CONCLUSIONS AND RECOMMENDATIONS

Approaches to plant life management:

- Principles of PLiM strategies for long term operation must be based on the state of current knowledge concerning the NPP’s system structure and components’ ageing status and the operating conditions. PLiM programmes may be generally planned using experience from NPPs worldwide, but plant–specific PLiM programmes are required for assessing the possibility of LTO. The best precursor for LTO is that a NPP is operated according to an ageing management and PLiM programme already from start-up.

- When SSCs are inspected, monitored, serviced, replaced or repaired according to the ageing and PLiM programme, they will be more reliable, and the point of time of replacement, for example, will be optimized for the business case. The PLiM approach is best based on a feasibility study, including a review of the NPP’s operating history to date, the availability of data (for example, water chemistry records, transient record keeping for fatigue usage assessment). The key, life-determining components (i.e. those deemed not replaceable or prohibitively costly to do so) obviously have a high priority, but those SSCs that are vital to safety have the most importance. Furthermore, due consideration must be paid to regulatory requirements, and a PLiM programme should be focussed on ensuring that a sufficient level of safety is maintained and that the SSCs remain free from spontaneous failure. The latter scenario causes loss of availability, is therefore potentially expensive, and may draw increased regulatory attention and possible operating constraints.

- To ensure that PLiM is done consistently with the strategic plan and the overall plant goals, objectives, and commitments, it is important that an integrated PLiM programme should be established as a set of plant-specific guidelines and generic guidelines based on Safety Guide for the Periodic Safety Review (PSR) issued by the IAEA or Generic Ageing Lesson Learned (GALL report) and the Standard Review Plan issued by the US NRC. This includes determining what systems need to be analyzed, what systems can be maintained, the priority order of the systems to be modernized and how the systems should be modernized.

- NPPs’ SSCs are serviced, inspected, repaired or replaced on a continual basis, according to the schedules and practices set out in the ageing and PLiM programmes. Thus the SSCs are not all replaced at the same time as a single major investment. The ageing management and PLiM programmes must however be sensitive and flexible enough to follow experiences in similar NPPs all over the world in order to be adjusted to address issues as they arise.

- A proactive attitude and good safety culture in the NPP is necessary to realize this. Care should be exercised to document all changes to the NPP’s operating conditions and changes to the plant’s configuration. Replacement SSCs should have at least function equivalence and be correspondingly approved by the designer and the regulator.

Economics of plant life management

- PLiM should be an integral part of the NPP’s overall maintenance, replacement, monitoring and regular servicing schedules, whereby it is recognized that PLiM focuses mostly on large, passive components that cannot be replaced (Reactor Pressure Vessel (RPV), Containment) or are economically prohibitive to do so. All other components are deemed to be technically and economically replaceable, should safety and reliability issues arise, for example Instrumentation and Control (I&C) components and systems. However, RPV heads, Steam Generators of Pressurized Water Reactor (PWR) and core shrouds of Boiling Water Reactor (BWR), if replaced, represent significant costs that must be amortized throughout the rest of the NPP’s life.

- As a NPP nears the end of its nominal or original design life it is usually amortized and thus is in an economically attractive stage. Investments in large SSCs must therefore be done with a view to assure safety but also with the good prospect of the NPP to pay back the investment in
terms of more electrical power sold in the continued operation phase. Continued operation is only possible if the plant’s safety is shown to be at least at the level of the original design basis, and the licensing renewal (mostly US practice) or periodic safety review (mostly Europe practice) has been done according to accepted practices. Notwithstanding the licensing status, continued operation will only be attractive to a utility/owner/operator if the NPP makes a profit.

- Economic planning thus necessitates continual review of how the NPP can maximize its electrical power output whilst lowering operational costs and assuring safety at all times. It is worth mentioning that many NPPs have performed power uprates (with levels of up to 20% relative to the previous rating). A NPP power uprates may be defined as the process of increasing the maximum power level at which a commercial NPP may operate. The three basic categories of NPP power uprates are currently understood as:
  - Measurement uncertainty recapture power up-rates (MUR),
  - Stretch power up-rates (SPU) and
  - Extended power up-rates (EPU).

- A cost-benefit analysis should be done for each action. It is necessary to do only those actions that maintain or improve safety according to regulatory requirements.

- IAEA-TECDOC-1309 is a useful guidance in assessing the economics of plant life extension;

**Ageing management and related operational programme**

- Research concerning ageing effects in SSCs should be continued in all relevant fields concerning NPP materials and the way they are affected by the environment they are exposed to. The RPV and its internals, primary pressure boundary piping and pressurizer are obviously vital to the safety and also economic viability of a NPP. Mitigation measures will be optimized using validated inputs from research, since knowledge about the ageing mechanisms will provide ways to avoid, mitigate or reduce their impact.

- Research and Development (R&D) is essential in ageing mechanism research. It is necessary to continuously investigate ageing phenomena and mitigating measures by enhancing the evaluation technology and inspection techniques, as well as collecting actual plant data and knowledge obtained from R&D results. Regulators and operators must be aware of R&D results concerning ageing mechanism of SSCs, and their impact on safety and economic issues. Concerning continued operation, the chemical and physical stability of materials used in SSCs have to be studied in terms of time dependence i.e. the changes in properties with time, under operating conditions. As more exposure is accumulated, the design and operation margins may be reduced; timely inspection and monitoring, using advanced technologies may assist in the detection of problems before they evolve into safety-threatening conditions.

