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Research priorities at the European Commission in relation to Maintenance Optimization and Nuclear Power Plant Life Management

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Abstract. Analysis of experience in many countries operating nuclear power plants (NPPs) suggests that, while differences in long term operation (LTO) programs are mainly related to the various national regulatory processes, the main features and basic technical requirements are similar. The implementation of these however needs reshaping in an integrated plant life management (PLIM) framework, bearing in mind the specific safety implications of LTO. R&D is essential to support this process, not only for long term extrapolation of the component integrity and behavior, but also for a proper maintenance system and for an adequate management structure ensuring effective management strategies at plant level, able to address organizational issues, spare part management, staff ageing, component obsolescence, etc. This is recognized by the European Commission, which supports R&D in targeted areas in the framework of the EURATOM program, both by "direct actions" i.e. projects managed and executed by its Directorate General Joint Research Centers (JRC) and by indirect actions i.e. funding of selected projects, managed by the Directorate General Research (RTD). This paper outlines the JRC's priorities in the current 7th Framework Programme in relation to R&D tasks for maintenance and ISI to support the highest safety level at member's NPPs and appropriate decision-making tools for the optimization of these programs. A newly developed UE model for PLIM, also integrating maintenance optimization issues, is presented for further discussion.

KEYWORDS: nuclear plants, maintenance, plant life management, research programs, European Union

1. Introduction

The current social and economic framework for the energy production is characterized by the following trends:

1) The open electricity market, which is going to be a reality in most of the European Countries in few years. Such economical and financial framework demands for significant reduction of the generation costs, very strict investment planning, outsourcing, controlled reliability of the equipment and components (incl. obsolescence) and therefore for reliable indicators of the effectiveness of the maintenance programmes
2) The generic trend towards the extension of the operating life of the existing plants. Such life extension requires a detailed review of the original design assumptions, also reflected into current maintenance practice, and the continuous monitoring of the component reliability (performance goals) in order to support a suitable trend of the safety evaluation beyond the design life.

As a consequence, in last years many electric utilities and nuclear power plants adopted policies for improved coordination of both safety and non-safety programs, called plant life management (PLIM). Its implementation has followed many different approaches, being intrinsically dependent

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on the national regulatory framework and technical traditions. The LTO process poses further challenges, particularly in view of the nuclear safety implications as well as the economic strategic and political ones. Therefore in recent years the need for tailoring available safety assessment tools to such needs has become very urgent. However, such adaptation often proved very complex due to the long time perspective of the PLIM (typically 30-40 years), as compared to the typical time framework where the available methods are currently employed (~10 years of the standard periodicity of the Periodic Safety Review process).

In Countries with some experience, the PLIM program proved very convenient, especially when coupled with Maintenance, Surveillance an Inspection (MS&I) optimization: average savings are reported in the range of 20-30% of total (maintenance) costs.

Moreover, in terms of safety, the control of equipment reliability, significantly improved with PLIM models for example through Ageing Management Program (AMP) and Reliability Centred Maintenance (RCM), made a long term asset management of the overall plant possible and the overall safety indicators significantly improved in many cases.

This is why R&D tasks are needed in this phase, not only in the long term extrapolation of the component integrity and behavior, but a also in new management strategies at the plant (PLIM), able to address organizational issues, spare part management, staff ageing, component obsolescence, etc, which are typical components of the PLIM (see for example [1]).

The Framework Programme 7 of the EU (FP7 [2] - Council decision 18/6/2006) in the area dedicated to the reactor systems calls for a research effort "to underpin the continued safe operation of all relevant types of existing reactor systems (including fuel cycle facilities), taking into account new challenges such as life-time extension and development of new advanced safety assessment methodologies (both the technical and human element)".

Consequently, the JRC Multi Annual Work Program (MAWP), in the Nuclear Safety "agenda" under the Euratom Program, developed two main tasks addressing the safety of nuclear installations and the nuclear fuel safety, respectively. The former is addressed in the following, being relevant to this context.

This paper provides a short summary of selected results obtained at the JRC under the 7th Framework programme (2007-2010) and summarizes the perceived scientific/technological challenges for FP7 on which JRC proposes to focus, based upon its competencies and skills, having in mind both the European and world-wide context and its potential evolution.

2. The PLIM problem – Definitions and selected EU experience

2.1. Setting the problem

The Plant Life Management (PLIM) problem was raised some years ago when it was clear that technological, safety, regulatory, human and economical issues had to be addressed at once in the overall management of the plant assets [1,2].

