Life Cycle Management Planning Sourcebooks—Overview Report

Technical Report

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REPORT SUMMARY

With the electric power industry largely market driven, nuclear plants are addressing long-term equipment reliability risk to stakeholders by applying life cycle management (LCM) to manage aging degradation and obsolescence of important systems, structures, and components (SSCs). This report describes how "Life Cycle Management Planning Sourcebooks" can reduce substantially the cost of applying the LCM process to the many important types of SSCs in operating plants.

Background
EPRI has developed an LCM process and supporting software application (1000806), and the Institute of Nuclear Power Operations (INPO) has integrated LCM into its equipment reliability industry guidance. Since then, plants have begun to prepare LCM plans for SSCs important to reliability, availability, and profitability. An LCM plan combines industry experience and plant-specific historical performance data to provide an optimum maintenance plan, schedule, and cost profile for the plant's remaining operating term. Industry's cost for producing such plans can be reduced if LCM planners have an "LCM Sourcebook" of generic industry performance data for each of the important SSCs they address. The general objective of EPRI's LCM sourcebook effort is to provide system engineers with generic foundation information, data, and guidance they can use to generate long-term equipment reliability plans for plant SSCs (aging and obsolescence management plans optimized in terms of plant performance and financial risk).

Objective
• To help future LCM Sourcebook authors prepare SSC-specific LCM sourcebooks that are useful industry-wide, technically sound, and as complete and uniform in format as appropriate and practicable.

• To show future LCM planners how to use sourcebook information and data for preparing plant-specific SSC LCM plans

Approach
Researchers first developed the concept of LCM sourcebooks by specifying a typical sourcebook's format and content, which were reviewed by EPRI LCM Technology Program utility advisors. Then work began on two prototype sourcebooks, one for an active SSC (instrument air system) and the other for a passive SSC (buried piping). These prototype sourcebooks are intended to serve as examples for future preparation of additional LCM sourcebooks. Only when substantial progress had been made on the prototypes was work begun on preparing this overview report.

Results

Part of this overview report consists of format and content guidelines for SSC-specific sourcebooks being prepared by future sourcebook authors. Included are ideas that, once customized for a specific SSC type, can be included in the sourcebook by its author. The more sourcebooks have the same "look and feel," the easier it will be for LCM planners to use them. The other part of this overview consists of a manual for LCM planners in operating plants. It contains detailed guidance on adopting or adapting information in the sourcebook to plant-specific LCM plans. Also included in the overview report are typical tables of contents for both an SSC-specific LCM sourcebook and a plant-specific LCM plan.

EPRI Perspective

This LCM sourcebook overview is important because it will be used in coming years by several SSC experts writing sourcebooks and by many plant engineers preparing LCM plans for their equipment. Benefits include up-front expert input for each type of SSC and the saving in effort compared with each LCM planner starting from scratch. EPRI, together with the DOE Nuclear Energy Performance Optimization (NEPO) program and utility collaborators, plans to sponsor additional LCM sourcebooks for as many important SSC types as may be useful to operating plants (perhaps 30 to 40) and as are allowed by industry-wide resources. The process of using sourcebooks as an aid in preparing LCM plans will improve as the industry gains experience. EPRI welcomes constructive feedback from users and plans to incorporate lessons learned in future revisions of the overview report and LCM sourcebooks. The two prototype LCM sourcebooks prepared in parallel with this overview are EPRI reports 1006609 and 1006616.

Keywords

Life cycle management
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CONTENTS

1 **INTRODUCTION 1-1**
1.1 Background 1-1
1.2 Objectives 1-2
1.3 Approach 1-2
1.4 Selection of Sourcebook Candidate SSCs 1-3
1.5 Overview Report Use and Organization 1-4
1.5.1 Guidance for Future Sourcebook Authors 1-4
1.5.2 Guidance for Preparers of Plant-Specific LCM Plans 1-5

2 **PREPARING LCM SOURCEBOOKS—FORMAT AND CONTENT 2-1**
2.1 Management Summary (Sourcebook Section 1.0) 2-1
2.2 LCM Sourcebook Introduction (Sourcebook Section 2) 2-2
2.2.1 Purpose of LCM Sourcebook (Sourcebook Section 2.1) 2-2
2.2.2 Relationship of Sourcebook to LCM Process (Sourcebook Section 2.2) 2-2
2.2.3 Basis for Selection of [SSC] for LCM Sourcebook (Sourcebook Section 2.3) 2-2
2.3 Background Information for SSC Type (Sourcebook Section 3.0) 2-3
2.4 Historical Performance Data from Industry Operating Experience and Performance History (Sourcebook Section 4.0) 2-4
2.4.1 Nuclear Industry Experience (Sourcebook Section 4.1) 2-4
2.4.2 Available Databases For Generic Data 2-5
2.4.3 Interrogation of Available Databases and Analysis of the Data 2-6
2.4.4 Review of Generic Communications (Sourcebook Section 4.2) 2-6
2.4.5 Review Maintenance Rule Performance Parameters 2-7
2.4.6 Assessment of EPRI PM Basis 2-7
2.4.7 Generic Performance Reviews 2-7
2.4.8 Aging Matrix and Aging Management Assessment (Sourcebook Section 6.1) 2-8
2.4.9 Technical Obsolescence Issues (Sourcebook Section 6.3) 2-9
2.5 Alternative LCM Plans (Sourcebook Section 7) 2-11

2.5.1 Potential Plant Operating Strategies 2-11
2.5.2 Development of Alternative LCM Plans 2-11
2.6 Guidance for Estimating Future Failure Rates (Sourcebook Section 8) 2-12
2.7 References and Information Sources (Sourcebook Section 10)..................................2-13

3 APPLYING GENERIC LCM SOURCEBOOK INFORMATION TO PLANT-SPECIFIC LCM PLANNING 3-1

3.1 Resource Planning for LCM Planning 3-1
3.2 Availability of Data Sources and Databases 3-2
3.3 Collecting Plant-Specific Information 3-3
3.4 Comparison of Generic Data to Plant-Specific Data and Conditions 3-12
3.5 Identifying Plant-Specific Aging Mechanisms and Conditions (Outliers).......................3-12
3.6 Comparing and Evaluating In-Plant Obsolescence Situations 3-13
3.7 Establishing Plant Unique Variations to Generic LCM Alternatives 3-13
3.8 Collecting Data for Economic Evaluation 3-14
3.8.1 Plant Outage Data 3-15
3.8.2 Data on Existing Preventive or Predictive Maintenance Programs 3-15
3.8.3 Data on Corrective Maintenance Tasks 3-16
3.8.4 Data for Proposed Preventive and Predictive Maintenance Tasks 3-16
3.8.5 Data for Proposed Equipment Replacement Tasks...3-17
3.8.6 Data for Proposed Elimination of Existing Maintenance Tasks 3-17
3.8.7 Regulatory, Licensing and Administrative Cost Data 3-17
3.9 How to Draw Conclusions for Planning Decisions...3-18
3.10 SSC-Level Versus Plant-Level LCM Planning 3-18

4 REFERENCES 4-1

A STANDARD TABLE OF CONTENTS FOR AN LCM SOURCEBOOK A-1

B TYPICAL TABLE OF CONTENTS FOR AN LCM PLAN B-1

C ACRONYMS C-1

LIST OF FIGURES

Figure 1-1 LCM Planning Flowchart – SSC Categorization and Selection (Indicated Sections refer to Appendix A) 1-6

Figure 1-2 LCM Planning Flowchart – Technical and Economic Evaluation (Indicated Sections refer to Appendix A) 1-7

Figure 1-3 LCM Planning Flowchart – Implementation 1-8

LIST OF TABLES

Table 2-1 SSC Contribution to Total Plant Faults (1987-1995 Data [6]) 2-5
Table 2-2 Application of Obsolescence Evaluation Criteria 2-10
Table 3-1 Basic Plant Information 3-5
Table 3-2 Economic and Financial Data.. 3-6
Table 3-3 System Engineer Interview.. 3-7
Table 3-4 Listing of SSC LCM Documentation 3-8
Table 3-5 Aging Management Maintenance Tasks 3-8
Table 3-6 Maintenance History Review of the SSC... 3-9
Table 3-7 Listing of Typical Plant PM Programs (Use this as a checklist to identify plant specific activities for the SSC) 3-10
Table 3-8 Inventory of SSC Maintenance Tasks and Parameters 3-11

1
INTRODUCTION

1.1 Background

Life cycle management (LCM) is the process by which nuclear power plants integrate operations, maintenance, engineering, regulatory, environmental, and economic planning activities in a manner that:

1. manages plant condition (aging and obsolescence),

2. optimizes operating life (including the options of early retirement and license renewal), and

3. maximizes plant value while maintaining safety.

An LCM plan is a long-range plan for preventive maintenance, replacement, refurbishment and/or redesign of an SSC important to safety and reliability that optimizes the SSC's contribution to plant value. A plan almost always applies to an SSC in an individual unit or plant, but if the benefits of standardization are a goal, it can apply to some or all SSCs of a specific type in a fleet of plants. The main activity involved with LCM is producing a long-range plan for preventive maintenance, replacement, refurbishment and/or redesign of an SSC important to safety and reliability that optimizes the SSC's contribution to plant value. An LCM plan consists of maintenance (and capital improvement) activities, their schedules, and their yearly costs. LCM planning allows rigorous assessment of strategic options such as license renewal, power uprating or early decommissioning. Although LCM focuses on aging of passive SSCs, it also addresses aging management of passive parts of active components and obsolescence of systems and components.