- A review should be performed on the effectiveness of the ageing management programme for current and projected continued operation, and any weaknesses of ageing management programme should be identified and addressed through the corrective action process and current operating experience review. Any new ageing management programme for the SSCs identified in the gap analysis for scoping and screening should be reviewed for the LTO application.

- The pre-design or pre-licensing phase has to include the following ageing aspects:
  - Choice of materials
  - Major drawings
  - Operating conditions
  - Collection of relevant data
  - Monitoring, surveillance
  - In service inspection and access ability
  - Radiation protection of workers

- In 2006, OECD-NEA started to conduct stress corrosion cracking (SCC) and cable ageing project with 14 NEA member countries and the IAEA. This project will last for 4 years. OECD-NEA also has organized to collect information, data and material samples from
decommissioned concrete structures to find out ageing and degradation phenomena of concrete structure. For research work, it is important to use, as far as possible, actual material that has seen operational exposure. This allows direct transfer of research results to the NPP.

**SSCs design modification, modernization, refurbishment and replacement**

- The design of SCCs should, as far as possible, allow for ease of inspection, monitoring and replacement. Ease of replacement translates into lower dose penalties for personnel involved in such tasks.
- Functional equivalence and improved reliability, design and materials should be characteristics of new SSCs used to replace aged ones.
- It is important to recognize that also the reliability of secondary side SSCs will become important as NPPs operate for longer times. Although such SSCs may be adequately managed for ageing effects (e.g. replacement), their contribution to overall costs have to be considered in the business case for LTO. Extensive replacements and modernisation tasks may become commonplace in the future.
- NPP operators must ensure that updated documentation pertaining to the NPP’s SSCs is readily available. It is a good practice to create a NPP’s own personnel team who are dedicated to manage all the plant’s documentation especially that related to SSCs and LTO aspects.
- All necessary documentation should be validated to confirm the current plant configuration. Documentation management is an important task within PLiM. Some utilities have a configuration management service dedicated to this activity in their organization.
- Due consideration has to be paid to the issues of procurement of SSCs. The world’s suppliers of nuclear steam supply systems (NSSSs) and the associated large equipments (e.g. reactor pressure vessels, steam generators, pressurizers etc.) have only a certain production capacity and thus a corresponding limit for delivering SSCs on a given schedule.
- Bearing in mind the time needed to get new designs approved or simply to replace components in an existing NPP, it is essential that an utility acts well in advance to order SSCs. This will be facilitated by an awareness of the SSC’s actual condition relative to its design requirements, inspection reports and test results. Changes in ageing rates may, for example, be caused by increased flow and vibration (power up-rate issues), or, in the positive sense, a decrease in degradation due to better design of equipment or improved water chemistry.

**Managerial issues concerned with plant life management**

- It is important to implement NPP ageing management and PLiM programmes as early as possible, ideally at start-up. PLiM has the potential to improve safety and reliability (availability) of SSCs. From the beginning, an efficient process for the exchange of information between operators and regulators should be initiated.
- Transparent, logical and state of the science PLiM practices may also find application in arguments for cases where NPP operation exceeding the original design life of a NPP is being proposed. The PLiM programme must be at all times flexible to take into account the current state of science and technology.
- Continued training, education, and knowledge management programmes are essential to ensure constant improvement in safe and reliable operation of NPPs. As NPP personnel retire, succession planning for recruitment of new personnel is a vital management task. It is suggested that international efforts should be increased to create a common and comprehensive programme for the development of training or personal qualification in the area of nuclear technology and safety, which includes ageing management and PLiM.
- NPPs should implement a plant-specific knowledge management programme to address the problem of the loss of knowledge when experienced personnel leave the NPP. Temporary job duplication is a good way to facilitate efficient transfer of knowledge and duties. A good
practice for transferring technical excellence is to involve young NPP employees during major replacement projects within PLiM under the leadership of experienced personnel. Young employees will thus be motivated to acquire essential knowledge through on-job participation. A process should thus be in place to ensure that all personnel who leave a NPP are fully debriefed with respect to their knowledge gained and their accumulated experience.

- International efforts should be increased to create a common and comprehensive programme for the development in the area of nuclear technology and safety, which also includes ageing management and PLiM for LTO.
- It is recognized that if NPPs operate longer, then provision should also be made, well in advance, for the storage/disposal capacity of spent fuel and other associated radioactive wastes arising. All tasks concerned with PLiM-LTO that may involve personnel exposure to radiation must be first planned and carried out according to ALARA principles.

**Regulatory Aspects**

- Open and rapid exchange of information between operators and regulators is necessary to facilitate timely comprehensive and effective resolutions of all aspects related long term ageing processes due to continued operation and unexpected issues as they arise.
- Compliance with the current licensing basis will ensure that all safety and legal requirements are satisfied, or are even exceeded, and will facilitate current and long term safe operation goals. The periodic safety review, where applicable, will remain an important tool to assess the safety of NPPs. The outcome of the periodic safety review dictates whether a NPP will be get regulatory permission to continue operation on the current license, or not. The US licensing renewal approach is also based on assurance of safety, taking into account the maintenance history and generic ageing lessons learned over the many years of operation of NPPs.