It is a fact that new global approaches have been triggered in recent years by a combination of factors such as:

- The generic trend towards plant life extension beyond the original design life, in order to exploit the plant design at the maximum level
- The market economy, which is pushing for a more stringent management of the economic assets
- The detection of significant ageing phenomena which were challenging the original design assumptions
- The need for preservation of the human knowledge in time, particularly in Countries with growing opposition to nuclear expansion
- The more stringent regulatory requirements in terms of safety assessment and monitoring

However, the PLIM models developed in recent years differ one from another because of the national frameworks and therefore a generalization sometimes appear difficult.

Interesting attempts were carried out by the International Atomic Energy Agency with some technical documents and papers [2], to identify common drivers among the different national

programs, but the discipline was never indeed regulated by binding documents to its Member States, by presenting commonly accepted principles, recognized by all the interested parties. Nevertheless, a large number of IAEA documents are available on basic safety concepts that could be relevant to life management programs [6-16].

In particular, a generic misunderstanding still survives in the engineering community among objectives and content of the different programs put in place in the different Countries which developed experience in the PLIM field. Programs such as License Renewal (LR), Long Term Operation (LTO), Plant Life Extension (PLEX), Periodic Safety Review (PSR), Ageing Management Program (AMP), etc. proved to share many technical tasks, but also to meet different objectives and to follow different regulatory frameworks.

The JRC-IE spent some research efforts in last years in the clarification of the many issues addressed by the European Countries' programs and developed some unified models, which received very high consensus in many engineering communities and particularly in the research network of European Countries interested to this discipline, SENUF [5]. A number of scientific papers were also published in order to foster the feedback from the engineering community [17-22].

As outcome of this effort, a list of generic considerations was developed as support to the development of a more unified approach to the common issue of managing the plant assets in time, meeting the highest safety standards:

1. The PLIM program appears the type of program most suitable to address long-lasting safety and economical issues and to present the most comprehensive approach to the plant asset management
2. The PLIM program is neither necessarily related to plant life extension, nor to license extension of any plant. It is a logical framework on which strategic thinking may find the appropriate answers in relation to safety, economy and human asset management.
3. Related programs such as LR, AMP, PSR, each with its own objective, may find in the PLIM framework the answers and the background information that they need to meet their specific objectives; however, they definitely represent separate programs, different from PLIM itself.
4. The PLIM program is crucially based upon a strong integration of many existing programs at the plants, such as asset management, life extension, ageing management, configuration control, predictive maintenance, etc. that share common assumptions and contribute to the same overall objectives.
5. Some special features are required to standard programs and also some specific programs are needed to be in place at NPPs in order to feed a PLIM program adequately. These features/programs creates the pre-conditions for a PLIM program to be successfully applied, such as: the maintenance program should be mostly reliability based, the ISI program should be possibly risk informed, a fuel management program should be in place, an outage optimization program should make available all data in relation to the economic implications of the outage duration, a knowledge management program should be in place, public acceptance analysis should be available, etc.
6. In order to manage the very complex structure of a PLIM program, specialized software tools and databases are highly recommendable, also for the management of the daily work, due to the huge amount of data to be processed and stored.

One example of approach to PLIM is shown in Fig.1, taken from the Finnish practice [5].

In this example, the PLIM program aims at demonstrating that during the design and possibly the extended plant operational life [3]:

1. The safety and ageing analysis remain valid and could be projected to the end of intended operational lifetime;
2. The effects of ageing on the intended safety function(s) are adequately managed all along the envisaged lifetime;
3. There is a mechanism to deal with unexpected ageing mechanisms that can surface.
4. There is a pro-active process for decision making, also involving non-safety equipments significant to plant availability
5. There is a program to manage human resources and knowledge
6. Plant economic assets are properly managed

