: APPROACHES TO PLIM FOR LTO

Twenty six papers were presented in sessions 1.1 to 1.6. The session's main subject was: "Approaches to Plant Life Management for Long Term Operation". The following topics were addressed in the presentations:

- The application of the stress test programme and severe accident management plan to the two oldest units Wolsong-1 and Kori-1 in Republic of Korea;
- The introduction of an ultra-high pressure cavitation peening method to induce compressive stresses on surfaces, in particular welds, to mitigate stress corrosion crack (SCC) initiation received regulatory acceptance. This technology will avoid costly repairs to mitigate SCC;
- The history and development of license renewal in the US from 40 to 60 years (1st license renewal) and approach for second license renewal (from 60 to 80 years). Clear guidance (documents) was already published;
- The new equipment qualification requirements covering the whole life cycle of a NPP taken by the Chinese regulator;
- The Chinese methodology for LTO approach which follows mostly the US NRC LR rule;
- A research programme on reactor pressure vessel material properties, with the objective to confirm and improve knowledge on material ageing. The sample materials for this programme were harvested from a decommissioned boiling water reactor unit (Hamaoka NPP);
- The work of an international working group on decommissioning insisting on the need to start activities and discussion with regulators and stakeholders early in the plant life cycle;
- An example of analysis and investigation process on an identified degradation mechanism on VVER1000 steam generators, illustrating the preventive measures that have arisen to minimize the degradation risk in the future;
- The use of concrete harvesting from a decommissioned unit showing the benefits that can be taken from testing on actual materials to improve soundness assessment methods of civil works structures.

The objective of this session was to share information and best practices in the applications and approaches to PLiM for LTO, particularly from the safety point of view, with the following specific topics:

- Sharing recent operating experience (OE);
- Methodology for PLiM, scope, terms, definitions;
- Methodology for components scope setting (scoping);
- Methodology for ageing mitigation;
- Feasibility studies for LTO;
- Provisions for licence renewal and second license renewal;
- Requirements for PSR;
- Considerations of design basis reconstitution;

— Quality assurance (QA) issues associated with PLiM.

It was noted that equipment qualification should be taken as one of the prerequisite activities in preparation of life management during plant operation.

In general, the effectiveness of current PLiM and ageing management programmes (AMPs) was confirmed. The importance of the policies supporting continuous safety improvements, e.g. PSRs was highlighted.

Some presentations focused on the importance of the consideration of the beyond design basis conditions for LTO and identification of the plant modifications to mitigate the consequences of such events. Implementation of these plant modifications was planned in the short, medium and long terms, according to priorities. Environmental issues were also brought to the forefront as crucial elements in LTO studies.

It was recognized that the ageing monitoring including performance monitoring and OPEX, obsolescence, and up to date knowledge basis are part of a successful LTO program. Identified R&D programmes help in 'knowing' some of the current 'unknowns', which is essential for a successful LTO programme. Where knowledge gaps are identified, R&D can cover and characterize the degradation mechanisms and their ageing effects that may originate from either environmental conditions or from ageing stressors.

The summary and recommendations of this session are:

— Ageing management programmes of NPPs need to be continuously developed and updated to take into account the latest technical knowledge, OPEX and the new regulatory requirements using the R&D results of the harvested material from decommissioned plants, and other technical background (setup & expansion of databases, e.g. equipment qualification);
— Regulatory requirements need to be further developed and updated to take into account the latest operating experience and R&D results.

6.2.SESSION 2: ECONOMICS OF PLIM

Nine papers were presented in sessions 2.1 to 2.2. The aim of this session was to improve plant economic performance through PLiM. The following topics were addressed in the presentations:

— Global challenges to nuclear power: Economics and market conditions, public perception, understanding and acceptance, OM cost of operating NPPs. Additional challenges dealing with resources, expertise and obsolescence;
— Potential business opportunities and risks, including power uprating issues related to PLiM;
— Cost effective strategy for modernization and refurbishment of heavy components (e.g. steam generators, reactor vessel heads and turbogenerators);
— Feasibility study (including economic analysis) for decision making of LTO;
— Cost effective technologies/practices for maintenance, inspection and surveillance;
— Flexible operation in response to increased grid variability.

With regard to the economics of PLiM, it was recognized that analytical tools for cyber security and physical protection are evolving, portfolio optimization tools for LTO are being developed, and comprehensive R&D programmes are being applied to support LTO.

The summary and recommendations of this session are:

- Economic conditions impacting energy prices are an immediate and long-term challenge to the success of LTO.
- It is important for those countries that identify a pathway to success in improving economic conditions, the information be shared.
- LTO is cost viable even with safety enhancement following the Fukushima accident.

