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LONG TERM OPERATION OF NUCLEAR POWER PLANTS – SALTO MISSIONS OBSERVATIONS AND TRENDS

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ABSTRACT

The objective of this paper is to enable organizations that operate, regulate nuclear power plants (NPPs) or provide technical support to NPP to benefit from experience gained during missions conducted under the International Atomic Energy Agency (IAEA) Safety Aspect of Long Term Operation (SALTO) programme.

As of February 2022, 70% of the 439 nuclear power reactors operating in the world had been in operation for more than 30 years and more than 30% for more than 40 years (source: https://www.iaea.org/PRIS). In 2005, the IAEA launched the SALTO peer review service to provide advice and assistance to member states embarking on long term operation (LTO) in enhancing the safety of NPPs. SALTO peer review service aim to provide the host organization with support in preparation for safe LTO, an opportunity to discuss practices with experts who have experience with ageing management and LTO, an objective assessment of the status of the preparedness for LTO with respect to IAEA Safety Standards, and recommendations and suggestions for improvement in areas where performance falls short of the safety standards or international best practices.

During the period of 2005 to 2020, 45 SALTO missions and 13 SALTO follow-up missions reviewed plants around the world. At 11 NPPs, safety aspects of LTO were reviewed in the frame of an OSART mission that included the LTO module. 498 recommendations and suggestions and 42 good practices identified during these SALTO and OSART missions form the basis of the evaluation provided in this paper.

Assessment of the SALTO mission results have been performed area by area and topic by topic. The results of the follow-up missions have been also analyzed. Most important and most frequent areas for improvement has been identified. Based on analysis results, overall trends have been drawn and cross-cutting issues identified.

INTRODUCTION

Programmes are being implemented for an increasing number of nuclear power reactors around the world for ageing management and long-term operation (LTO). As of February 2022, 70% of the 439 nuclear power reactors operating in the world had been in operation for more than 30 years and more than 30% for more than 40 years (source: https://www.iaea.org/PRIS).

The IAEA has developed a set of Safety Standards to support member states in preparation for safe LTO, the most important being the Specific Safety Guide SSG-48, 'Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants' [1] published in December 2018. This Safety Guide supplements and provides recommendations on meeting the requirements related to ageing management and long-term operation that are established in IAEA Specific Safety Requirements SSR-2/1 (Rev.1), 'Safety of Nuclear Power Plants: Design' [2], and IAEA Specific Safety Requirements SSR-2/2 (Rev.1), 'Safety of Nuclear Power Plants: Commissioning and Operation' [3]. It provides guidance for operating organizations on implementing and improving ageing

management, obsolescence management and on developing a programme for safe long-term operation for nuclear power plants. It may also be used by the regulatory body in preparing regulatory requirements, codes and standards, and in verifying effective ageing management, obsolescence management and preparation for safe long-term operation of nuclear power plants.

In 2005 the IAEA launched Safety Aspects of Long Term Operation (SALTO) peer review service to provide advice and assistance to member states embarking on LTO in enhancing the ageing management and safety of nuclear power plants (NPPs).

SALTO peer review service aim to provide the hosting organization with an objective assessment of the status of ageing management and the preparedness for LTO with respect to the IAEA Safety Standards; an opportunity to discuss practices with experts who have experience with ageing management and LTO, and recommendations and suggestions for improvement in areas where performance does not meet the IAEA Safety Standards

The SALTO review is performed in line with the SALTO Guidelines, Service Series 26 (Rev.1), published in 2021 [4]. Further details regarding to SALTO peer review service can be also found in paper 'Long term operation of nuclear power plants – IAEA SALTO peer review service and its results', NED 8070 [5] and paper 'Long term operation of nuclear power plants – IAEA SALTO missions observations and trends', NED 8805 [6].

SALTO peer review service is available to all IAEA member states. It can be requested by NPPs or regulatory authorities any time during the NPPs operational life time as it supports establishment of appropriate activities for ageing management of NPPs. 26 out of 32 member states operating NPPs have already invited SALTO workshops and 18 member states have already hosted or invited one or more SALTO missions. LTO modules of OSART missions were conducted in additional 8 member states. Vast majority of IAEA member states sends regularly experts and observers to participate in SALTO missions.