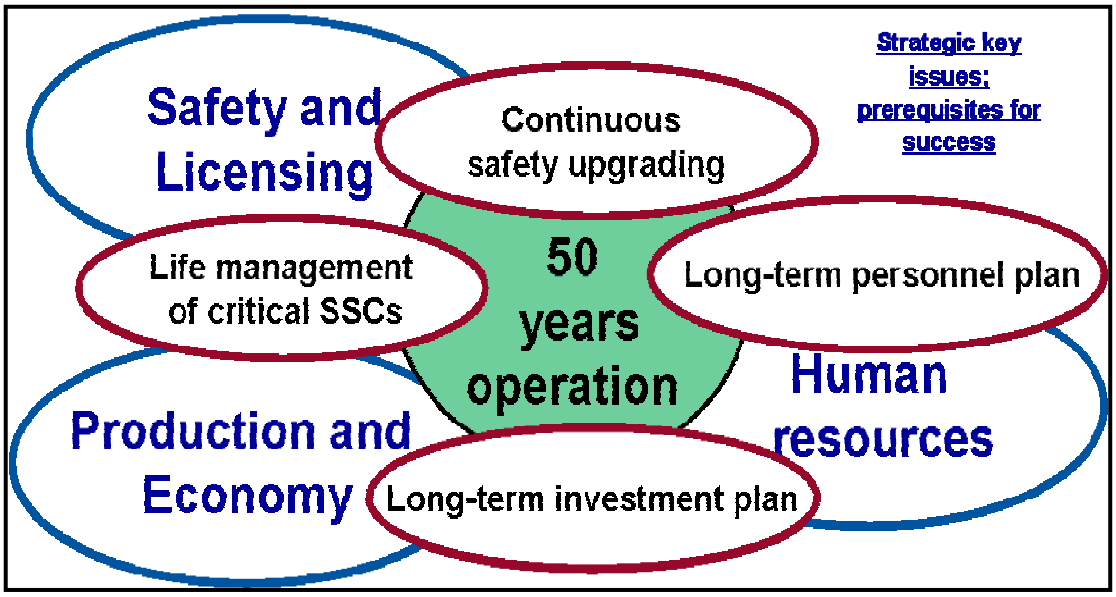

Fig. 1. Examples of approach to component life management [5].

In this framework some programs play the most crucial role, namely:

- The ageing management program (AMP)
- The maintenance, surveillance and inspection (MS&I) program
- The knowledge management program (KM)
- The asset management program
- Major plant upgrading programs (if in place, such as power uprating, modernization, etc.)

In particular, the AMP is a transversal program [3] cross-cutting maintenance, surveillance, and in service inspection programs and other operation related programs. It addresses ageing mechanisms prevention, control and consequence mitigation. The operating experience shows that active and short-lived SSC are in general addressed by existing maintenance programs. Conversely, the performance and safety margins of the passive long-lived SSC are assumed to be guaranteed by design. However, the analysis of the operating experience showed that unforeseen ageing phenomena may occur either because of shortcomings in design, manufacturing or by operating errors, calling for a refined, self-improving program.

The maintenance program for a nuclear power plant covers all preventive and remedial measures that are necessary to detect and mitigate degradation of a functioning SSC or to restore to an acceptable level the performance of design functions of a failed SSC [15]. In this sense, the integration with surveillance and in-service inspection is crucial, as the most advanced types of maintenance do integrate the three programs which have a common objective: to ensure that the plant is operated in accordance with the design assumptions and within the operational limit and conditions. Therefore in the following, MS&I will address all the three programs in an integrated form.

It is clear that the MS&I program is a crucial part of PLIM, being by far the main contributor to both operating costs (after operation) and operation planning.
However, in order to support a PLIM framework, MS&I should have a specific list of attributes, making both safety assessment and cost optimization possible.
In conclusion, the implementation of an AMP and a predictive MS&I (maintenance, surveillance and inspection) program is definitely a condition for the operation within the limits of design or licensed lifetime and is a condition for a PLIM as well.

KM and asset management are traditionally isolated programs from MS&I and AMP. PLIM recognizes the need for their integration and sets an overall optimization framework.

2.2. Countries' generic experience with PLIM

Thanks to the large survey on Countries' practice carried out at the JRC [5], also through the organization of many international events, it was possible to summarize the most relevant aspects of some Countries' practice in the field of PLIM, with special emphasis to the relationship with other programs running at the EU Countries.

- The USA, Canada, Spain and some other Countries accumulated a valuable experience in recent years in PLIM issues and related programs. The interest of the international community of plant operators on reliability based approaches to PLIM and maintenance optimization in particular is definitely growing. The US approach is codified in the INPO AP-913 [23], closely followed by some Europeans.
- Other European Countries are more in favor of integrated approaches to Plant Life, such as Finland, with a more explicit control of the component degradation and a clear day-to-day basis for the decision makers on replacement, maintenance and operation.
- In many European Countries, PLIM is accompanied with a PSR program. The combination is not surprising, as PLIM is typically a utility driven program, while PSR is driven by the Safety Authority. Many technical tasks (those safety related) are similar, but objectives, time frame and regulatory implications are definitely different.
- Some pre-conditions for PLIM in many countries include maintenance optimization, RI-ISI, fuel management, outage optimization, knowledge management, public acceptance, seismic upgrading, etc. making sometimes the program very complex. In all cases they are assisted by complex software tools and databases, also for the management of the daily work.
- The relationship among PLIM and the other programs running at the NPPs is now quite clear in the EU Countries: well known programs such as component integrity, ageing management (AMP), life extension (PLEX), periodic Safety Review (PSR) and Plant Life Management (PLIM) are in fact well connected, but definitely not interchangeable. Despite of the different names, mostly derived from the national regulatory and engineering frameworks, there is a clear hierarchy among them. In particular, component integrity is a basic science dealing with the failure modes of the different components, their detection and their control. The AMP is an operational program in place at any NPP, which integrates maintenance, ISI and organizational issues aiming at controlling the component degradation. PLiM addresses safety as well as economics, knowledge management as well as decision making, and provides an overall framework to keep the whole plant in a safe and economically sustainable condition.