6.3.SESSION 3: AGEING MANAGEMENT AND PREPARATION OF LTO

A total of thirty eight papers were presented in sessions 3.1 to 3.9 including presentations on the status of ageing management and LTO preparation in individual MS and/or in specific NPPs. Presentations were made on specific technical issues (e.g. thermal ageing, irradiation embrittlement, corrosion, water chemistry, ageing of non-metallic, concrete, etc.) involving extensive research programmes in the form of experiments and computational analyses. Presentations confirmed that virtually all MS with NPPs strongly consider LTO beyond original design life, mostly to 60 years and in some cases even beyond, and perform corresponding research projects to tackle ageing related technical issues. The following topics were addressed in the presentations:

- The need for further improvement of IAEA guidance to support ageing management and LTO;
- The SALTO peer review service is a matured IAEA service to support MS in the preparation for safe LTO. This programme should be widened among the MS;
- The IGALL Programme is developing into a strong reference base for NPPs ageing management. AMPs, time limited ageing analyses and operating experience from some MS still need to be added/completed;
- The need for further discussion (e.g. IGALL, workshops, development of Safety Standards and Safety Reports) to reach common understanding of ageing management and LTO technical detailed tasks (scope setting, ageing management review of active and passive components, time limited ageing analyses);
- The need for continuous improvement for AMPs - share best practices and lessons learned for AMP implementation; more active participation in IGALL; and share results and lessons learned from SALTO reviews;
- Very extensive discussions were done after presentation on the inner part of reactor pressure vessel – core baffle geometrical distortion, baffle-to-former-bolts cracking and inspection;
- The IAEA is requested to provide training for ‘new’ AMP users to ensure technology transfer and development of human resources for IGALL use and sharing operating experience;
- Japan, USA and France perform a large research programme. These research results would be a good contribution to the improvement of database of IGALL;
- Coordination, collaboration and leveraging of research results important to support LTO (e.g. vibration fatigue on small bore piping);
- The IAEA should consider how to promote modernization and economic efficiencies to support LTO;

— The development of simulation platform to capitalize knowledge on AM.

In addition to radiation embrittlement, environmentally-assisted fatigue and corrosion, it was noted that one of most serious degradation mechanisms of primary circuit component materials is the thermal ageing. Long-term monitoring of the changes in the primary circuit structural material properties and the understanding of the temperature effects on ageing are of paramount importance. Two approaches are followed: The use of surveillance coupons and the harvesting of samples of material from operating components with subsequent detailed testing and analysis. The summary and recommendations of this session are:

— It is essential to perform environmentally-assisted fatigue testing on industrial scale components so as to exhibit the margins incorporated in the codified approach covering environmental fatigue
— There is a need to continue information exchange on material and structural integrity issues and share it through IGALL with MS;
— Share best practices and lessons learned for ageing management programme implementation through the active participation in IGALL.

6.4.SESSION 4: CONFIGURATION AND MODIFICATION MANAGEMENT FOR SAFETY ENHANCEMENT

14 papers were presented, divided into 3 sessions. The aim of this session was to share information on SSC safety enhancement, design modernization, refurbishment and replacement programmes. The following topics were addressed in the presentations:

— New techniques and special facility for weld repair of highly irradiated materials;
— Advanced non-destructive test techniques with respect to their capabilities and limitations for lifetime management of low pressure turbine blades;
— The use of comprehensive condition monitoring platform and the application of on-line monitoring and diagnostic solutions for rotating machinery, valves etc.

Advanced non-destructive examination (NDE) methods to detect and characterize SCC in LWR environment are necessary to support LTO. It was recognized that different ways are being followed: adapting existing NDE methods, developing new ones, increasing resolution, moving towards on-line monitoring and prognosis. The use of statistical models for the evaluation of irradiation-assisted SCC (IASCC) failures and for the development of the capability to predict them is an encouraging trend in the industry.

Conclusions that can be drawn from sessions 4.1 to 4.3 are that many promising technologies are emerging which will address needs in instrumentation and control systems (I&C) as well as assist in characterizing and monitoring degradation in components and structures important to LTO. Recommendations to the IAEA for near-term implementation are:

— LTO programmes have gained from studies directed at improved understanding of NDE techniques available, their benefits and shortcomings. Further development of promising non-destructive test techniques for specific applications can be improved and developed. An important consideration is for researchers to look beyond their research fields or industries for potential solutions;
— New condition monitoring technologies as well as repair/mitigation techniques being developed are starting to show the potential for significant economic benefits for LTO.