In January of 2001, EPRI published Report Number 1000806, "Demonstration of Life Cycle Management Planning for Systems, Structures, and Components -- with Pilot Applications at Oconee and Prairie Island Nuclear Stations" [1]. That report includes a detailed description of an LCM planning process (including an SSC screening/selection process) and summaries of six LCM plans for two plants. The six LCM Plans consisted of buried piping, buried cable, and main turbine for Oconee and 480VAC distribution, instrument air and nuclear instrumentation systems for Prairie Island.

In the next phase of the LCM planning project, two additional utilities, South Carolina Electric and Gas (SCE&G) and Wolf Creek Operating Corporation (WCNOP) participated. Each selected three systems for LCM planning. The six additional SSCs are the main condenser, chilled water system, and radiation monitoring system for VC Summer [2] and the reactor protection system, emergency diesel generators, and main steam and feedwater isolation valves for Wolf Creek Generating Station [3].

In generating these initial twelve LCM plans, it became clear that there are a host of common elements in the LCM planning process that can be captured in a generic form and that are transportable among BWR and PWR plants, thus avoiding duplication of the need for the same research by each plant. Additionally, it was recognized that a good part of the research conducted for the pilot systems was not only applicable to the plant, but had substantial generic value that needed to be captured. These considerations gave rise to the concept of SSC-specific "LCM Sourcebooks". An LCM Sourcebook is a compilation of the generic information, data, and guidance an engineer typically needs to produce a plant-specific LCM plan for an SSC (it is more of a reference manual than a technical treatise). A sourcebook will enable plant engineers to develop a plant- specific plan with substantially less effort than if they had to start from scratch. Using this sourcebook approach, the engineer need only add plant-specific data and information to complete an economic evaluation and LCM plan for all the important SSCs in the plant.

This Overview Report provides both a roadmap for future LCM planners (plant engineers or expert consultants) and guidance for consistent format and content to future LCM Sourcebook authors. The Overview Report documents generic information and guidance applicable to all LCM Sourcebooks.

1.2 Objectives

The ultimate objective is to provide the industry with a compilation of existing generic "foundation" information and data useful as a starting point for plant-specific LCM planning for a wide range of important SSC types in operating plants. The more specific objectives of this overview report are to provide:

- Background, purpose and content of SSC-specific LCM Sourcebooks
- Guidance to future LCM Sourcebook authors for producing LCM Sourcebooks that are useful industry-wide, technically sound, and as complete and uniform in format as appropriate and practicable
- Guidance to future LCM planners on how to use the foundation information and data in a sourcebook for generating plant-specific SSC LCM plans, thereby significantly reducing the cost to industry for achieving the benefits of LCM

1.3 Approach

This Overview Report was prepared by the researchers who contributed to establishing the EPRI LCM process and prepared the majority of the twelve EPRI LCM plans. An attempt was made to achieve, through review and comment, an EPRI member utility consensus on the desired format and content of LCM Sourcebooks. This Overview Report sets forth the style and process of the sourcebooks and provides the required guidance of how to use the foundation information to prepare plant-specific LCM plans. It furthermore provides a link between the Generic LCM

Planning Demonstration Report [1] and the SSC-specific sourcebooks. Lastly, the report documents generic information applicable across the SSC specific sourcebooks.

Although the LCM report [1] describes two economic LCM planning software applications (LcmPLATO and LcmVALUE), LCM Sourcebooks do not assume that a particular software will be used to carry out plant-specific LCM planning. LCM planners will be able to benefit from sourcebook information regardless of the tools they employ for LCM planning efforts.

In parallel, two prototype LCM Sourcebooks were prepared, one for an active component (Instrument Air System - IAS [4]) and the other for a passive component (Buried Piping [5]). These prototype sourcebooks are intended to serve as examples for future preparation of additional LCM Sourcebooks. It is planned to prepare additional LCM Sourcebooks for as many major SSC types as may be useful to operating plants (perhaps 30 to 40) and as allowed by industry-wide resources.

1.4 Selection of Sourcebook Candidate SSCs

The two prototype SSC specific Sourcebooks (IAS and Buried Piping) were chosen by the EPRI LCM Working Group, consisting of representatives from the four LCM Demonstration sponsor plants. Key considerations in the selection included

- generic applicability of an SSC type to BWR and PWR plants,
- availability of an underlying[1] LCM plan, which reduces the need for and expense of new research,
- desirability of having a representative of both active and passive SSCs and,
- relative importance of an SSC with respect to plant operation and maintenance.

To identify which additional SSC LCM sourcebooks should be produced, the LCM Technology Advisory Committee has developed a priority list of important SSCs. Starting with a comprehensive list of SSCs, the sourcebook candidates were ranked in accordance with the average priority assigned by the committee members, considering applicability to many plants, importance for power production and safety, potential for degradation and obsolescence, and concern for maintenance.

The candidates for future (2002 and beyond) SSC LCM sourcebooks in order of utility priority are:

1. Main Turbine
2. Main Condenser
3. Feedwater Controls/Heaters480 VAC Electric

[1] A underlying plan is a previously prepared plant-specific LCM plan for the SSC type addressed by a sourcebook.

5. 125 VDC Electric

6. Large Transformers

7. Emergency/Normal Service Water

8. Main Generator

9. MOV/HOV/AOV

10. 4160 VAC Electric

11. Main Steam System

12. EHC Turbine Controls

1.5 Overview Report Use and Organization

The main link between this overview report and the LCM report [1] is the process flow chart (Figures 1-1, 1-2 and 1-3), in which box numbers designate process steps and section numbers refer to sections of the sourcebook. For this report, the flowchart was modified only to improve clarity and to reflect new thinking and lessons learned from the license renewal process with respect to aging management and technical obsolescence (i.e. Step 11 has been subdivided into three distinct tasks).

When preparing an LCM plan, it is advisable to have on hand the SSC-specific LCM Sourcebook, the LCM planning report [1], this overview report, and any existing LCM plans from other plants that are available. Researchers generating additional SSC-specific sourcebooks should have the LCM planning report and this overview report on hand. They might also refer to the prototype sourcebooks for achieving consistency of format and level of detail.

This overview report consists of two major sections as follows:

1.5.1 Guidance for Future Sourcebook Authors

Section 2 of this report provides the format and content guidance for the SSC-specific sourcebooks being prepared by future sourcebook authors. It is not the intent of this section to prescribe the format and content rigidly, but rather to provide an outline and checklist for the essential elements of a sourcebook. Some topics may not be applicable to certain SSCs or the generic data may not be available or appropriate, in which case a statement of that finding and its basis may suffice, or an applicability assessment may be appropriate. The emphasis should be directed toward providing as much foundation information and generic data in the sourcebook as may be useful for the utility engineer in crafting his or her plant-specific LCM plan for that SSC.

Where available, generic information applicable to most SSC-specific sourcebooks is presented under Section 2 of this report in the respective subsection. Specific information and guidance in the overview report should be referred to as appropriate in each LCM sourcebook.

Lastly, in adhering to a standard format and content for the sourcebooks, their use will be simplified by finding similar information in specific sections and they will have a consistent "look and feel".

1.5.2 Guidance for Preparers of Plant-Specific LCM Plans

Section 3 of this report provides detailed guidance to the utility engineer in applying the information given in the SSC specific sourcebook in the preparation of plant-specific LCM plans. It is emphasized that there are many different ways to arrive at LCM planning solutions and often the input relies on assumptions, estimates or sound engineering judgment. This section presents and includes some of the lessons learned from generating the twelve pilot SCC LCM plans and the two prototype SSC specific LCM Sourcebooks. It also documents generic data and information generated during that process. In the end, plants may want to compare their plant-specific LCM plans to those of other plants and this is only meaningful if reasonable consistency of assumptions and estimates is maintained.

It is also considered a benefit to the utility engineer to have most of the applicable generic information on hand and to be able to readily assemble and analyze the plant-specific information for the subject SSC.

Appendix A provides a standard Table of Contents for sourcebooks to be generated in the future and tested in the two prototype sourcebooks. It is intended as guidance to sourcebook authors to achieve a consistent "look and feel" across the planned family of sourcebooks.

Appendix B provides an illustration of a typical plant-specific LCM plan Table of Contents. For some systems or components the focus of the LCM plan may be significantly different (e.g. more complex, much simpler, or requiring special studies). Thus, an industry standard LCM plan is not appropriate.