2.3. PLIM at the design stage for the new reactors in the EU: AP1000 and EPR

The comparison of the approach to PLIM among other technology areas suggests some interesting considerations. For example, in the aerospace industry the maintenance program (considered one of the most crucial component in PLIM) is optimized at the design phase, due to the large number of identical aircrafts; in the nuclear practice, time is needed to accumulate statistics and to develop confidence in the optimization procedures.

However, it is common judgment that PLIM should be applied since the design phase of the NPPs, possibly based on the lesson learnt from the operating fleets. In this sense, practice could be assimilated to that in other industrial technologies, as mentioned above.

Up to today, the development of standards and design rules for the new generation reactors is lagging behind. This delay also makes the certification of the new reactors quite difficult. At the same time, also the safety assessment methods and the QA rules for construction and operation need to be revised. The role of both licensee and regulators is still to be defined in many countries.

This generic statement is applicable also to the PLIM relevant aspects which do deserve an early understanding at the design phase. In particular, ageing considerations should be addressed since the design stage, for example providing inspectability, replaceability, and access to the most sensitive components and a solid basis for the control of their degradation.

Ageing should also be addressed since the beginning of operation in order to make available a broad range of data for trending and optimization.

In particular, the following PLIM/ageing relevant issues should be addressed in the pre-design or pre-licensing phase of new reactors:

- Choice of materials
- Major drawings
- Operating conditions
- Collection of relevant data
- Monitoring, surveillance
- ISI : inspectability / access
- Radiation protection of workers

For example, in the Areva/EPR, the following design actions are taken in order to improve the PLIM performance [24]:

- Accessibility of the reactor building during normal operation to perform maintenance tasks and inspections, but also to start refueling seven days before reactor shutdown and to continue demobilization three days after reactor restart
- Improved main coolant loop cool down, depressurization and vessel head opening after shutdown bringing the standard outage time to 16 days.
- Very low radiation level to workers
- Some modifications in SG or Pressurizer or RVI
- Improvements of nozzles and tees for thermal fatigue reduction
- In general FU factors have to be less than 0.5 for limited ISI in Operation

In the Westinghouse AP1000 [25] the following design actions intend to address the PLIM issues:

- Large use of passive features, also to reduce MS&I tasks
- Variable speed in the reactor coolant pump, to shorten startup and shutdown
- Special design of the digital I&C which reduces the I&C surveillance testing
- Large use of component standardization to reduce parts inventory and training
- Built-in testing capabilities is provided for many critical components
- Easy access for MS&I tasks and lifting devices
- Few nuclear grade equipment
- Very low radiation level to workers

3. The maintenance program in the Long Term Operation perspective: why PLIM needs an optimized maintenance program?

In 2003 the JRC-IE carried out a preliminary investigation of the priorities in the European Countries in relation to the PLIM programs. The conclusion was that there is a generic convincement in the nuclear community that the maintenance program should have specific attributes in order to support a long term operation (LTO/PLEX) program for the plant. In this sense, the International Standards (e.g. the IAEA), but also the national experience of USA, Spain, Hungary, etc. proved a confirmation of this statement. More specifically, the maintenance programs based on standard preventive maintenance (time based), not oriented to the monitoring of its effectiveness and to the prediction of the damage, are not considered suitable to support the LTO/PLEX programs. Crucial attributes for maintenance programs in order to support LTO/PLEX are considered: the verification of the performance goals, the root cause analysis of failures, the feedback from maintenance to the ISI program, and the feedback on the OLC (operational limits and conditions).

All Countries implementing an LTO program applied extensive modifications to their requirements on maintenance at first step, setting up mechanisms to monitor the effectiveness of the maintenance activities. In particular, the following features are believed to be indispensable for a maintenance program in a PLIM framework:

1) Monitor the performance of the SSCs (structures, systems and components) which may have impact on safety during all operational statuses of the plants;
2) Assess and manage the risk that may result from the proposed maintenance activities in terms of planning, prioritization, and scheduling.