- Managers need to understand that multidisciplinary teams are needed in addressing scientific gaps, or engineering problems. Solutions to problems cannot be compartmentalized into one area of focus;
- Ageing of I&C is a crucial topic for NPP. Modernization through digital systems could be a solution that may improve performance and the obsolescence management.

6.5.SESSION 5: HUMAN FACTORS AND MANAGERIAL ASPECTS

4 papers were presented in one session. The aim of this session was to share experiences and lessons learned on system management, on the successful resolution of the technical issues and challenges presented in the previous sessions, and to identify outstanding human factor and managerial aspects in the field. Presentations covered the following:

- Research needs to develop human factor methods and technical bases to enable design, development, and deployment of new digital technologies;
- Human resource development and workforce planning for LTO;
- Knowledge management methods/process to keep plant history and experiences;
- Stakeholder involvement and public understanding ;
- Management of external and internal human resources to mitigate the severe accidents;
- Effects of severe accident scenarios on human performance and potential human reactions;
- Development of a standardized operator interface and control board layout based on human factors engineering principles and regulatory guidance when the mixture of the old and new technologies exists together;
- Development of knowledge base covering all life cycle including construction, commissioning, operation and transition for decommissioning.

6.6.SESSION 6 : REGULATORY APPROACHES TO AGEING MANAGEMENT AND LTO

16 papers were presented, divided into 4 sessions. It is recognized that it is essential to exchange information about regulatory requirements in different MS. The aim of this session is to discuss the distribution of roles and responsibilities among the parties involved and to address regulatory policy considerations. The following topics were discussed:

- Development of new regulations on ageing management and LTO;
- Many MS either directly utilize IAEA Safety Standards and Safety Reports within their regulatory requirements for LTO, or use them to improve the development of their regulatory requirements;
- Endorsement of the IAEA Safety Guide SSG-25 on PSR in many MS to support for LTO;
- Some MS have defined additional safety factors to the 14 provided in the SSG-25 for the PSR
- Some MS consider adding a new safety factor to the PSR to cover the public interactions and the transparency;
- Necessity of stakeholder involvement to improve public acceptance of LTO;
- Common understanding of the LTO preparation by the utility and the regulator to ensure a successful LTO review and safe LTO;
- Transparency with the public being an integral part of the U.S. license renewal process to cultivate public awareness;

- Use of the limited scope U.S. license renewal approach requires implementation of other essential elements of the U.S. regulatory process to ensure an adequate LTO review;
- A proposal for IGALL Phase 4 was suggested;
- Some ageing effects for non-replaceable structures or components i.e reactor vessel, containment could create life limiting conditions;
- The regulator should retain sufficient expertise to do independent reviews of critical licensee calculations;
- The use of technical support organizations can be essential to assist regulatory and utility staff for unique reviews, such as LTO;
- Harmonization of the safety classification of SSCs would be a positive step to reduce scope.

Recommendations to the IAEA for near-term implementation are:

- A variety of approaches are used for regulation of LTO, many of these approaches either referenced or are based on IAEA standards and guides (SSR-2/2, SRS-82, SVS-26);
- Common understanding of the LTO preparation by the utility and the regulator to ensure a successful LTO review and safe LTO;
- Use of IGALL and SALTO peer reviews and workshops were cited as providing a substantial benefit for NPPs entering LTO and for regulators as well.

7. PANEL DISCUSSION SECTION

7.1. PLANT LIFE MANAGEMENT APPROACHES, ECONOMICS AND SAFETY ENHANCEMENTS

Session Chairperson: J. Hanson, USA
Panel Members: U. Wildner, J.P. Perrin, Y. Dou, M.B. Bakilov, K.S.Kang

The session was opened by the Moderator, Mr. J. Hanson (Senior project manager, life extension and new technology, NEI, USA).

Udo Wildner (AREVA, Germany) indicated that the market is driving operations cost reductions while at the same time regulators are requesting increasing safety. Passive cooling systems can help to do both. Coolant degasification systems can help reduce outage times for PWRs. Load following is needed to help NPPs to minimize the periods of production for negative or low prices. German studies show there is not a big financial loss without having load follow. He questioned whether this is the same in other countries.

J.P Perrin (EDF, France) described the EDF LTO programme. Eighteen units will reach 40years of reactor operation by 2020. He indicated that PSRs (with emphasis on conformity checking & safety assessment) will drive the modification programme for LTO and that the 10 year outage programme for full plant inspection will ensure plant conformance. Safety objectives are to address DBAs, internal and external hazards (so as to reduce core damage frequency), spent fuel pool cooling accidents with core melt.