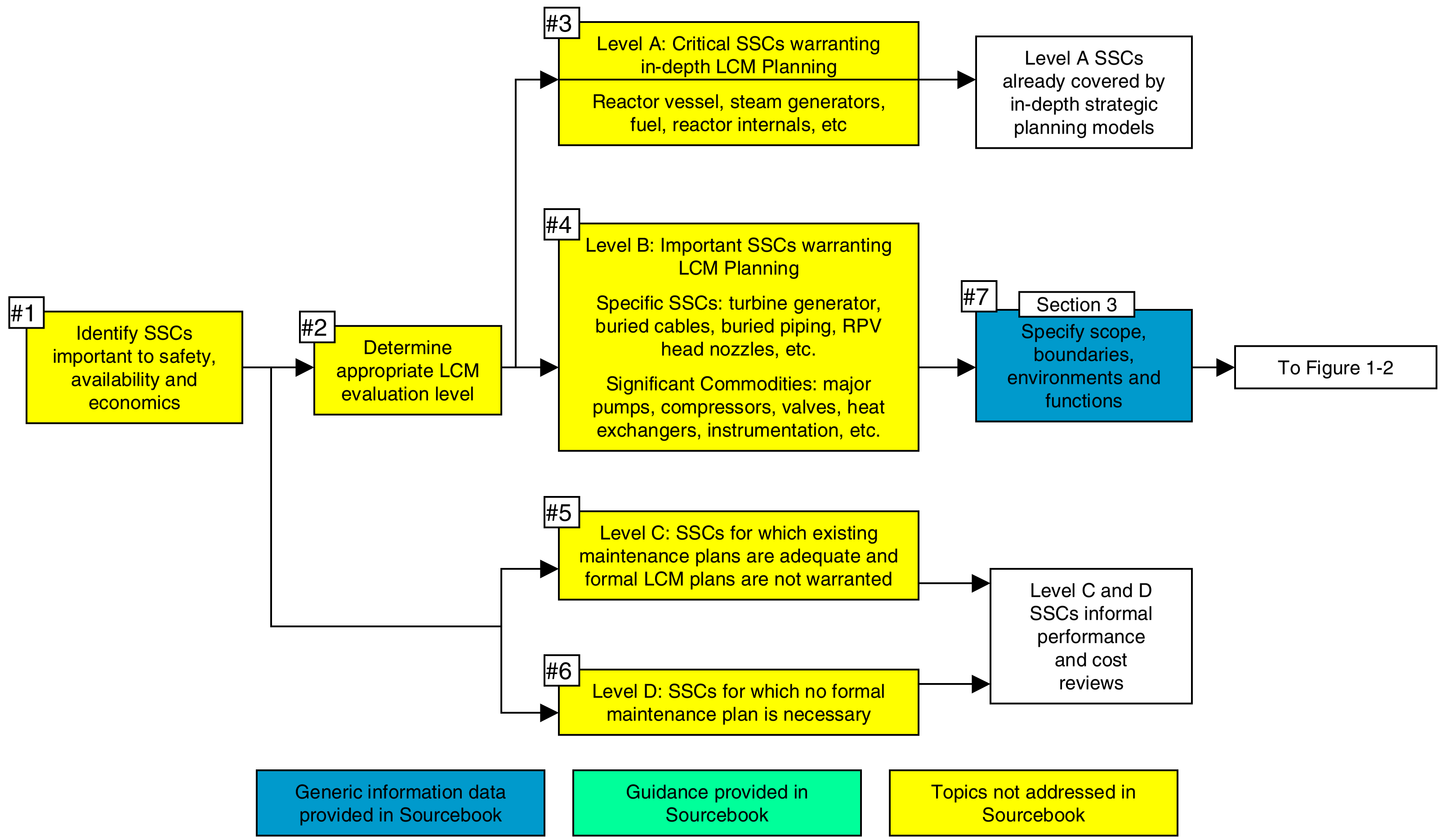


Figure 1-1
LCM Planning Flowchart – SSC Categorization and Selection (Indicated Sections refer to Appendix A)

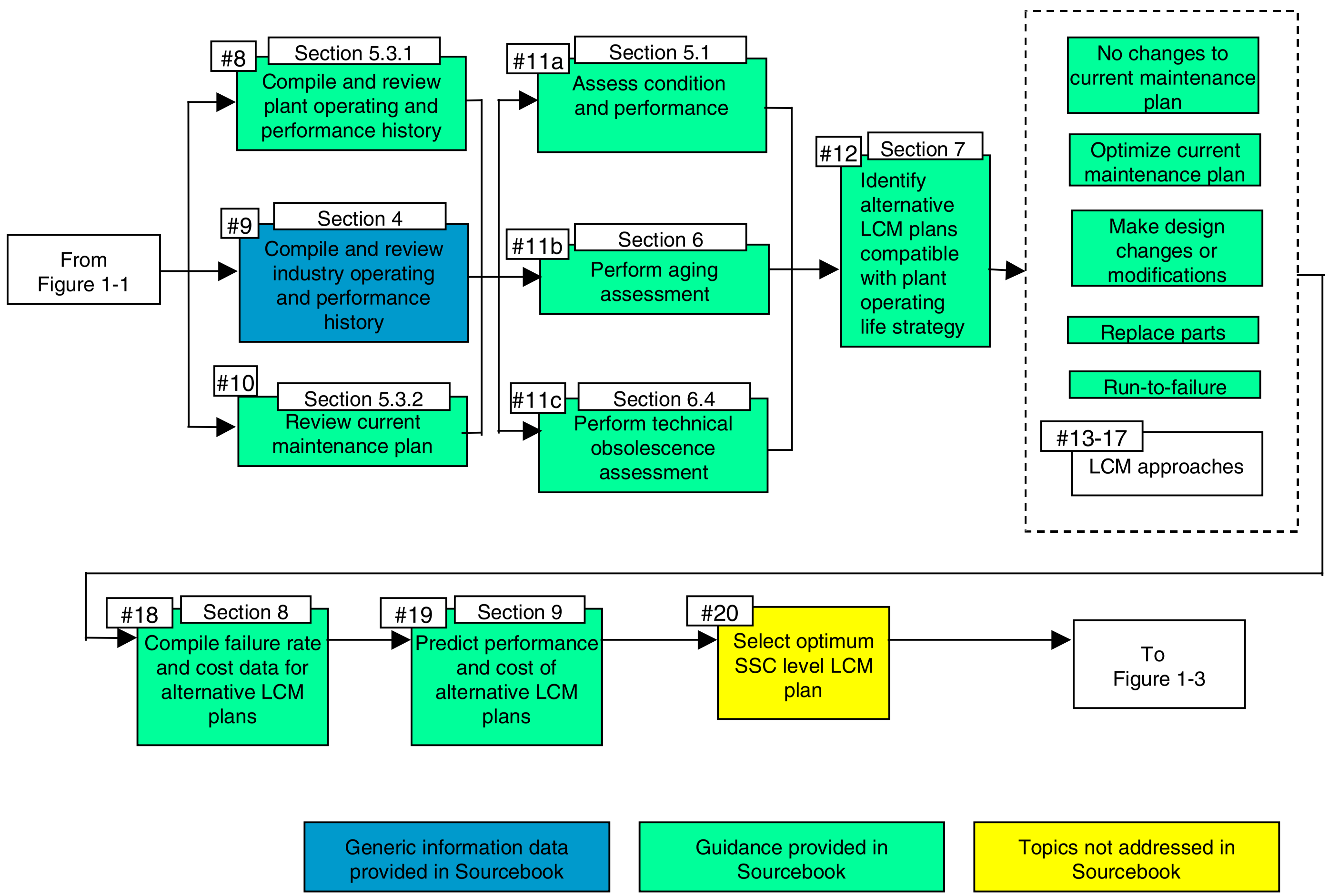
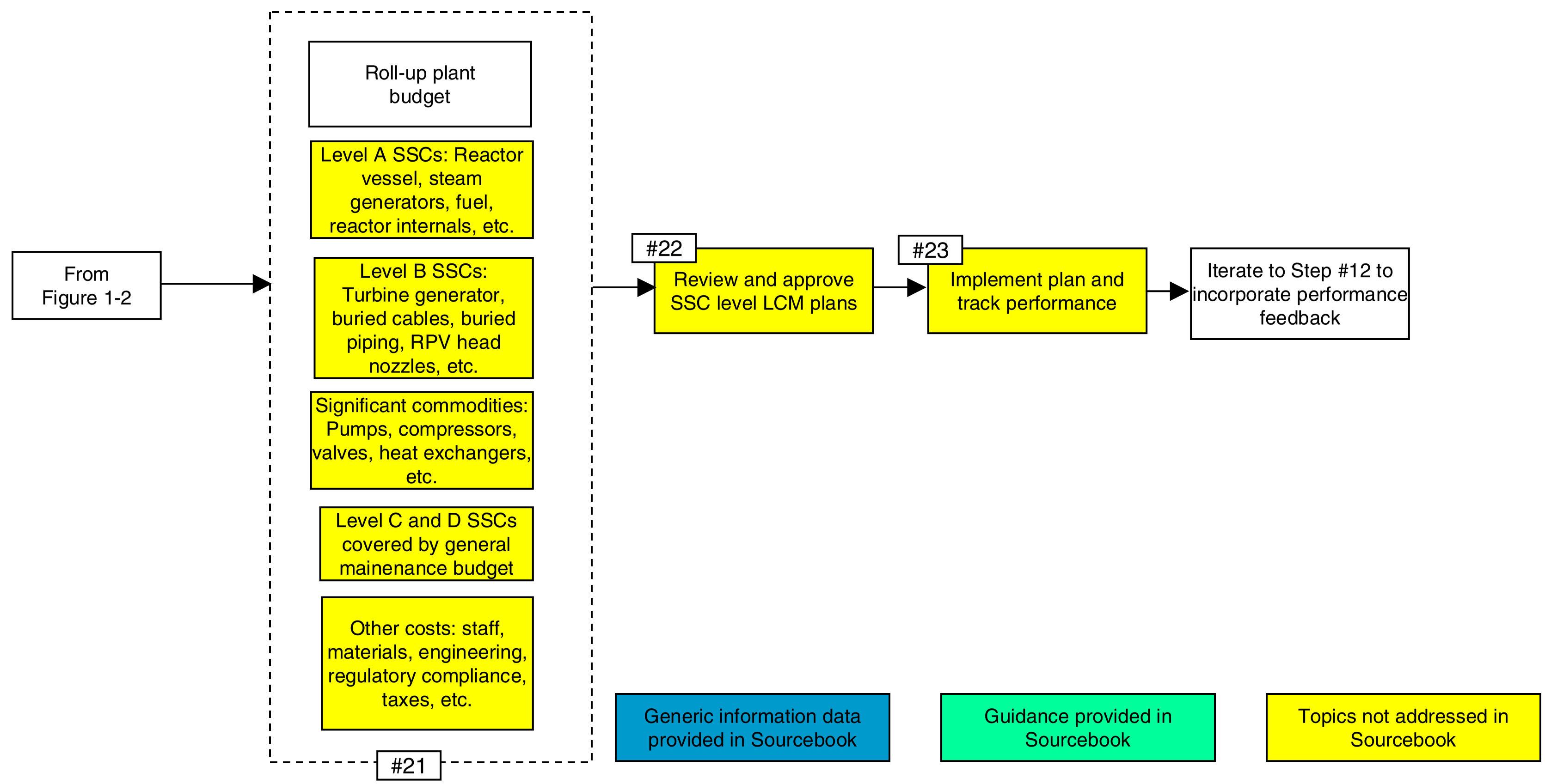


Figure 1-2
LCM Planning Flowchart – Technical and Economic Evaluation (Indicated Sections refer to Appendix A)



Note: Ensure that costs are not double counted in SSC inputs and "other costs."