In order to implement these requirements, some issues have to be addressed, namely:

1) The identification of the **scope** of the condition based maintenance rules: typically the Countries choose the safety related SSCs, SSCs which mitigates accidents or transients, SSCs interacting with safety related SSCs, and SSCs that could cause scram or actuation of safety related systems. Therefore, many non-safety related SSCs may see the application of such maintenance rules, with augmented efforts in monitoring their performance and planning their reparation.
2) The setting of the performance **goals** for every component in the scope of the maintenance rules, ranking them according to their risk significance for the plant safety. This task may end up very challenging as, when industry experience is not available, either dedicated PSA tasks have to be developed (with special requirements on PSA quality) or special qualification programs for the evaluation of the component reliability.
3) The performance **monitoring** techniques for the very broad categories of structures systems and components in the scope of the rules.
4) The assessment of the safety **during implementation** of maintenance actions.
5) The **feedback** from the result of the monitoring of the component reliability back into the inspection, surveillance and maintenance procedures. Root cause analysis, equipment performance trend analysis and corrective actions have to be developed on a case by case basis.

In this sense for example the experience of the USA and Spain (where a LTO/PLEX program is well established), Hungary, and Finland (where a PLIM model is in place at the Loviisa NPP) are a confirmation of this generic statement: all these countries modified their regulatory requirements or practice on maintenance, in the direction mentioned above, as one of the preconditions for the LTO/PLEX of their plants.

The SENUF WG at the JRC carried out a detailed analysis on the experience of some of the above mentioned countries on the interfaces between LTO/PLEX and maintenance programs, as a background for the development of a state-of-art approach to modern maintenance programs. The most relevant conclusions are summarized in the following chapters.

As summary of the Country practice in the field of MOPT, a quick questionnaire was run at one of the above mentioned events organized in 2007 on maintenance optimization issues. The result is summarized in the following table 1.

Table 1 – Summary of the experience in selected European Countries on specific PLIM related issues

Country	Type of non-time based M	Its scope (n.of systems)	M Optimisation process in place	Cost issues included?	Reduction in M cost after M	in CDF	in outage duration	SFW used for M planning/optimisation	Network of spare parts	Indicators on M	Risk monitor available
RF – RBMK100			plans					Desna / Primavera	Utility level	10	
Hungary	CBM	5%	CBM	yes	5%	no	40 - 28	Passport / ?	No	10	
Slovakia EMO	CBM	<10%	RCM - CBM	yes	10-15%	n.a.	45 - 26	Arsoz / Primavera	With Bohunice with big parts	30	Yes on living PSA
Ukraine			plans	plans				Primavera	no	no	
BG – VVER1000	diagnostic	Circ. Pumps, containment, etc.	plans	no			51 - 45	Primavera	With Temelin	Not sistematically	no
CR - Dukovany	CBM		Adaptive maintenance model,RCM, cost benefit, use of PSA etc.	yes	?		Overall decrease 48% in outages duration From 2 to 3 types	Passport / Primavera / MNT Graph, use of Safety monitor system		yes	Yes on living PSA
Cernavoda	CBM	50% (all safety related)	CBM analysis	No, plans			32 – 22, plans for 20 (every two	Passport	Few cases with Candu owners	10	Yes based on living PSA
Lithuania	CBM	<10%	CBM analysis	no	10%	no	10%	Fobos (IFS) / Primavera	no	~15	Yes, only for pipes (300 mm), main circulation circuits

In addition to that, Ukrainian, Slovenian, Czech, Russian representatives expressed in many occasions [4] their interest to adopt a MR-like approach in their Countries, even starting on a voluntary bases, most probably closer to the ”equipment reliability” model (INPO AP-913, [36]). Many of them already created some training centers which are developing procedures in this direction.
In conclusion, in relation to the operating cost reduction as a consequence of a kind of MOPT , the following reductions [4] in maintenance costs/tasks were recorded:

- In SWE, 10 - 20% of the effort, especially for I&C calibration intervals
- In SP, 20% in work, 30% in number of tasks
- In HUN, expected, not quantified
- In CZ, 30% on a restricted number of systems selected for a benchmark (according to the implemented Phare project in Dukovany NPP)
- In SKR, expected, not quantified.

It was noted that the “equipment reliability” program is not mandatory in most of the Countries (including the US). However, it is gaining growing interest for its systematic approach to the management of the plant safety. In particular, the correlation among the many existing safety related programs and the consistent classification of items (important, critical, run-to-failure) seems to be very attractive and practical.
The main goals of the maintenance program in the framework of PLIM can be summarized as in the following:

- Assure plant safety
- Maintain optimal plant availability
- Optimize operation and maintenance costs
- Assure and develop industrial safety
- Comply with codes, legislation and regulation
- Decrease failures of safety and availability critical components
- Find and implement performance improvements
- Increase the reliability and maintainability of the machinery and the performance of maintenance support
- Increase the economical service life of equipment and plant

A precondition for a MS&I program to be effectively inserted into a PLIM architecture is that the maintenance program is continuously optimized on the basis of the risk importance of any structure, system an component (SSC), controlling the overall reliability of operation and preventing functional failures.