He explained that a modernization is being made through Grand Carénage programme which is costing EDF – an extra 4 Billion euros/year. EDF's internal target is set for a 60 year life of all units, although regulatory authorization would be given every ten year period beyond the 4th ten year outage. Lifetime extension up to 60 years should be reasonably achievable when supported by well-designed life management programme, thorough ageing analysis of non-replaceable components including reactor pressure vessel and containment building, extensive R&D programmes to support those analysis and modifications to close gaps with new NPPs as far as reasonably practical.

Yikang Dou (SNERDI, China) indicated that technical policies on operation license extension (OLE) in China were issued in 2016. An application for LTO must be submitted 5yrs before license expiry. For Qinshan 1, the OLE application was submitted in December 2016 to National Nuclear Safety Administration (NNSA), with permission expected for LTO in 2021. The challenges of LTO are high safety requirements, fast development of wind/solar power at decreased prices, economic slow increasing (globally) and radioactive waste issues.

Murat Bakirov (CMSLM, Russia) summarized a number of other presentations made at the conference. He recommended more cooperation among VVER owners outside Russia.

Ki-Sig Kang (IAEA) indicated that major PLiM considerations for LTO are to include the viability of market price. For example, in Europe, it has dropped from about 100 to about 30 euros per MWh over past 5 year.

He showed global data trend that since 2000, the unplanned unavailability is going down, while the planned unavailability is going up, especially after Fukushima accident. Refuelling outage duration (PWR/BWR) is significantly reduced in a few MS. He questioned that how the industry can improve economics while increasing safety requirements and what can be the optimum life for LTO. He indicated that the IAEA is working to release new guidelines on economic assessment of LTO and associated software (LTOFIN).

During the question and answer session there were discussions on electricity market models including the price given for nuclear power, and on how the industry can get the young generation become interested in nuclear power.

7.2.AGEING MANAGEMENT AND PREPARATION FOR LTO

Session Chairperson: G.A. Wilson, USA

Panel Members: S. Ratkai, S. Bernhoft, F.Henry, R. Krivanek

The session was opened by its Chairman, Mr. G.A. Wilson (Director, division of materials and license renewal, NRC, USA).

Similarities and differences among LTO approaches were discussed, e.g. intensive PSR (Korea), License Renewal (US NRC), and these approaches were compared to the IAEA Safety Standards dealing with LTO. It was pointed out that the use of the license renewal approach based on the 10CFR54, which has been adopted by many MS, requires implementation of several other essential elements of the U.S. regulatory process to ensure an adequate LTO review.

The discussion also addressed how the LTO approaches used in various MS take into account identified safety issues and design basis modifications (such as Fukushima lessons learned).

Ms. S. Bernhoft identified the various areas and focus of EPRI long term research plan related to the subsequent license renewal (60 to 80 years). The new NRC GALL programme related to the subsequent license renewal was discussed.

Mr. R. Krivanek summarized the status of the IAEA LTO related activities and plans for the future. The New Safety Guide SSG-48 on AM and Development of a Programme for LTO for NPPs, which supersedes the Safety Guide NS-G-2.12 and the Safety Report No. 57, will be published in 2018. IGALL Phase 4 is being initiated. A new Safety Report providing detailed guidance on specific areas of LTO preparation and review will be developed. SALTO Peer Reviews will continue to be implemented.

7.3.CHALLENGES AND NEEDS FOR PLANT LIFE MANAGEMENT FOR LTO

Session Chairperson: G. Young, USA
Panel Members: G. Rzentkowski, O. Martin, I.S. Hwang, H.M. Hashmian, G. Pironet

Garry Young (director license renewal, Entergy) opened the panel discussion and introduced speakers.

Greg Rzentkowski (IAEA) described some of the challenges and needs for LTO of NPPs. These included that the industry has to continue to evolve and adapt to changing circumstances, that harmonization and standardization of requirements and designs are needed and that regulators provide a clear and stable framework.

To maintain and enhance nuclear safety, the industry needs to address the LTO of ageing fleet, post Fukushima improvements, efficiency of new builds and the safety and licensing of innovative designs, including those of SMRs.

The industry needs to address public acceptance of nuclear power, which has been shaped by past accidents and a low tolerance for risk. It is paramount to the success of future reactors. Safety challenges include more understanding of ageing phenomena for the existing fleet.

The IAEA activities supporting LTO including safety standard development (PSRs, AM and LTO), capacity building and peer review services such as the OSART LTO module, SALTO, Site and External Events Design Review Service (SEED), and technical review services (e.g. design assessment), and noted that SALTO reports typically are released into public domain and this can help with public acceptance.

Some necessary improvements identified by recent SALTO missions include the declaration of LTO policy, need for clarity of national regulations for LTO, organizational arrangements for LTO, having complete AM reviews and time limited ageing analyses, timely completion of LTO programmes and consideration of reasonable safety improvements.