The primary objective of this paper is to enable organizations that operate, regulate NPPs or provide technical support to NPP to benefit from experience gained during missions conducted under the SALTO and OSART programmes during the period of July 2015 to June 2018. The IAEA performed the analysis of SALTO missions and LTO modules of OSART missions conducted in this period of time and published it in a working document 'SALTO Missions Highlights 2015-2018' in 2019 [7].

Chapter 2 provides an overview of the SALTO missions and LTO modules of OSART missions performed between July 2015 to June 2018. Chapter 3 summarizes areas for improvement classified by review area observed during the missions between July 2015 to June 2018. Chapter 4 summarizes the results of SALTO follow-up missions as well as OSART follow-up missions. Individual findings varied considerably in scope and significance. However, the findings do reflect some common strengths and opportunities for improvement.

OVERVIEW OF SALTO MISSIONS

During the period of July 2015 to June 2018, 14 SALTO missions listed in table 1 reviewed plants around the world. For 9 plants, safety aspects of LTO were reviewed in the frame of an OSART mission that included the LTO module, table 2.

Table 1. PRE-SALTO and SALTO missions

No.	Plant	Mission type	Year
23	Qinshan 1	Pre-SALTO	2015
24	Koeberg	Pre-SALTO	2015
25	Doel 1/2	Expert Mission	2016

26	Kozloduy 5	Pre-SALTO	2016
27	Atucha 1	Pre-SALTO	2016
28	Forsmark 1/2	Pre-SALTO	2016
29	Armenian 2	Pre-SALTO	2016
30	Doel 1/2	SALTO	2017
31	Qinshan 1	SALTO	2017
32	Oskarshamn 3	Pre-SALTO	2017
33	Ringhals 3/4	SALTO	2018
34	South Ukraine 3	Pre-SALTO	2018
35	Angra 1	Pre-SALTO	2018
36	Kozloduy 6	Pre-SALTO	2018

Table 2: OSART missions with LTO module

No.	Plant	Mission type	Year
188	Bruce B	OSART	2015
189	Pickering	OSART	2016
193	Olkiluoto 1/2	OSART	2017
194	Krsko	OSART	2017
195	Sequoyah	OSART	2017
197	Bugey	OSART	2017
199	Torness	OSART	2018
200	Almaraz	OSART	2018
202	Loviisa	OSART	2018

The results of these missions based on the findings collected are summarized in this paper and provide a series of snapshots of the status of the plant`s activities to ensure safe LTO. The IAEA evaluated the general trends and achievements derived from these SALTO missions (including OSART LTO module reviews) and these are presented in this paper.

With respect to safe LTO, the amount and significance of recommendations and suggestions made during the SALTO missions correlates in principle with the level of compliance with the IAEA Safety Standards; the amount and significance of good practices indicates the level of implementation of the best international practices in the industry.

While the nuclear industry has made significant advances in safety, there is always room for further improvement: SALTO peer review teams have identified many safety aspects of LTO where improvements are still needed. At the same time, the assessment teams and plants reviewed have provided the IAEA with valuable feedback that allows continuous improvement of the IAEA services aimed at safe LTO.

221 issues (130 recommendations and 91 suggestions) and 16 good practices identified during these 14 SALTO and 9 OSART missions form the basis of the evaluation provided in Section 3 of this paper. It must be noted that level detail and consequently amount of issues from 14 SALTO issues is significantly higher than level detail and amount of issues from 9 LTO modules of OSART missions performed.

The main task of the assessment was to evaluate and give a weight to the evaluation. The following wording was used to group the results:

- Wording 'In all plants' or 'in all cases' is used when 21 or more issues were given during 23 different plant reviews for areas A-E, and when 11 or more issues were given during 12 different plant reviews for area F (more than 90% of the cases);
- Wording 'In many plants' or 'frequently' is used when 11 to 20 issues were given during 23 different plant reviews for areas A-E, and when 6 to 10 issues were given during 12 different plant reviews for area F (from 45% to 90% of the cases);
- Wording 'In some plants' is used when 4 to 10 issues were given during 23 different plant reviews for areas A-E, and when 2 to 5 issues were given during 12 different plant reviews for area F (from 15% to 45% of the cases);
- Wording 'In a few plants' is used when 3 or less issues were given during 23 different plant reviews for areas A-E, and when 1 issue was given during 12 different plant reviews for area F (up to 15% of the cases).