Figure 1-3
LCM Planning Flowchart – Implementation

2
PREPARING LCM SOURCEBOOKS—FORMAT AND CONTENT

Each LCM sourcebook should contain at least the information described in this section. Text in italics can be used verbatim in each sourcebook. The section numbering should be the same for all sourcebooks (see prototype table of contents in Appendix A). However, as appropriate, additional types of information for the SSC type can be added to a sourcebook in a closely related section or in an appendix. Each of the subsections below addresses the content of an LCM Sourcebook. However, only some subsections relate one-to-one to sourcebook sections.

2.1 Management Summary (Sourcebook Section 1.0)

This LCM Sourcebook is intended to guide your plant engineer or expert consultant in preparing a life cycle management plan (long-term reliability plan) for the plant's [name of SSC] *The guidance consists mainly of generic information, data, and references; industry-wide IAS issues and ways to ensure they are addressed at your plant*; [name of SSC] *aging mechanisms together with the maintenance activities to manage them; and alternative LCM plans that can be considered during long-term planning for the* [name of SSC].

The system components [or component parts] *that are most important to long-term reliability are* [list].

Depending on the level of detail desired for the plant-specific LCM plan, the generic [name of SSC] *data in this sourcebook may be used to benchmark your plant's data, thereby allowing engineers to focus on areas where there may be significant opportunities for cost-effective improvements or for reductions of onerous maintenance activities.*

[Name of SSC] industry issues to date are [list and nutshell comments].

Potential aging degradation and counteracting maintenance activities include: [list].

Some potential alternative LCM plans are [thumbnail descriptions].

This sourcebook can not only supplement the [name of SSC] *expertise of your staff. It can also reduce the cost to prepare a* [name of SSC] *long-term LCM plan by about a third compared with starting from scratch.*

2.2 LCM Sourcebook Introduction (Sourcebook Section 2)

2.2.1 Purpose of LCM Sourcebook (Sourcebook Section 2.1)

This LCM Sourcebook is a compilation of the generic information, data, and guidance an engineer typically needs to produce a plant-specific LCM plan for a [name of SSC]). The sourcebook will enable plant engineers or outside experts to develop an LCM plan with substantially less effort than if they had to start from scratch. The engineer need only add plant-specific data and information to complete an economic evaluation and LCM plan for the [name of SSC]. It must be recognized that not all generic information in a sourcebook applies to every plant. Some of the data can serve as a benchmark when performing plant-specific LCM planning. The data may also show indicators or precursors to problems not yet experienced at a given plant. Caution and guidance is therefore provided in the plant-specific guidance sections [Sections 5, 8, and 9 of the sourcebook] for the use and application of the generic information. These sections also contain useful tips and lessons learned from the EPRI LCM Plant Implementation Demonstration program [Ref.] and any related plant-specific LCM plans that may exist.

2.2.2 Relationship of Sourcebook to LCM Process (Sourcebook Section 2.2)

The process steps for LCM planning are described in detail in the EPRI LCM report [Ref.]. The LCM planning flowchart in Figure 2-1 to 2-3 of this sourcebook is essentially the same as Figure 1-1 to 1-3 of the LCM Sourcebook Overview Report [Ref.] and Figure 2-2 of the LCM report [Ref.]. The chart is segmented into the four elements of the LCM planning process: SSC Categorization/Selection, Technical Evaluation, Economic Evaluation, and Implementation. Process step numbering has been maintained consistent with the LCM report. Section numbers refer to this sourcebook. Color codes identify topics for which generic data are provided by section reference; topics for which plant-specific LCM planning guidance is provided by section reference; and topics not addressed in the Sourcebook.

2.2.3 Basis for Selection of [SSC] for LCM Sourcebook (Sourcebook Section 2.3)

The [SSC name] was selected for preparation of a sourcebook by EPRI-member utility advisors. The main reasons for its selection were

- *It is applicable to many (or all) plants (BWRs, PWRs, or both)*
- *It is important to safety risk or a regulatory concern*
- *It is important to power production*
- *It is subject to significant degradation or obsolescence*
- *It has a history of chronic maintenance problems.*

[Select from these bullets and/or add others.]

Using an initial listing of important SSCs, the sourcebook candidates were ranked in accordance with the average priority given by LCM Advisory Committee members and considering generic applicability, SSC importance for power production and safety, potential for degradation and obsolescence and concern for maintenance.

2.3 Background Information for SSC Type (Sourcebook Section 3.0)

A brief description of the SSC and basic information (Step #7 in Figure 1-1) should include the following elements:

- **Safety and Operational Significance**
  Describe the generic safety and operational significance of the SSC, BWR or PWR specific variations of the SSC, industry wide variation in names and terminology for the SSC, likely inclusion of the SSC in License Renewal or Maintenance Rule scope, whether it is typically modeled in the PRA/PSA and its risk significance, safety system functions or mitigating functions, key roles the SSC plays in the power production of the plant, capability to scram or trip the plant or potential to cause injury or damage upon failure (toxic contents, steam, flammable, radioactive, etc.).

- **SSC Functions and Boundaries**
  Identify the SSC functions, both passive and active, that will be addressed. The boundaries of the SSC included in the sourcebook can then be defined by identifying those portions of the SSC required to accomplish the SSC functions. Then describe / define the principal and critical components of the SSC, aspects of SSC and component redundancy, supplemental trains, functional redundancy, interconnections to other SSCs, fail-safe positions of components, auxiliary services required for the SSC operation (electrical power, heating/cooling, lubrication, instrumentation, prime movers, insulation, etc). Discuss grouping of components into commodities and potential sampling approaches for evaluation for large component families (i.e., by model, size, vendor, material, function). Include a process or functional diagram(s), component drawings or photos, typical installation sketches, logic diagrams and similar visual tools.

- **SSC Design and Operating Parameters**
  Prepare a list or table with the key design and operating parameters (pressure, temperature, flow, voltage, amperage, capacity, size ranges) for the principal SSC components. Identify model numbers, vendors, types of components typically seen and used in the industry, and the common materials used. With respect to operating conditions, provide a discussion on the typical locations of the SSC within the plant, its environment and exposure range (indoor, outdoor, atmosphere controlled, radiation, elevated temperature, inside containment, etc) affecting aging and degradation of the SSC.
  If known, identify potential outliers not addressed in the sourcebook and plant-specific conditions not specifically evaluated or excluded for specific consideration. The intent of the sourcebooks is to address "most" of the US nuclear power plant fleet, while recognizing the significant differences in plant design, especially in the balance of plant.

2.4 Historical Performance Data from Industry Operating Experience and Performance History (Sourcebook Section 4.0)

This section of the sourcebook contains the bulk of the generic foundation information (Step #9 in Figure 1-2) and presents the research results for the SSC to be used in a plant-specific LCM Plan.

2.4.1 Nuclear Industry Experience (Sourcebook Section 4.1)

To provide an industry benchmark for generic historical SSC performance used in the plant's PRA, the USNRC conducted a review of industry-wide initiating events for the period 1987 to 1995 (NUREG/CR-5750, Table D-4 [6]). The relevant data for initial plant faults (IPFs) from the NUREG are tabulated separately for PWRs and BWRs in Table 2.1. If one assumes that each fault contributes equally to plant shutdowns, an estimate of the percent contribution of failures of a specific SSC like instrument air system is represented by the number of IPFs for that SSC divided by the total faults (1,327 for PWRs and 658 for BWRs). This "system contribution factor" is shown as a percentage in table 2.1.

This average generic SSC contribution (as applicable to a BWR or PWR) can be used as an initial generic benchmark for the SSC specific sourcebook. These factors, after comparison against the plant specific data, can then be further used in the NPV loss calculations in plant-specific LCM plans, to determine the impact on lost power generation attributed to the SSC. The values shown, when compared to plant specific values, provide a first glimpse at the potential impact of SSC failures and a first order assessment with respect to plant-specific SSC performance (i.e. whether the plant-specific value lower or higher and by how much). For SSCs not represented in Table 2.1, it can be safely assumed that the generic failure rate is negligible with respect to lost power generation. This table and the explanatory discussion should be included in the sourcebooks for the SSC types that are covered in the table.