The Vienna Declaration of Nuclear Safety has called for reasonably practicable or achievable safety improvements to be implemented in a timely manner, and for national requirements and regulations that should take into account the IAEA Safety Standards. If we assure fuel will not leave RPV then the industry will have largely addressed practical elimination.

Oliver Martin (EC-JRC, Netherlands) presented the most significant challenges for PLiM/LTO. The biggest challenge he identified was plant economics. Distortions of electricity markets caused by incentives for renewables and abundance of natural gas in some countries make it difficult to keep nuclear power generation cost competitive. In some countries the governments impose taxes on nuclear fuel or nuclear power generation, or put pressure on utilities to (preliminary) close their NPPs. In addition utilities are faced with a number of challenges on the cost and supply chain. These include formal strict quality assurance documentation requirements for SSC to mitigate regulatory compliance uncertainties, difficulties among potential suppliers to the nuclear industry to understand nuclear requirements, the obsolescence issue (suppliers of nuclear SSC do not exist anymore of they have left the nuclear industy) and the general difficulty to use modern state of the art technology in NPPs.

In order to overcome the cost challenges, the utilities and the nuclear industry in general need to modernize its supply chain. The link between nucler safety requirements and industry practices to manufacture, select and procure SSC need to be re-defined. It should be generally possible to use standard non-nuclear industry equipment (licensed according to International Organization for Standardization (ISO), European Norm (EN), America Petroleum Institute (API)) in NPPs with additional requirements on environmental and seismic qualification, at least for safety class 3 components or lower. Further on it should be generally possible for nuclear technology vendors to manufacture components according to the nuclear codes and standards with which they are most familiar.

Another solution that would help utilities in bringing down costs is mutual recognitions of practices between countries (e.g. ISI qualifications). The latter could also be adopted for generic design assessments and licensing of Gen III/III+ designs. Also very important is the continuation of existing harmonization exercises, e.g. IAEA IGALL (for ageing management), multinational designs and evolution programme (MDEP; understand differences in nuclear design codes) and ENIQ (for inspection qualification).

ENIQ is a utility driven network dealing with the reliability and effectiveness of non-destructive testing (NDT) for NPP. ENIQ is recognised as one of the main contributors to today's global qualification codes and guidelines for in-service inspection (ISI)

Another concern is the ageing nuclear workforce. Staff with experience in construction and operation of NPPs is retiring and the nuclear industry lacks attractiveness for new and younger qualified staff.

Il Soon Hwang (SNU, Korea) indicated that public acceptance is of extreme importance. NPPs must address all "PEACE" requirements. That is, he explained that they must be proliferation resistant, environmentally friendly, accident tolerant, protect the climate and be economic. He encouraged the the IAEA to invest more on building regional regulatory cooperation framework and on infrastructure cooperation so that both challenges including blackswans and political pressure can be better managed. The IAEA has limited resources and scope, but can focus more on the institutional origins of accidents (addressing compromising regulations and management) by spending less on having a specific plant focus.

Hash M. Hashemian (AMS, USA), talked about how NPPs can have better health with age. He compared NPP upgrades to medication or surgery for people that can increase human life span. Technology is available to assist with remote maintenance (cable ageing, sensors, etc.) using on-line monitoring technology. For example, neutron detectors can measure movement of reactor internals; I&C upgrades, wireless technology and diagnostics can improve plant performance.

Jean Barbaud (EDF, France) indicated that renewables will increase the need for load following of operating NPPs. Upgrades identified by PSRs will be implemented in France during the subsequent 10 years outage (an extended outage longer than normal refuelling outage). Individual modifications or upgrades on existing systems can be considered "reasonably practicable", but some modifications are risky due to high interaction with existing systems. Modifications considered should have been examined on cost-benefit impact so as to provide significant benefits.

An European topical peer review is in progress (Nuclear Safety Directive (NSD) article 8e) to benchmark AM practices of European NPPs. LTO beyond 40 years should be reasonably achievable.

A question and answer session followed during which the importance of public outreach was highlighted. Some participants emphasized IAEA to have more authority to review safety aspects of operating NPPs.