SUMMARY OF AREAS FOR IMPROVEMENT CLASSIFIED BY AREA

In this Section the summary of areas for improvement classified by each area is provided for the missions in Tables I and II. The area of 'Human resources, competence and knowledge management for LTO' was reviewed only as a part of 12 SALTO missions. It should be also noted that the numbers provided for each area for improvement given in brackets provide a number of mission reviews in which this issue was observed against the total number of reviews.

It should be also noted that the numbers provided for each trend observed in brackets provide a number of reviews in which this issue was observed against the total number of plants or reviews.

Organization and functions, current licensing basis, configuration/ modification management

- In a few plants, there is an indication that regulatory expectations for safe LTO are not clear for the plant (3/23). In some plants, NPP and regulatory authority documents developed to provide requirements and guidance for LTO do not cover all safety aspects (4/23).
- In a few plants, organization for supporting LTO is not fully established (3/23). In some plants, exiting organization is not adequate for supporting LTO (7/23).
- In a few plants, the plant LTO policy is not established, leading to problems related to strategy, tasks, roles, responsibilities, organizational structure and how well the organization knows the LTO approach and expectations (3/23).
- In some plants, the content of the LTO implementation programme is not complete (6/23).
- In some plants, PSR is not comprehensive (5/23). In a few plants, final safety analysis report (FSAR) is not being fully updated for LTO (2/23).
- In some plants, design basis documentation is not adequately managed to ensure its availability for the plant. (6/23) In a few plants, function of design authority is not fully implemented. (2/23)

Scoping and screening and plant programmes relevant to LTO

- In many plants, scoping and screening is incomplete (19/23). Following type of issues were identified

during the reviews (some items occurred in the same plant, so the sum does not correlate with the above total number):

  - Definition of criteria for scope setting and boundaries between systems, structures and components (SSCs) are unclear (7/23);
  - Incomplete documentation of the process/ results of scope setting (4/23);
  - The methodology for scope setting is not established (3/23);
  - The methodology for scope setting is not consistently used for LTO (3/23);
  - Ageing of the active and short-lived systems and components (SCs) is not properly managed (3/23).

- In many plants, existing plant programmes are not adequate for LTO (15/23). Typical issues are given below (some items occurred in the same plant, so the sum does not correlate with the above total number):
  - Insufficient coordination of existing plant programmes with ageing management (11/23);
  - Insufficient evaluation of effectiveness of existing plant programmes (7/23).

Ageing management review, review of ageing management programmes and revalidation of time limited ageing analyses for mechanical components

- In a few plants, the scope setting of mechanical SSCs for LTO components is not properly implemented (1/23).
- In many plants, AMR of mechanical SCs for LTO is not adequately performed (e.g., gaps in condition assessment, identification of potential ageing effects, identification of relevant programmes to manage ageing, documentation) (12/23).
- In some plants, AMPs for mechanical SCs are not adequately developed or implemented (e.g., gaps in identification of managed ageing effects, trending, acceptance criteria, corrective actions, documentation) (6/23).
- In a few plants, a proactive programme for managing technological obsolescence is not developed/ fully established (2/23).
- In some plants, quality or identification of TLAAs for mechanical SCs is not complete or systematic (5/23).
- In some plants, revalidation of TLAAs for mechanical SCs is not complete or adequate (7/23).
- In some plants, data management (consistency and completeness) of mechanical SCs is not adequate (4/23).