One way of achieving this goal is the implementation of a rigorous SSC classification and the selection of the most appropriate maintenance tasks (and periodicity) for each type of equipment. The classification should be based on the importance to safety and operation, requirements of nuclear regulations, replacement costs, environmental risks and maintenance experience. Classification can be changed based on operation and maintenance experience.

The maintenance unit should be responsible for executing and planning normal maintenance work, carrying out the work in refurbishment and investment projects, carrying out inspections and periodical tests, managing spare parts, organizing personnel training and enforcing an appropriate QA system.

4. A unified proposal for a PLIM model integrating Maintenance Optimization

4.1. Introduction

Previous sections highlighted the main issues behind the development of a PLIM model, its main features and the experience of few European and non-European Countries in this effort.
As a consequence, the JRC-IE researchers developed a preliminary version of a new PLIM model that they believe could significantly improve the performance of the European plants. A first draft of this model is available at [1].

The model was subsequently validated at one European plant that is believed to have one of the most advanced PLIM model in place. As a result of the validation carried out at Loviisa NPP, a new model was developed and is shortly described in the following.

4.2. PLIM objectives

PLIM can be defined as a program (or even a combination of programs and procedures) aiming at a safe and cost-effective operation of a nuclear power plant in the longest possible time period.
In this sense, it represents a framework for optimized, day-to-day, decision making aiming at a plant long-term operation with optimal utilization of resources.
In other words, PLIM objective is the development of a consistent framework program at the plant which enables the plant

- to produce electricity in a safe and responsible way by continuously improving the power plant operation and safety
- to secure an efficient generation portfolio

This objective is typically achieved with coordination of some key programs at the plant, such as: operation, asset management, maintenance surveillance and inspection (MS&I), ageing management, knowledge management, and nuclear safety.

4.3. Approach to PLIM

In order to achieve the goals set up in the previous chapter, the PLIM program has to consider the following main components (see Fig.2):

1. Nuclear safety and licensing
2. Production and economy (including fuel and waste management)
3. Human resources

The long term investment plan is the basic tool for managing the investment portfolio where all the technical programs provide input.
The generic PLIM structure is the result of the integration of selected existing programs at the plant and the development of suitable links and feedback loops.

In particular the following programs are directly coordinated by PLIM:

- Maintenance, surveillance and inspection (MS&I), including control of human factors
- Ageing management, component obsolescence and plant configuration control
- Knowledge management
- Asset management and investment planning

Plant modernization, power uprating, fuel management may also be part of PLIM, but they are not necessarily implemented at all plants.

This concept is described in Fig.2, where the four main components of PLIM are highlighted in the central program, the input and the output are in the vertical lines and other programs are listed in the lateral boxes.