8. CONCLUSIONS AND RECOMMENDATIONS

The session chairs, or their representatives each reported back to the conferences, and identified highlights and conclusions from their respective technical areas. The following points were considered:

- In reviewing what occurred at Fukushima it appears that it is quite unlikely that there was any effect of ageing degradation which contributed to the loss of function in SSCs important to safety, due to the ground motion by the earthquake. It is also unlikely that the effects of ageing degradation phenomena contributed to the occurrence and increased the scale of the Fukushima Daiichi accident. However it is difficult to confirm the status of equipment at this time and additional investigation will be needed when access to the site becomes possible and additional data are obtained at some time in the future.
- Close monitoring of operational experience and events around the world provides valuable input to the PLiM process. Regular safety peer reviews provide useful inputs and PSR overseen by regulator also encourages operators to keep their NPPs in good condition and the technology updated to the latest technology advances.
- Technical issues for the international community to consider include assessment of external natural events (seismic, tsunamis, flooding, fires, hurricanes, severe weather), and external manmade events (aircraft impact, severe grid disturbances, attacks to computer based systems, gas releases). As plants continue to operate, it is necessary to better assess events involving sites with several neighbouring units, long term loss of electrical power supply (SBO), emergency operating procedures, the reliability of power supply, provision of back up power sources, and portable power sources, with connection possibilities. In the event of an incident it is necessary to address the long term loss of the ultimate heat sink (loss of service water, emergency operating procedures, heat removal to atmosphere/sea, portable water sources) and severe accident management (with/without fuel failure, with/without containment failure, with/without high radiation environment, with/without adequate operating personnel).
- In all accidents it is necessary to take actions to minimize radiological release in case of loss of shielding against radiation (containment, spent fuel pool), combustible gas control (equipment, accident management measures), spent fuel cooling (impact of fires, explosions or loss of pool integrity, heat power limitation), emergency preparedness/management (dose projections, radiation protection, protective actions, evacuation zones), and critically crisis communication/Public information.
- R&D on LTO should cover (1) degradation phenomena that have not seen transitional conditions, such as frequent start-up, or (2) degradation phenomena with low probability of occurrence, but high impact on safety, and (3) potential synergies between different degradation mechanisms in a negative sense. This includes verification methods to predict the occurrence of these degradation mechanisms individually or in combination.It is essential to keep all low-carbon energy options open. Nuclear energy is part of the solution. It offers a triple win with reduction of CO_2 emissions, increased security of energy supply, and economic benefits, but all lessons from Fukushima need to be drawn for both existing and future reactors. Transparency and increased international cooperation are essential, identifying and implementing best practices and restoring public confidence will likely be the most difficult challenge.

8.1.CLOSING REMARKS PROVIDED BY G. RZENTKOWSKI, DIRECTOR, DIVISION OF NUCLEAR INSTALLATION SAFETY

In the aftermath of the Fukushima Daichii accident, the degree to which NPPs will contribute to the global energy solution remains unclear. Its role will depend greatly on its to capability of meeting emerging challenges and adapting to new circumstances in an efficient and effective manner. Any future accident, should it occur, will have far reaching global consequences. Therefore, ensuring the safety of nuclear installations is and will continue to be, our collective responsibility.

The IAEA initiated activities related to ageing management and PLiM in the early 1990s, and is attaching a high importance in the establishment of Safety Standards and guidance documents to address this issue. The IAEA is also providing its MS various types of assistance, such as safety peer reviews, workshops and training courses.

All information, recommendations and suggestions provided at this conference through the key note speeches, oral and poster presentations as well as panel discussions, exhibitions from nuclear industry have met the expectations outlined by the Deputy Director General, Mr. Chudakov, at his opening remarks at the Monday opening session. Furthermore, they are an important input for the improvement of the relevant activities of the IAEA. The following conclusions and recommendations were found to be meaningful:

- Importance of continuous nuclear installation safety improvements;
- Strong safety culture and proactive attitude are key issues;
- Technical developments often allow meeting the latest safety requirements through advanced design solutions;
- Most of the hardware problems seem to have technical solutions, on the other hand, soft problems, such as management are more difficult and complex;
- The IAEA Safety Standards and guidance documents, especially Safety Guides on PSR and Ageing management and LTO incorporates key issues relating to LTO, taking into account different national regulatory schemes;
- Information exchange, sharing and operating experience, are key elements of PLiM and safe LTO. The IAEA should facilitate information sharing among MS and MS are encouraged to contribute and report to the IAEA Incident Report System (IRS) and use lessons learned.

The IAEA SALTO peer review service expanded more and more since the first mission in 2005, as presented by Mr. Krivanek. The IAEA SALTO review was cited as of great assistance in addressing the safety issues associated with LTO. Conclusion and recommendations from this conference will be duly addressed in the relevant IAEA programmes and projects, namely in the IAEA Major Programme, Nuclear Energy and Nuclear Safety:

- Review and strengthen IAEA Safety Standards and improve their implementation;
- Strengthen IAEA peer reviews services including OSART and SALTO peer review missions;
- Strengthen the effectiveness of operating organizations;
- Strengthen the effectiveness of national regulatory bodies;
- Strengthen and maintain capacity building;
- Strengthen the integrated engineering support of NPPs;
- Effectively utilize research and development.