Ageing management review, review of ageing management programmes and revalidation of time limited ageing analyses for electrical and I&C components

- In some plants, the scope setting of electrical and I&C SSCs for LTO is not properly implemented (5/23).
- In some plants, AMR for electrical and I&C SCs for LTO is not adequately performed (e.g., gaps in condition assessment, identification of potential ageing effects, identification of relevant programmes to manage ageing, documentation) (6/23).
- In some plants, the equipment qualification (particularly environmental qualification) programme is not comprehensive (9/23).
- In some plants, AMPs for electrical and I&C SCs are not adequately developed or implemented (e.g., gaps in identification of managed ageing effects, trending, acceptance criteria, corrective actions, documentation) (4/23).
- In a few plants, the practice of equipment storage in close proximity of electrical and I&C safety

equipment may jeopardize operability during and after a seismic event (2/23).

- In some plants, a proactive programme for managing technological obsolescence is not developed/ fully established (7/23).
- In few plants, quality or identification of TLAAs for electrical and I&C SCs is not complete or systematic (2/23).
- In few plants, revalidation of TLAAs for electrical and I&C SCs is not complete or adequate (1/23).
- In some plants, data management (consistency and completeness) of electrical and I&C SCs is not adequate (4/23).

Ageing management review, review of ageing management programmes and revalidation of time limited ageing analyses for civil structures

- In a few plants, the scope setting of civil SSCs for LTO components is not properly implemented (1/23).
- In many plants, AMR for civil SCs for LTO is not adequately performed (e.g., gaps in condition assessment, identification of potential ageing effects, identification of relevant programmes to manage ageing, documentation) (13/23).
- In some plants, AMPs for civil SCs are not adequately developed or implemented (e.g., gaps in identification of managed ageing effects, trending, acceptance criteria, corrective actions, documentation) (10/23).
- In a few plants, quality or identification of TLAAs for civil SCs is not complete or systematic (3/23).
- In a few plants, revalidation of TLAAs for civil SCs is not complete or adequate (2/23)

Human resources, competence and knowledge management for LTO

- In many plants, human resources policy and strategy to support LTO is not adequate or not fully developed (10/12).
- In many plants, competence management is not adequate or fully implemented (6/12).
- In many plants, knowledge management or knowledge transfer processes for LTO are not adequate or fully implemented (9/12).

SALTO AND OSART LTO MODULE FOLLOW-UP MISSIONS RESULTS

SALTO follow-up missions (table 3) as well as OSART follow-up missions (table 4) are integral part of the services, and take place approximately 2 years after the main missions. In the period July 2015 to June 2018 there were 4 SALTO follow-up missions to review the implementation of previous SALTO results. Issues from 1 OSART LTO module were reviewed during the OSART follow-up mission in this period.

Table 3: SALTO follow-up missions

No.	Plant	Country	Year
19	Ringhals-1/2	Sweden	2016
20	Dukovany	Czech Republic	2016
21	Tihange-1	Belgium	2016
22	Laguna Verde	Mexico	2017

Table 4: OSART follow-up missions with LTO module

No.	Plant	Country	Year
188	Bruce B	Canada	2017

Table 5 presents the results of the follow-up missions regarding the resolution of the findings (totally 50 issues):

Table 5: Resolution of issues

Status of issues	No.	%
Resolved	16	32.0%
Satisfactory progress	27	54.0%
Insufficient progress	7	14.0%

The results of the follow-up missions demonstrate the effectiveness of the SALTO programme and in particular the commitment of the plants to implement improvements identified by SALTO teams. SALTO peer review service also offers supporting activities (i.e. workshops, supports missions) after the individual missions.

OVERALL TRENDS

Table 6 shows the number of findings in each standard review area.