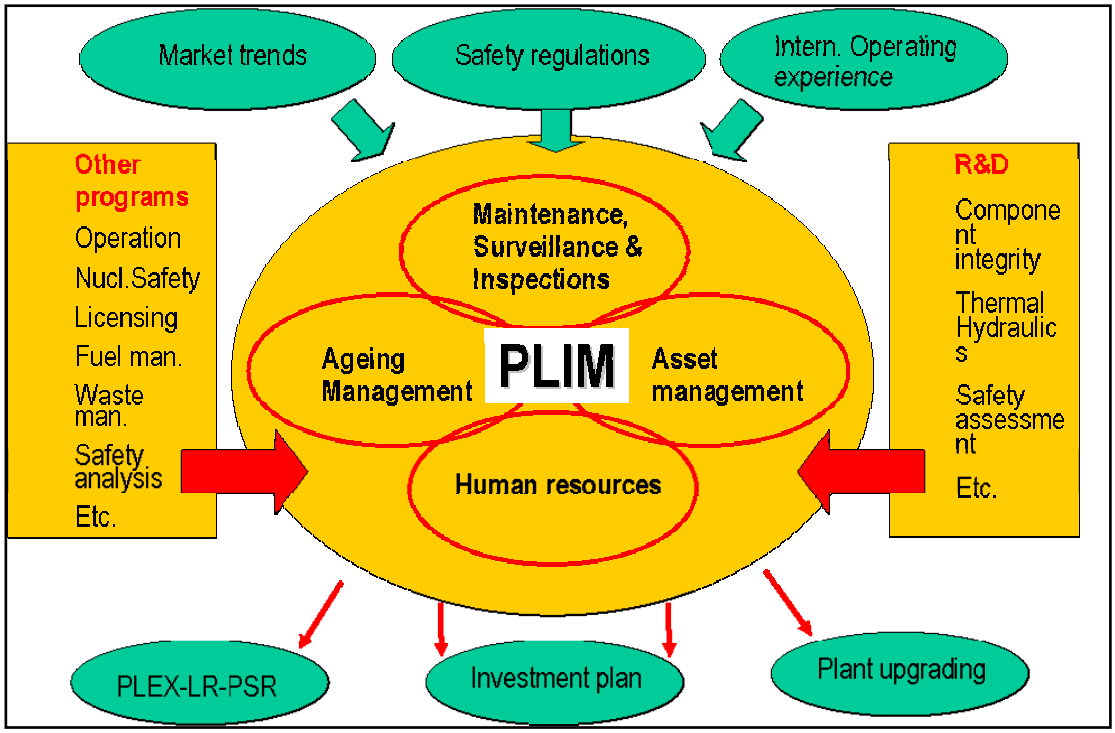

Fig. 2. Approach to PLIM and interfaces with related programs

These programs should also meet specific pre-conditions on their main features, as discussed above and summarized in Fig.3.

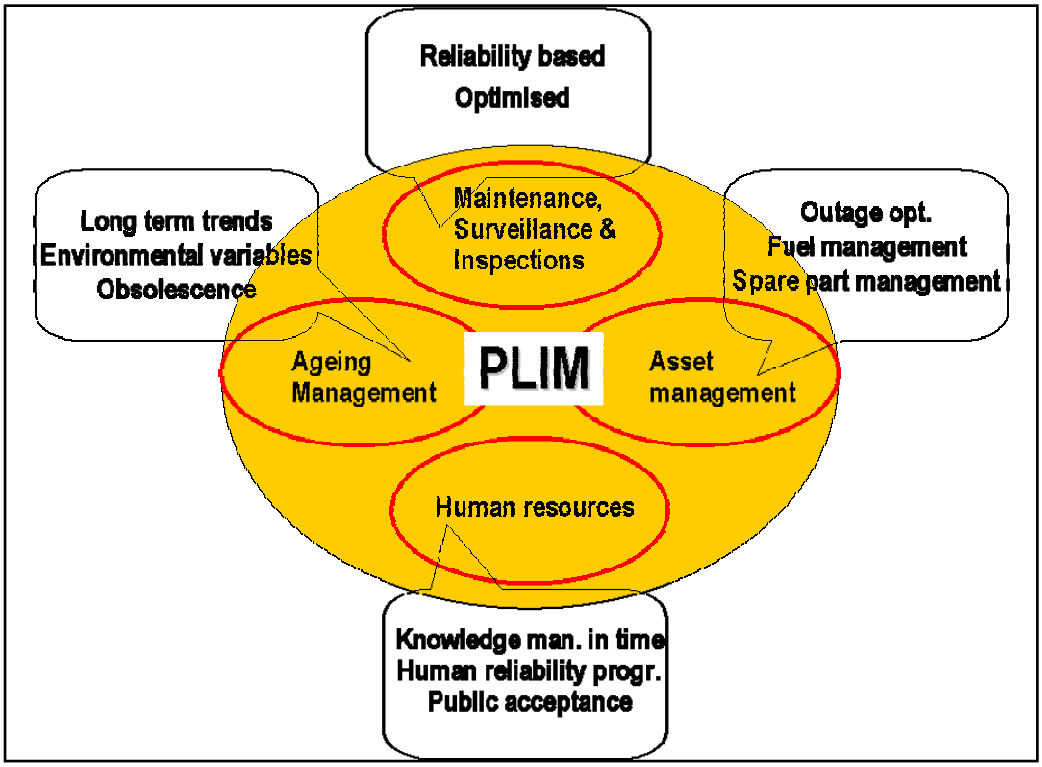

Fig.3. Preconditions for the key programs to be part of PLIM

Other programs represent a generic background for PLIM, and exchange data with PLIM, but they are not explicitly part of it, such as: operation, nuclear safety, fuel management, waste management, licensing (including the continuous updating of the Safety Analysis Report), engineering, etc.

At last, important programs may be based upon PLIM, but they are not part of it, such as: plant life extension, license renewal, periodic safety review, plant upgrading (including power uprating), public acceptance, etc.

From the technical standpoint, the approach to plant life management consists of:

- Identification of critical systems, structures and components (SSCs) from the standpoint of the plant operation and safety
- Classification of the identified SSCs
- Identification of loadings and ageing mechanisms
- Development of method for the lifetime prediction
- Identification and implementation of applicable ageing countermeasures
- Feedback to MS&I programs and other relevant programs
- Development of the investment planning

4.4. PLIM Scope - Component classification

A consistent application of PLIM suggests the use of a dedicated component classification, where safety, availability and cost issues contribute to form the criteria.