8.2.CLOSING REMARKS BY THE CHAIRMAN OF THE CONFERENCE, MICHEL MASHI

Michel Maschi, in his closing remarks, reminded the audience the duties and the guidance given by Mr Chudakov and Mr Miniere at the opening session, that the success of the conference resides in 3 main tasks, namely:

- Strengthening of the international co-operation;
- Encouraging the culture of active sharing and learning;
- Sharing the key learnings gained from a huge collective experience.

Acoording to the wide audience and the lively discussions in each technical session, all along the whole week, it can be said that these objectives have been achieved and that the further contact and discussions that have been started during this conference will be certainly be continuing among interested parties.

The presentations in different technical sessions have demonstrated that a lot has been and being done regarding PLiM and more especialy LTO. Nevetheless, we still have many things to achieve, among them, we should work together on:

- Identifying areas for improvement;
- Defining some key actions to the success of our industry;
- Making sure that we are on the best path to deliver safe, efficient, competitive and low carbon nuclear energy worldwide.

The results shared during this conference confirmed that all these topics are dealt with at the national and international level. Some have already been achieved others are in good progress. The benefit of this conference is to mesure the strength of nuclear community for LTO Programmes.

As for the areas for improvement, we need to innovate.

It was clear from Mr Chudakov words that innovation is key to operate in safer and economical way for longer time and that the innovation applied to the existing plants will benefit to the future of nuclear as a low carbon and sustainbale energy source. A lot of examples have been already presented in details in the technical sessions of the conference, but I just want to highlight two examples: sessions, e.g.:

- Developing new calculation models using non-conservative approach;
- On line monitoring and data analytics for improving maintenance strategy.

All of us face the same challenges when dealing with PLiM and it is really a strength when you prepare a strategy with solution and processes that have been consolidate between pairs and shared in an international context. Education and training is also a key takeover of the conference. Indeed we need to be attractive for our best engineers and propose them high scientific challenges to tackle, and also a clear path for their careers through training processes.

Finally, the public acceptance is critical for getting the agreement to extend the life of our reactors. We have seen that the situation was really different when you are in France, Japan, Canada and, or USA for example. But two clear lessons are obvious to keep in mind:

- We have to be transparent;

— We have to develop a broad and efficient communication.

For the success of our industry, I want to suggest 3 key actions that are:

1. Strengthening of the international collaboration;
2. Sharing the best practices not only the successes but also the risks,;
3. Implementing multidisciplinary approach: managerial, technical, regulatory and public.

Now, we need to have a systemic approach and to pay attention to all these domains at the same time. Again, without innovation our industry nuclear power will not be any more competitive and attractive.

Many initiatives are under process for the whole cycle of the nuclear industry. We still need to develop new simulation codes to improve our understanding of the aging processes, to promote new technologies to invent new ways of training and development of human resources.

We need the support of the IAEA and international bodies but also the agreement or clear guidance of policy makers. The safety authorities must be recognised for the benefit of safer industry and also public acceptance. At the end we clearly believe that without public confidence our industry cannot proceed further.

Finally we can agree all that LTO is crucial to prepare for the future energy mix combining nuclear and renewable, and secure sustainably a safe, clean and competitive power output. Our common goal is to contribute to the climate challenge, limiting the temperature increase for the future of our planet. To succeed we need to innovate, to communicate between us and stakeholders and to reinforce the positive social and economic benefit of the nuclear industry.

8.3.CONCLUSIONS AND RECOMMENDATIONS

Conclusions for the conference were drawn in the closing remarks provided by G. Rzentkowski, Director, Division of Nuclear Installation Safety, IAEA. The conference was declared to have been a success in that it had more than met the expectations from the event outlined by the Deputy Director General, Mr. M. Chudakov, during his opening remarks. All information, recommendations and suggestions provided at this conference through the key note speeches, oral and poster presentations as well as panel discussions provide important input to the community and will help to guide and improve the relevant activities of the IAEA.