Table 2-1
SSC Contribution to Total Plant Faults (1987-1995 Data [6])

SYSTEM-CATEGORY	Initial Plant Faults IPF		Contribution Factor %	
ALL EVENTS	**BWR 658**	**PWR 1327**	**BWR 100**	**PWR 100**
LOSS OF OFFSITE POWER	4	13	0.607	0.980
LOSS OF VITAL BUS	7	3	1.060	0.226
LOSS OF IAS	13	13	1.976	0.980
FIRE	10	21	1.520	1.583
INADVERTANT CLOSURE OF MSIVs	16	5	2.432	0.377
LOSS OF CONDENSER VAC.	27	13	4.103	0.980
TOTAL LOSS OF FW FLOW	24	62	3.647	4.672
LOSS OF NON-SAFETY BUS	5	20	0.760	1.507
LOSS OF AC I&C BUS	12	19	1.824	1.432
LOSS OF NON-SAFETY COOLING WATER	16	34	2.432	2.562
PARTIAL MSIV CLOSURE	11	36	1.672	2.713
PARTIAL LOSS OF FEED WATER FLOW	45	240	6.839	18.086
PARTIAL/TOTAL LOSS OF CONDENSATE. FLOW	18	36	2.736	2.713
EXCESSIVE FEEDWATER	49	61	7.447	4.597
VALID RPS TRIPS	64	132	9.726	9.947
REACTIVITY IMBALANCE	6	88	0.912	6.631
TURBINE TRIPS	173	284	26.292	21.402
MANUAL REACTOR TRIPS	55	48	8.359	3.617
SPURIOUS SSAs	14	22	2.128	1.658
OTHER TRIPS	89	177	13.523	13.338

2.4.2 Available Databases For Generic Data

The most comprehensive data reside in the two databases maintained by INPO – NPRDS and its successor, EPIX. Both databases are accessible by authorized utility contacts.

NPRDS focused on failure data of safety related equipment. Although maintenance of the database was discontinued in 1996, it provides a US fleet-wide count of SSC failures on an annual basis, such that trends can be established for the applicable period. To compute failure rates from the NPRDS data, one must estimate the population of SSCs of interest in the fleet.

The EPIX database includes SSCs that are typically included within the scope of the Maintenance Rule and therefore includes SSCs important to power production (that could cause a scram). EPIX also has extensive SSC and failure cause search capability not previously available in NPRDS. Typically, SSC sorts for "ALL PLANTS" produce the widest net for failures of a specified SSC type. The failures can be sorted by date, year, plant, plant type, or vendor.

INPO also generates a number of SSC-specific documents, such as good-practice guides, maintenance guides, and diagnostic program descriptions. An index of these documents on the INPO web site should be searched for SSC-specific information.

EPRI has a substantial library of SSC specific information from research reports, maintenance guides, workshops, seminars and surveys. SSC-specific searches can be conducted by keyword on the EPRI web site (www.*epri.com*). The searches will find articles and documents produced by NMAC. Abstracts are available on the web site for screening. Full documents are available through downloads, EPRI (George Sliter 650-855-8699, *gsliter@epri.com*), the EPRI Orders Center (800 313 3774, Option 2), utility libraries, or by direct purchase.

Another source of generic data is the NUREG series of reports issued by the USNRC. Newer reports (1998 onwards) are available through the NRC web page (www.nrc.gov) and via ADAMS, the NRC's electronic public library, while older reports can be accessed via the NTIS web page (www.ntis.gov). Especially useful are the NUREG reports issued under the NRC's Nuclear Plant Aging Research Program (NPAR), which are summarized and tabulated in NUREG-1377 [7].

2.4.3 Interrogation of Available Databases and Analysis of the Data

Once the information has been assembled, the data will have to be evaluated for applicability (i.e., BWR or PWR specific), trended over time, assessed for accuracy and potential short-comings, calculation of failure rates and SSC populations and conclusions must be drawn to present as clear a picture as possible, such that the data can be useful for SSC LCM planning.

2.4.4 Review of Generic Communications (Sourcebook Section 4.2)

The USNRC produces a great amount of generic communications to the plants, documenting generic concerns and advisories regarding equipment failures, performance problems, human errors, and other topics. Of importance to LCM planning and LCM sourcebooks are the identification and review of applicable SSC-specific generic communications to learn about historical and recurring problems. Most of the communications were issued because the NRC made a finding that the SSC had failed or caused performance or safety concerns at more than one plant. Often, these communications are an indicator or precursor to problems that should be anticipated at the plant, if not already experienced. The following generic communications are pertinent to the sourcebooks and can be accessed via the NRC web page:

- Information Notices (IN)
- Information Bulletins (IB)
- Generic Letters (GL)
- Regulatory Issue Summaries (RIS)
- Generic Safety Issues (GSI)

The generic communications should be screened for SSC applicability and the pertinent ones should be summarized with respect to their importance in LCM planning. The plant is expected to review its specific response to issues and the resulting corrective or preventive actions. An EPRI database is available for the SSC screening and identification of Generic Communications [8].

2.4.5 Review Maintenance Rule Performance Parameters

EPRI has developed a generic Maintenance Rule System Monitoring Basis Database (SYSMON) [9], which includes generic monitoring plans and performance parameters for most SSCs. The SSC-specific monitoring plans and performance parameters should be reviewed for applicability and documented in the sourcebook to facilitate plant-specific benchmarking. Tolerances and ranges set for the performance parameters, if any, should be evaluated and documented in the sourcebook.

2.4.6 Assessment of EPRI PM Basis

Another key EPRI project is the EPRI Preventive Maintenance Basis [10] and its successor, the electronic “Preventive Maintenance Information Repository” (PMIR) [11], providing preventive maintenance templates for some 40 major SSCs. For each SSC type, the templates identify recommended maintenance tasks and task intervals. The template(s) applicable to a sourcebook should be identified and reproduced or referenced in the sourcebook to serve as a benchmark and starting point for LCM PM practices under consideration. The template also needs to be reviewed for applicability to long-term aging and for potential additions or modifications as a result of other sources for PM and PdM aging management activities (e.g. equipment owners groups, vendor recommendations, or regulatory requirements).

2.4.7 Generic Performance Reviews

The generic performance review should result in a road map to identify and apply successful performance enhancements available for the SSC. By reviewing the data sources and information discussed above, a set of preventive and predictive maintenance tasks or task enhancements are developed. This set should be as comprehensive as the data permits, as no one specific set will be appropriate or useful to all the plants. This list is viewed as a menu and checklist to be used in the LCM plan development. Discussions regarding the particular effectiveness of a program/task or preferences, advantages/disadvantages, ease or difficulty of implementation, frequency of the task and similar program attributes should be included, where available and appropriate. When tasks are defined for a family of components, i.e. breakers or MOVs, a sampling approach to PM or staggered schedules for the individual components should be considered (e.g. for a 5-year PM, doing 20% each year will accomplish 100% every 5 years).

2.4.8 Aging Matrix and Aging Management Assessment (Sourcebook Section 6.1)

The principal focus of this section is to develop a comprehensive generic aging evaluation matrix from available industry information (Step # 11B). For passive SSCs within the scope of the License Renewal Rule, 10CFR54, the NRC in cooperation with the industry (NEI) has issued a compendium of aging information, including an aging matrix consisting of the following information columns:

- Identification of the structure/component and its principal material(s)
- Characterization of the expected environment and its range(s)
- Identification of aging effects and their associated aging mechanisms
- Effective aging management programs that can be credited

The NRC document, referred to as the GALL Report [12], short for “Generic Aging Lessons Learned”, should be reviewed for SSC-specific requirements. It is cautioned that the GALL report only deals with a regulatory set of requirements (or recommendations) to preserve the passive safety functions of the long lived SSCs. Other more comprehensive aging management tasks may be appropriate for the day-to-day maintenance of the passive SSCs and maintenance of the active SSC functions and to assure that other SSC functions, such as power production functions, are not degraded by aging effects.

In addition to the GALL report, the NPAR reports [5] provide a valuable resource for aging assessment, covering both passive and active SSCs, even though only safety-related functions are addressed. Sandia National Laboratories, under the sponsorship of the US DOE, has issued a number of “Aging Management Guides”(AMGs) [13], which provide a detailed aging assessment and recommendations for effective aging management tasks. Many of the SSC-specific EPRI reports also contain degradation and aging management information, specifically the license renewal Mechanical Tools [14] and Electrical Handbook [15]

For some components, aging information may be available from sources outside the nuclear industry, such as the fossil and hydropower industry (EPRI), aircraft, petrochemical and nuclear Navy. Keyword library searches may be required to identify relevant information sources.

An aging matrix should include an identification and consideration of the typical SSC service conditions and environments, operational duty (fatigue, vibration) and material vulnerabilities. The potential failure modes and their consequences should be identified (e.g. fatigue cracking of high pressure pipe displays leakage as an indicator before failure) when they may result in significant business risk or affect safety. In many cases, active components have redundancy to avoid or mitigate complete functional failure; however, for safety-related and some important-to-power production systems, the objective is to ensure that aging will not degrade the levels of redundancy provided in the SSC design.

The aging assessment also needs to include a list of effective aging management programs or tasks for each of the potential aging effects. It is cautioned that plant specific conditions for aging and degradation may vary significantly and the important variations need to be identified and addressed. These variations may include proximity to oceans and saltwater cooling, aggressive groundwater and soil, plants in cold or hot climates, different water chemistries, material choices and use of preventive programs (coatings, paint, dewatering, etc). The matrix provides a ready comparison for preparing LCM plans and identifying potential enhancements to make aging management more effective.