Table 6: Findings overview divided into review areas

	A	B	C	D	E	F
Recommendations	16	31	20	24	22	17
Suggestions	26	17	17	16	7	8
Good Practices	2	5	3	3	1	2
Missions	23	23	23	23	23	12

Comparison with results of SALTO missions and LTO modules of OSART missions in the period of 2005-2015 (published an IAEA working document ‘SALTO Missions Highlights 2005-2015’ in 2016 [8] and presented also in ‘Long term operation of nuclear power plants – IAEA SALTO missions observations and trends’, NED 8805 [6]), the following trends can be observed:

a) Missions during 2015-2018 (3 years period) records more issues (221) as those raised during eight years in 2007-2015 (208). This shows intensive activity in this area with high demand from member states;
b) Number of issues per mission per area has decreased (2015-2018 vs. 2005-2015). This shows better understanding and clarity of IAEA Safety Standards, better IAEA support of NPPs prior to the missions through workshops and participation of plant experts in SALTO missions as observers and in IGALL Programme. It leads to better preparedness for SALTO missions by the plant. Exception is relatively new area F, introduced in 2012, where number of issues per mission has increased and better IAEA support of NPPs is needed;
c) Number of good practices per mission has decreased (0.70 good practices per mission in 2015-

2018 vs. 1.13 good practices per mission in 2005-2015) while number of good performances is increasing (not shown in this paper). This shows good information exchange and sharing of experience which is strongly supported by IAEA. It should be noted that since good practices has to be novel, they can be identified only once but if implemented in some other plants, they are recognized as a good performance.

Comparison of the follow-up missions results in 2015-2018 with results in the period of 2005-2015 shows that share of 'resolved' issues has decreased from 48% in 2007-2015 to 32% in 2015-2018 and share of 'insufficient progress' issues has increased from 5% in 2007-2015 to 14% in 2015-2018 due to significant delays in implementation of LTO programmes in several NPPs, mostly due to political decisions in those countries and reorganization in utilities.

Cross-cutting issues over several review areas of SALTO guidelines [4] were analyzed. The following trends can be observed:

a) A least one issue is raised for every core topic (scope setting, AMR, AMP and TLAA) during every SALTO mission;
b) Issues on SALTO missions core topics (scope setting, AMR, AMP and TLAA) account for app. 55%;
c) Common issues in other than core topics in many plants, some with frequency of more than 80%, such as knowledge management, equipment/ environmental qualification, human resources /staffing, data management, obsolescence management.

The IAEA noted a continuing higher-than-average number of requests by member states for SALTO missions. The number of such missions increased from one to two missions per year in 2007 to 2011, to three to four per year in 2012–2015 and to six to nine per year in 2016-2018.

SALMIR database comprising of all SALTO mission results since 2005 was prepared by IAEA and made available to member states in 2018 to share lessons learned and experience from SALTO peer review service.

The peer review approach has proven to be a very effective mechanism to perform safety reviews of complex issues. SALTO peer review service has been established as an effective tool to review the compliance with IAEA standards and international best practices, to provide opportunity for NPP staff to discuss their practices with experienced experts, to strengthen the public confidence to NPP and to support in licensing renewal procedure (or extension of operational permission procedure).

CONCLUSIONS

Analysis of results of SALTO missions and LTO modules of OSART missions in the period of 2005-2020 showed despite much better trained reviewers and improved methodology of SALTO missions, the decreasing number of issues per mission per area. It demonstrates better understanding and clarity of IAEA Safety Standards and better preparedness of NPPs for SALTO missions and safe LTO of NPPs.

Number of good practices (must be novel) per mission has decreased while number of good performances has been increasing. This shows good information exchange and sharing experience which is strongly supported by the IAEA.

The IAEA noted a continuing increase in requests by member states for SALTO missions. The number of such missions increased from one to two missions per year in 2007 to 2011 to six to nine per year in 2016-2019. There was a temporary decrease due to corona pandemic in 2020 with only two SALTO missions performed but six SALTO missions were performed in 2021 despite the persisting covid restrictions.

The IAEA Specific Safety Guide No. SSG-48 [1] states that 'ageing management is most effective when it is properly carried out at all stages of the lifetime of a nuclear power plant'. There is an important number of countries embarking on nuclear energy, commissioning first units and many

new builds in countries already operating NPPs. Large portion of NPPs is already operating in LTO but heading towards further operation extension beyond 50 or 60 years. It was one of the main reason for revision of the IAEA SALTO Guidelines in 2021 [4]. It includes important new direction to provide SALTO peer review service also to NPPs in early phase of operation and NPPs already operating in LTO period preparing for further extension of lifetime.

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