The following general recommendations can be extracted from the technical content presented:

— Adopt systematic AM, LTO, and PLiM approaches that foster continuous safety improvements;
— Maintain a strong safety culture and a proactive attitude;
— Set up a technical development programme to allow the latest safety requirements to be met through more efficient advanced design solutions;
— Soft problems, such as management, training needs and organizational issues are challenging as they are more insidious and complex to detect and then resolve;
— From the view point of nuclear safety, the NPP operator’s responsibility is to implement ageing management with sufficient supervision, not only of its own staff but also of contractors and subcontractors, including vendors and designers, manufacturers and technical support organization. All such parties shall adequately consider ageing mechanisms while they carry out design, fabrication, taking into consideration the IAEA Safety Standards and experience feedback from operations and from R&D. This concept

should bring about a series of challenges to NPPs throughout their lifecycle including LTO and decommissioning;
- New on-line monitoring technologies as well as repair/mitigation techniques being developed are starting to show the potential for significant economic benefits for PLiM.

In the way of recommendations to the IAEA, it is important to note that:

- Safety standards and guidance documents, especially the IAEA Safety Guides on PSR and AM and LTO and other guidance should be continuously updated to incorporate research results and operational experience feedback.

There are increasing needs to strengthen international cooperation to ensure that knowledge and best practices are shared and adopted throughout the global nuclear community. In response, the IAEA will consider the recommendations from this conference, and where appropriate, will implement them in the relevant IAEA programmes and projects, namely:

The IAEA will:

- Strengthen IAEA peer reviews, in particular SALTO peer review;
- Provide support and guidance to strengthen the effectiveness of national regulatory bodies and operating organizations;
- Continue reviewing and updating the IAEA Safety Standards and further promote their implementations;
- Strengthen and maintain capacity building (training, human resource management programme etc.);
- Assist MS to effectively launch and disiminate research and development results through exchange of information, and seek to communiate information and insights within the nuclear community.

The conference recommendations will also serve as input to the following IAEA activities and programmes:

- Programme and budget preparation 2019- 2021;
- In the preparation of technical cooperation project and extra budgetary programme projects;
- Preparation of proposals for CRPs (coordinated research projects);
- IGALL Programme development work.

Finally, it is important that all associated MS continue to exchange information and cooperate in establishing effective AM/LTO/PLiM programmes. The IAEA will continue to support MS in these activities:

- Successful achievements of PLiM applications were reported in support of LTO in both technical and economic fields. AM activities, including material degradation (integrity assessment, embrittlement, cracking and fatigue), maintenance and inspection techniques were presented in support of LTO programmes;
- The SALTO peer review service will continue to support MS in the preparation and implementation of LTO consistent with IAEA Safety Standards;
- To succeed in LTO, it is essential to keep on working and communicating with involved stakeholders to reinforce the positive social and economic benefit of the nuclear industry and to keep strong safety culture and proactive attitude;

- A continuous information exchange related to operating experiences, regulatory practices, and the latest knowledge in AM, LTO and PLiM is essential;
- IGALL Programme will continue to serve as a forum for exchanging experience on AM;
- Openness between the regulator and the utility is important to gain a common understanding of the LTO preparation and implementation;
- Development of on-line monitoring techniques for operation and maintenance cost reduction

All presentation materials are uploaded on the IAEA website and informed the participants to share information (https://www.iaea.org/NuclearPower/Meetings/2017/2017-10-23-10-27-NPES.html).

9. CONTENTS OF THE SUPPLEMENTARY FILES

The on-line supplementary files for this publication can be found on its individual web page at www.iaea.org/publications.

For ease of reference the content is organized in the following folders.

- General Information
- Papers and Posters Presentations
- Powerpoint presentations
- Photos

ACRONYMS AND ABBREVIATIONS

AM	Accident management
CCF	Common cause failure
DBA	Design basis accidents
EAF	Energy availability factor
EDG	Emergency diesel generator
EPRI	Electric Power Research Institute
ENSREG	European Nuclear Safety Regulators Group
FAC	Flow accelerated corrosion/flow assisted corrosion
GALL	Generic Ageing Lessons Learned
GHG	Greenhouse gases
IAEA	International Atomic Energy Agency
IFRAM	International Forum for Reactor Ageing Management
IGALL	International Generic Ageing Lessons Learned
LTO	Long-term operation
LWRS	Light Water Reactor Sustainability (Programme)
MS	Member States
NEA	National Energy Administration
NEI	Nuclear Engineering International
NPP	Nuclear power plant
NRC	U.S. Nuclear Regulatory Commission
OSART	Operational Safety Review Team
PLiM	Plant life management
PSR	Periodic Safety Review
RPV	Reactor pressure vessel
SALTO	Safe Long Term Operation
SAMG	Severe Accident Management Guidelines
SC	Structures and components
SCC	Stress corrosion cracking
SLR	Subsequent license renewal
SNETP	Sustainable nuclear energy technology platform
SSC	Structures, systems and components
TLAA	Time-limited assumption
TMI	Three Mile Island
WGIAGE	Working Group on Integrity and Ageing of Components and Structures

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