Section 6.2 of the sourcebook should present expected lifetimes (or ranges of lifetimes) for various components included in the SSC.

2.4.9 Technical Obsolescence Issues (Sourcebook Section 6.3)

For some SSCs, obsolescence rather than aging is the most life-limiting issue and can be of substantial consequence to a plant (Step # 11C). While no SSC is completely immune, the problem affects mainly electrical and instrumentation systems, particularly analog controlled equipment, active electrical components, equipment using computers, electronic cards/logic, and signal processing and monitoring components. To evaluate the potential for technical obsolescence, a nine-point criteria and severity ranking scheme was developed and may be used for generic assessments of obsolescence concerns of the SSC, as shown on Table 2.2. The severity ranking of the SSC is performed by completing the responses to the nine questions. For each affirmative answer (YES), the corresponding score is entered in the YES column and a total score is determined by summation. The individual questions have been assigned weight factors because not all questions are of equal importance. The following ranks are provided as a guideline:

- Total Score is < 6.0, RED and the SSC obsolescence is serious. Potential options to deal with obsolescence and contingency planning should be identified. Guidance on the modeling, timing and costs of these contingencies and the associated risks should be provided.
- Total Score is from 6.0 to 10.0, YELLOW and the SSC may have longer term concerns for obsolescence. Contingency planning and options should be considered.
- Total Score is > 10, GREEN and the SSC is not likely affected by obsolescence.

Another EPRI methodology dealing with obsolescence assessment is provided in the EPRI-Lite tool [16]. Interview templates are available to determine obsolescence concerns and a system reliability ranking.

Table 2-2
Application of Obsolescence Evaluation Criteria

	Technical Obsolescence Evaluation Criteria	SCORE	YES
1	Is the SSC still being manufactured and will it be available for at least the next five years?	5.0	
2	Is there more than one supplier for the SSC for the foreseeable future?	3.0	
3	Can the plant or outside suppliers manufacture the SSC in a reasonable time (within a refueling outage)?	3.0	
4	Are there other sources or contingencies (from other plants, shared inventory, stock-piled parts, refurbishments, secondary suppliers, imitation parts, commercial dedications, etc) available in case of emergency?	3.0	
5	Is the SSC frequency of failure/year times the number of the SSCs in the plant times the remaining operating life (in years) equal or lower than the number of stocked SSCs in the warehouse?	3.0	
6	Can the spare part inventory be maintained for at least the next five years?	3.0	
7	Is the SSC immune to significant aging degradation?	1.0	
8	Can newer designs, technology, concepts be readily integrated with the existing configuration (hardware-software, digital-analog, solid-state, miniaturized electronics, smart components, etc)?	3.0	
9	Is technical upgrading desirable, commensurate with safety and cost effective?	3.0	
	Total Obsolescence Score		

2.5 Alternative LCM Plans (Sourcebook Section 7)

2.5.1 Potential Plant Operating Strategies

Since operating strategies will be specific to a plant, the sourcebook should identify and address a set of potential strategies to be considered in generating potential LCM plans (see next section). The following should be considered as a minimum:

- The plant will be decommissioned consistent with the current license provisions, i.e. at year 40.
- The plant will be operated for a period of 60 years with a 20-year license renewal extension.
- The plant will be shut down prematurely as a result of economic/technical reasons or by political/regulatory pressure. Examples are:
  - Need for PWR steam generator replacement late in life
  - Need for BWR reactor vessel internals replacement late in life
  - Lack of on-site spent fuel storage capability
- Other variations of potential plant operating strategies could stem from what-if scenarios (e.g. the impact of stranded capital cost, extension of license renewal to an 80-year term, or a large power up-rate of say 20%).

In the sourcebook, the strategies need only be discussed with respect to the SSC type on a generic basis. It is recognized that the plant strategies are very plant specific, beyond the first two cited above. It is also obvious that the best LCM alternative for a specific SSC may not be the optimum solution on a plant level basis for any given strategy (see Section 3.10).

2.5.2 Development of Alternative LCM Plans

For each potential plant operating strategy, the sourcebook should identify and describe several LCM plan alternatives. Each alternative consists of one or a combination of the following more-or-less standard approaches:

- The base case is typically the "Continue as-is" LCM plan alternative. It is the explicit or implicit long-term plan that would be followed absent an LCM planning study. This may include minor changes or enhancements in the PM or PdM programs.
- Optimize the current maintenance program by adding effective PMs and PdMs not currently performed for the SSC, optimizing frequencies, deleting excessive and onerous tasks, or shifting maintenance from off-line to on-line. Also included are considerations for effective aging management and technical obsolescence contingencies.
- Make design changes or modifications to optimize the life cycle cost, such as additional redundancy, larger size/capacity, more resistant materials, and implementation of protective/mitigative actions.

- A component or components are repaired or replaced with upgraded technology, improved performance, reduced maintenance.
- Other innovative alternatives and approaches that may be SSC specific.

The bases for the alternatives selected and the associated aspects (existing versus new PMs, expected reliability/availability improvement, changes in risk, lost power generation, timing of activities, potential benefits, etc) should be discussed and presented.

If possible, a hypothetical illustration should be presented, utilizing underlying LCM plans, when available, to assess reality of alternatives and to provide a sense of direction for plant-specific LCM plan development

2.6 Guidance for Estimating Future Failure Rates (Sourcebook Section 8)

This section of the sourcebook (Part of Step # 19) uses the compiled failure data discussed in Section 2.4 together with engineering know-how and judgment to estimate future performance (failure rates, reliability, availability) of the SSC. Of course, the bottom-line is that predicted failure rates can only be made for a specific SSC in a plant-specific LCM planning study. This section gives generic guidance on how to estimate failure rates. Section 8 of the sourcebooks gives SSC-specific guidance for use in preparing plant LCM plans. LCM planners need to recognize that one of the most difficult and variable aspects of LCM planning is the prediction of long-term failure rates needed to calculate the future lost power production. For this reason, EPRI has plans to develop improved methods for predicting long-term reliability of SSCs.

The following are general guidelines useful for estimating future failure rates:

- Prediction of failure rates should, to the extent possible, account for all significant variables (e.g. equipment model, materials, and size; ambient environment and duty cycles; and age/aging degradation).
- Failure rates are expressed as failures per year or failures per hour of operation. For standby equipment, a failure rate may also be expressed as failures per demand (to start or to run), which must be converted to an annual failure rate by multiplying by the number of annual demands.
- A point value failure rate is actually the probability of an SSC failing within, say, a year. If a probability approach is used, a probability distribution would be used to characterize the uncertainty in the estimate of failure rate/probability.
- Current plant-specific failure rates may be projected to remain the same in the future for the base case LCM alternative (unless previously unanticipated aging failure mechanisms come into play). Under the MR, failure rates have been trended since 1994, providing one basis for projecting the established trend for the future. This would be another way to project historical rates.
- If an effective preventive maintenance and aging management program has been implemented, the expected failure rates should remain fairly constant. This is in contrast to

the conventional bathtub curve predicting increased failure with age, which is largely applicable to run-to-failure equipment.

- Differences may exist, and are often justified, between generic data and plant specific failure data due to variation in maintenance practices, age of the equipment, unique service conditions or environments.
- Many failure rates are heavily influenced by human errors. It is well understood that failure rates increase with increasing frequency of invasive maintenance, which therefore should be kept to a minimum.
- Analytical or curve-fitting tools may be considered for forecasting failure rates, such as Weibull or Gaussian history distributions to model long-term aging effects
- When developing and analyzing SSC failure data, the number of failures or the component population may be too small to allow extrapolation to a reliable estimate of failure rates. In such cases, a sensitivity study on the failure rate is the preferred approach.

LCM planning generally includes the implementation of additional PM activities, changes in the PM frequency, or installing an in-kind new item of equipment. Failure rate adjustment factors (increases or decreases) may be applied to the current failure rates to estimate the future failure rates expected due to PM changes. The following indicates two ways to arrive at adjustment factors:

- For a component or component assembly that has been a run-to-failure item until a full PM program is implemented, an empirical failure rate reduction of 3.0 to 4.0 can be expected [1, Table B-11].
- For a component or component assembly that has been subject to a fixed maintenance task interval and for which the task interval is reduced by 50%, a failure rate reduction of 2.5 can be analytically projected [11]. Conversely, for a component or component assembly that has been subject to a fixed maintenance task interval and for which the task interval is doubled, a failure rate increase of 2.5 can be projected [11].

2.7 References and Information Sources (Sourcebook Section 10)

A detailed listing of the information sources used in compiling the SSC-specific data should be maintained and a comprehensive reference listing should be included in the sourcebook. Additional references that may be helpful in applying the sourcebook to plant specific SSCs and industry references to be consulted for plant specific work should also to be included. Information that is available from data banks should be identified, with details of how to access the data. Generic information available via the Internet should be identified with the relevant instructions for access, including software needed (Acrobat, PdF), web page address, keywords, etc.

Section 4 of this report lists key references applicable to many SSCs.