All structures, systems and components at the plant, regardless of their safety relevance, should be covered by such classification.

According to the classification, a suitable grading of measures may be applied and therefore different levels of MS&I and AMP, economic analysis etc. may be assigned.

A proposal (see also Fig.20 from [5]) may group different classes as in the following:

- **Class A**: critical components and structures directly limiting the plant life with their availability/integrity, non replaceable. Example: reactor pressure vessel, steam generator, pressurizer, main coolant pump, containment structures. Example of MS&I strategy: full scope monitoring and analysis of the degradation
- **Class B**: critical components, systems and structures from the standpoint of their importance to safety and their cost of replacement/reparation. Examples: primary circuit, high and low pressure safety injection systems, feedwater system, condensers, turbine, generators, diesels. Example of MS&I strategy: condition based MS&I
- **Class C**: sensitive components, systems and structures. Examples: nuclear intermediate cooling, sprinkler, drainage and vents, main steam line, residual heat removal, circulating and service water systems, condenser cooling system. Example of MS&I strategy: preventive (time-based) MS&I
- **Class D**: other components and structures. Example: condenser purification system, auxiliary boiler plant, drinking water supply, sewerage. Example of MS&I strategy: run-to-failure

It is noted that such approach is still quite heterogeneous, as it mixes up components, systems and special equipment. Therefore the proposed classification may be reviewed to provide a more homogeneous approach that would make the interfaces with the maintenance classification or spare part classification much easier and traceable, because more homogeneous.

For components in classes A,B,C, a sort of component "health certificate" is recommended for continuous review and upgrading by the system engineers. The certificate should make reference to the design basis and should collect the results from the AMP, the operation and the ISI programs, including the pending issues detected by previous tasks.

4.5. The organizational structure that supports the PLIM – The system engineers

The PLIM program requires important changes in the traditional plant organization. In particular, the following preparatory organizational tasks should be implemented:

- Development of a PLIM supervision and coordination Unit
- Nomination of System Engineers, full time in charge of selected systems, especially for Class A
- Identification of research and engineering specialists in different disciplines at the TSO organization, ready to cooperate with the system engineers to address methodological issues, interpretation of results, interfaces with the scientific and engineering community, etc.

System engineers are the main interpreters of the PLIM program at the plant; they should be responsible for the life management of a particular system, structure or component. They represent the system "owners". These engineers are typically responsible for the following tasks [5]:

- Preparation and control of inspection, monitoring and maintenance activities related to life management of systems; structures and components critical to safety
- Detection and assessment of aging mechanisms and effects
- Preparation and implementation of improvements in the field of proactive maintenance.
- Maintain and populate the life management system
- Update the information in the long range planning system
- Keep updated the records of the component/system health status in the reference documentation system
- Guarantee the reporting

Some interfaces between the system engineers and other groups/depts. are particularly important in the PLIM framework, namely

1. The operators: plant TS and OLC may be discussed and changed (with the due authorizations) as a consequence of detailed analysis of the operating experience and of the MS&I outcome.
2. The MS&I technicians: objectives, periodicity, scope and other attributes of the programs may be agreed and modified
3. The Safety specialists (either on site or at the TSO): they own the plant safety analysis and therefore all the acceptance criteria for ageing and degradation should be agreed and reviewed with them
4. The technical support group: the decision to repair/replace/maintain a component or structure is taken jointly and approved by the management group of the PLIM.

5. Conclusions

The European Commission, especially in the framework of the EURATOM programme, identified specific R&D priorities to be mainly addressed by “direct actions” managed by the Joint Research Centre (JRC) in the field of the Plant Life Management of its nuclear facilities. The best chance for implementation is given by the newly launched Framework Programme 7 (FP7), where large coverage is given also to the nuclear safety issues. The activities under the current 7th FP (2007-2011) combine continued effort in the area of component structural integrity with several new initiatives in the areas of maintenance optimization and risk-informed approaches.

The paper provides an analysis of the research actions already in progress at the European Commission-Joint Research Center (EC-JRC) in the specific field of maintenance optimization, through the most recent results of the research on a unified PLIM model in the EU, and intends to provide a basis for a review of the research priorities.

From the preliminary results, a confirmation can be drawn on the unique capability of the EC for coordinating European R&D in support of harmonized best practices for plant life management. The continuous support of the network participants (increased in some cases of 50% in the year 2007) show that the selected activities do reflect the priorities of the stakeholders, in particular plant operators and national safety authorities, coherent with the JRCs mandate under the Euratom framework programmes.

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