3
APPLYING GENERIC LCM SOURCEBOOK INFORMATION TO PLANT-SPECIFIC LCM PLANNING

3.1 Resource Planning for LCM Planning

Because LCM planning extends across many departments and disciplines within a plant it is advisable to appoint a dedicated LCM coordinator. Strategic and organizational aspects of LCM planning are discussed in detail in the EPRI LCM Implementation Guide [17]. Some pilot plants implemented LCM planning using a centralized office under a manager, with the detailed work being performed by outside contractors, while others developed a wider in-house application, using system engineers or managers for the data collection and analysis. The latter requires more in-depth training of a larger staff to assure consistency in LCM planning. In addition, resource planning should include identification of suitable software tools for implementing LCM planning.

A utility wishing to set up an LCM planning organization will need a corporate sponsor having access to senior management with budget and schedule prioritization. Additionally, an LCM coordinator or manager, as mentioned above, is required to manage the program. Resource estimates were made during the LCM Demonstration project and appear in Reference 1. Typically, a plant may designate between 30 and 60 SSCs (level As and Bs) for detailed LCM planning. Resource requirements for LCM planning for each important SSC range from 300 man-hours for large and complex systems to 150 man-hours for simple non-safety systems or components.

The LCM planning team will require assistance from other plant experts, including but not limited to financial, planning, outage planning, maintenance crafts, PRA/PSA, procurement, documentation, EPIX/NPRDS coordinator, and Maintenance Rule manager.

Once the organization is in place, the first task for the LCM planning team is the selection and prioritization of LCM planning candidate SSCs. This will provide the necessary input to the resource plan, budget and schedule.

Next, suitable software tools should be selected. One source of tools could be various and suitable software packages already existing at a plant (e.g. preventive maintenance optimization and net present value calculators). EPRI has developed several tools to assist in LCM planning

One is LcmTEMPLATE. This MS-ACCESS database guides LCM planners through the steps needed for construction and technical evaluation of LCM alternatives.

Another is EPRI-Lite, which assists in identifying the most important SSCs warranting LCM planning and performance issues associated with each SSC. [16]

A third is LcmVALUE. This Excel spreadsheet software does economic evaluation of LCM alternatives once they are specified [18]

A fourth is LcmPLATO [19], an MS-ACCESS database that combines the LcmTEMPLATE construction and technical evaluation of LCM alternatives with the same economic evaluation as in LcmVALUE LcmPLATO also serves as an LCM database of aging mechanisms and effects and how they link with various components and commodities within systems.

Only LcmPLATO has been developed as a production grade software tool. A detailed user manual, tutorial, and test cases are available from EPRI [19]. EPRI can also collaborate with plants to perform trial applications.

LcmVALUE and LcmTEMPLATE can be brought to production grade level as utility interest is expressed and resources allow.

Additional information on LcmPLATO, LcmTEMPLATE, and LcmVALUE can be found in the EPRI LCM report [1].

3.2 Availability of Data Sources and Databases

Because LCM planning relies heavily on existing plant data, it is important to identify the available data sources (Step # 8 in Figure 1-2). Most plants have a controlled SSC listing, detailed to the individual component level, which provides a reliable listing of potential systems to be considered in LCM planning. The Maintenance Rule (MR) required a precise determination of SSCs providing functions that are to be included in the scope of MR. If the SSC is not included in the MR scope, its functions are not likely important to safety or power production. Thus, the MR listing would constitute a good starting point for LCM candidate selection.

Many plant failure data are now provided in conjunction with Maintenance Rule programs and in maintaining the plant probabilistic risk assessment as a living document. These undertakings provide an excellent source of reviewed and up-to-date failure data for SSC types typically both addressed under the Maintenance Rule and modeled in the plant PRA). The following are cautions as to the data they provide:

- Maintenance Rule programs and PRAs emphasize functional failures rather than degraded performance. LCM plans should consider degraded performance to the extent possible.
- PRA models of systems might assume that the probability of passive failures of piping occasioned by gross leakage or catastrophic rupture is insignificant compared to the probability of active component failures and thus ignore it. However, these passive failures are important to account for in LCM planning.
- The acquisition of plant-specific failure data for LCM purposes will of course be facilitated if data are available from PRAs or Maintenance Rule program records or if procedures with

which to gather appropriate plant and generic failure data have been exercised as part of (or are available for) the performance of PRAs.

Another important and common database needed for LCM planning is the Work Order database, sometimes part of a larger plant information management database program, such as “CHAMPS” or “IMPACT”. The Work Order database provides the information for historical SSC performance (corrective work orders), SSC failure data from which to determine plant-specific failure rates, maintenance activity data (such as man-hours per activity, skill level involved, frequency or task interval), and material use or cost associated with repair or replacement.

Personnel interviews are used to solicit specific information from individuals, including, but not limited to the following:

- System Engineer for SSC specific data
- Maintenance crafts for determination of required task resources, materials use, burden hours (health physics, security, scaffolding, staging, decontamination, draining/disposal, etc), on-line versus off-line work
- Planning for future outage schedules, SSC repair/ replacement plans, outage impact
- Maintenance Rule manager for SSC performance parameters and trends
- PRA/PSA for SSC-specific failure rates and availability assumed in the PRA
- EPIX Coordinator to extract and evaluate needed EPIX data for other plants
- Procurement/Purchasing to provide costs for replacement and spare components
- Estimating to identify costs associated with installation of replacements, repairs, redesign, engineering studies, disposal, etc
- Operations to solicit input on operating problems with the SSC, work-arounds, potential enhancements
- Financial staff to provide long-term electricity price projections for estimating the cost of future lost power generation, projected inflation, and discount rates.

3.3 Collecting Plant-Specific Information

Collecting plant-specific information for LCM planning (Step # 8) can be a difficult and time-consuming task. The location of and responsibility for plant-specific information varies greatly from plant to plant. Therefore, the managers and engineers tasked with LCM planning are in the best position to know or track down the places, databases, and individuals where the information resides. To provide guidance to LCM planners, the experience gained during the pilot studies and from the demonstration plants was used to construct Tables 3.1 through 3.7, which facilitate and organize the collection of plant data. Table 3.8 is a summary table containing data in a form ready to be input to LCM planning tools.

In Table 3.8, the process of listing the current maintenance activities is illustrated. It is important to make this inventory as complete as possible, while recognizing that certain tasks are not economically significant (i.e. annual cost is less than $2,000.00), but may have an important preventive or predictive value (i.e. thermography may cost only $ 50.00 per year per component, but is a key diagnostic tool). The entries required for LCM planning are self explanatory, with the following clarifications:

- The “Number of Components” represents the total number of a group of similar components within the SSC boundary (i.e. MOVs, Breakers, Pumps)
- “Labor Hours” should include all labor associated with the task. Burden hours for scaffolding, staging, decontamination, etc are included, while contractor assistance, engineering studies, temporary fixes, etc, may be modeled as separate task(s), if not performed each time with the maintenance activity.
- “Labor Category” consists of the actual cost per labor hour. It may be a mix of the skills required for the task.
- “Material Cost” includes the cost of materials used for the task, cost for replacement items, repairs (outside), capital costs, spare parts, inventory sale (negative cost), lost power production, regulatory cost, etc.
- “Frequency or Failure Rate” represents the frequency or task interval on a per year basis (i.e. a task performed at each 18 months refueling has a frequency of 12/18=0.667). For corrective actions a failure rate is entered for required replacements or repairs (i.e. for an SOV requiring replacement every 12 years, the rate is 1/12=0.0833).

Table 3-1
Basic Plant Information

Information Topic	Example	Plant-Specific Data
Name of Plant	*XYZ*	
Net Electrical Rating, MWE (each Unit)	*1120*	
Number of Units at Plant	*1*	
Unplanned Capacity Loss Factor to Date, %	*8.94*	
Lifetime Planned Capacity Loss Factor, % (if the plant is cycled or run at reduced capacity)	*10*	
Start Date of Commercial Operation	*03-1985*	
Current Planned Retirement Date	*03-2025*	
Potential Retirement with License Renewal	*03-2045*	
Potential for Power Uprate, %	*4.5*	
Refueling Cycle, Months	*18*	

Table 3-2
Economic and Financial Data

Information Topic	Example	Plant Specific Data
Future Average Price of Electricity, $/MWE	*28.00*	
Peak Price of Electricity, $$/MWE	*64.00*	*Note, this value may be used for unplanned outages of less than 24 hours during peak demand periods*
Current Power Replacement Cost, $/MWE	*32.50*	
Projected Annual Inflation, %	*4.2*	
Projected Discount Rate, %	*8.6*	
Cost of Labor, $/Hr:		
Engineering	*65.00*	
Maintenance Craft	*40.25*	
Unskilled	*35.60*	
Consultants	*118.00*	
Current Annual SSC Maintenance Cost, $/year	*643,000*	

Table 3-3
System Engineer Interview

- ❑ Provide a simple diagram (logic) of the SSC, boundaries, major components
- ❑ List the major components and its individual numbers (grouping if possible)
- ❑ Provide a listing of important SSC problems in the past
- ❑ How many MW Hours of lost power has the SSC caused in the past
- ❑ Provide a list of major repairs, replacements, enhancements, design changes made to the SSC and the estimated cost of each
- ❑ Provide a list of SSC generic problems encountered in your sister plants
- ❑ Complete the obsolescence assessment form with the SE
- ❑ Provide the SSC failure rates as used in the PRA/PSA and indicate if generic or plant specific failure rates are used
- ❑ Determine the availability values assumed for the SSC in the PRA/PSA
- ❑ Identify MR performance parameters have been established for the SSC
- ❑ Provide parameters and values, trends (availability in %, lost MWhrs, MPFFs, others) since 1996.
- ❑ Provide a listing of aging effects or degradation noticed for the SSC components
- ❑ Provide a listing or inventory of all the current SSC maintenance tasks
- ❑ Determine the current physical condition of the SSC (see condition assessment form)
- ❑ Is there a "Get Well Plan" in place or planned for the SSC, provide details, if yes
- ❑ Provide listing of SSC parameters monitored in the control room, locally or by chemistry (pressure, delta T, inlet/outlet temperature, rpm, voltage, amperes, tube leakage, offgas flow, water levels, etc)
- ❑ Determine the environmental exposure conditions for the SSC?
- ❑ Identify any abnormal service conditions (high cycle, corrosive fluids, underwater, etc)
- ❑ Replacement cycle for run-to-failure components or consumable SSCs, condition monitoring methods

Table 3-4
Listing of SSC LCM Documentation

- ❑ Functional description or DBD for the system
- ❑ Listing (or data sort) of the major components, type, size, model, vendor, function
- ❑ Listing of all plant scrams, power reductions, trips, extended outages and their causes
- ❑ Copy of all SSC maintenance, inspection, testing, exercising, surveillance and diagnostic procedures (PM and CM)
- ❑ Number of spare components on hand in the warehouse
- ❑ Copy of work orders for CM activities (replace, repair, refurbish, troubleshoot, bypass, etc)
- ❑ Copy of repetitive PM work orders
- ❑ Copies of vendor manuals and maintenance recommendations
- ❑ Copies of vendor brochures, drawings, photos and catalog cuts
- ❑ EPIX run for all plants, sorts for components, vendor, model, etc. as applicable from 1997 through now
- ❑ Provide copies of plant specific responses to NRC or internal review memo for applicable generic communications
- ❑ Provide Maintenance Rule performance trends for the system over the last 5 years (availability, reliability, lost power generation, MPFFs, RMPFFs)
- ❑ Cost of new SSCs, repairs, refurbishment, upgrade, redesign, etc

Table 3-5
Aging Management Maintenance Tasks

COMPONENT	DEGRADATION MECHANISM	CURRENT PLANT AGING MANAGEMENT PROGRAM-TASKS	POTENTIAL ENHANCEMENTS
Tubes (Sample entry)	*Erosion-Internal*	*On-line tube cleaning*	
	Erosion-External	*Visual inspection at 18 months*	
	MIC	*MIC control program, chemistry*	
	Cracking (SCC, Fatigue, impact)	*none*	*Eddy current inspection, 20% sampling per refuel*
	Bio-Fouling	*On-line tube cleaning*	

Table 3-6
Maintenance History Review of the SSC

W. O. No.	WORK ORDER DESCRIPTION	FAILURE CAUSE	PROCEDURE	DATE	MAN HOURS	MAT. COST
	(examples)					
8908472	*Repair LP Condenser Tube Leaks*	*Suspected MIC*	*None*	*03-25-89*	*398*	*600.00*
9504565	*Perform EC, Waterbox 1 Tubes*	*Find tube holes*	*Vendor*	*10-09-95*	*190*	*0*
9808471	*Condenser Valve Repair*	*Valve leakage*	*--*	*04-16-98*	*400*	*1350.00*
9703635	*Replace Expansion Joint, Turb. Neck*	*Aging of material*	*P0190.13A*	*03-15-97*	*220*	*12600.00*

Table 3-7
Listing of Typical Plant PM Programs
(Use this as a checklist to identify plant specific activities for the SSC)

Generic PM Program Name	Is the PM Program Currently Applied to the Component: YES	NO	Provide Program Document Reference, any Remarks, Frequency, Limitations (Inaccessible, Elective, As Required)
Condition Monitoring Programs:			**NA=Not Applicable**
Surveillance Testing			
Functional Testing			
Leak and Hydro Testing			
Thermography			
Vibration Monitoring			
Oil Analysis (Ferrography)			
System Performance Trending (MR)			
Component Performance Monitoring (ΔT, ΔP, Flow, Current, Voltage, etc)			
Water Chemistry			
Valve Performance Testing			
Check Valve Testing			
Erosion/Corrosion Monitoring			
Minimum Wall Thickness Testing			
Relief Valve Testing			
In-service Inspection (ASME Section XI)			
In-Service Testing (ASME Section XI, O&M)			
Motor Megger Test			
Motor Current Analysis			
Equipment Exercising (Manual)			
Control Room Monitoring, Alarms			
Local Monitoring			
Bearing Temperature Monitoring			
Calibration			
Cycle Monitoring			
Insurance Inspections			
Corrosion Coupon Monitoring			
Time Directed PM Programs:			
Operator Rounds			
Internal/External Inspections			
Clean-Inspect-Lubricate			
Packing and Seal Adjustment			
Oil/Grease Change			
Refurbishment, Overhaul			
Wear Part Replacement			
NDE Testing			
Cleaning (Dirt, Dust, Fouling, Crud)			
EQ Replacement			

Table 3-8
Inventory of SSC Maintenance Tasks and Parameters

ITEM	TASK DESCRIPTION	MAINTENANCE CATEGORY (1)	NO. OF COMP. n	LABOR hrs	LABOR CATEGORY (2)	MATERIAL COST $	FREQUENCY or FAILURE RATE per year
	Example of Maintenance Tasks						
1.0	*Condenser Tubes (1 bundle)*						
1.1	*Video Scoping (before/after cleaning)*	*PM*	*1*	*8*	*CR*	*0*	*0.666*
1.2	*Visual Insp. (before/after cleaning)*	*PM*	*1*	*4*	*CO*	*0*	*0.666*
1.3	*100% Tube Cleaning*	*PM*	*1*	*24*	*CR*	*70000*	*0.666*
1.5	*EC Tube Wall Trending*	*PM*	*1*	*40*	*EN*	*0*	*0.666*
1.7	*Leakage Dye Test*	*PM*	*1*	*40*	*CR*	*30000*	*0.666*
1.8	*Tube Plugging On Line*	*CM*	*1*	*200*	*CR/US*	*4000*	*1.00*
1.9	*Tube Plugging in Outage*	*RR*	*1*	*40*	*CR/US*	*2000*	*0.666*
1.11	*Complete Tube Replacement*	*RR*	*1*	*0*	*CR/US*	*8x10+6*	*once*
5.2	*Power Reduction for degraded condenser*	*LPG*	*1*	*0*	*NA*	*Lost MWh x $/MWh*	*40*

(1) PM: Preventive maintenance, surveillance, testing and inspection
LPG: Lost power generation CM: Corrective maintenance, repair
RR: Planned Replacement, Refurbishment
(2) CR: Craft Labor US: Unskilled labor VE: Vendor CO: Consultant
EN: Engineering

3.4 Comparison of Generic Data to Plant-Specific Data and Conditions

Once a solid inventory of plant-specific maintenance activities has been assembled, comparison or benchmarking to the generic bases can be accomplished as follows:

- The plant specific maintenance tasks (Table 3.8) are compared to the generic listing given in the SSC specific Sourcebook and differences are identified, both those generic tasks representing a potential enhancement and those plant specific tasks having a potential for discontinuance. These differences provide a first glimpse at the potential plant specific maintenance enhancements.
- The EPRI SYSMON parameters are compared to the plant specific maintenance rule performance parameters to determine if plant data is adequate to characterize the SSC performance.
- The EPRI PM Basis SSC specific Template (or the applicable PMIR template) is compared to the corresponding plant specific tasks to determine if the plant PM tasks are consistent and have the appropriate criticality ranking, frequency and task attributes. Again, opportunities for enhancements are identified.
- The generic SSC system contribution to lost power generation is compared to the plant specific data to determine if the plant specific SSC performance is satisfactory or could benefit from adjustment.
- The generic failure rates given in the SSC specific Sourcebook are compared to the plant specific data to evaluate the causes for differences and to identify opportunities for enhancements through redesign or new preventive or diagnostic tasks.
- The generic aging effects and mechanism matrix given in the SSC specific Sourcebook is compared to the plant specific SSC conditions and aging management activities to determine if additional actions are desirable.
- Complete the obsolescence questionnaire to determine the seriousness of SSC specific obsolescence and identify corrective actions and contingencies to avoid future problems (or apply EPRI-Lite [16]).

3.5 Identifying Plant-Specific Aging Mechanisms and Conditions (Outliers)

When reviewing the generic aging matrix, an applicability assessment needs to be made, to assure that the conditions, configurations and environments at the LCM locations are representative and fall within the ranges stated for the generic data. The absence of observed aging effects at the plant may not provide sufficient basis for excluding aging effects -- they may just be slower or are not manifested yet. Plant-specific conditions may also be more aggressive for certain aging effects (i.e. a cold climate will promote freeze-thaw damage and proximity to the ocean will accelerate corrosion). The sourcebook should spell out these considerations.

During the corrective Work Order review, age related degradation already experienced should be evident as a result of the root cause determinations, repetitive work orders for coating maintenance, replacement of components, excessive spare parts use and similar indicators. For age related degradation not yet seen at the plant, the generic aging matrix given in the sourcebook provides an opportunity to identify additional preventive and mitigative aging management actions for the SSC.

3.6 Comparing and Evaluating In-Plant Obsolescence Situations

A simplified obsolescence assessment has been presented in Table 2.2. This simple test should be conducted by a team of knowledgeable engineers, with the purpose of gathering the pertinent data and to arrive at a consensus with respect to the seriousness of obsolescence for the specific SSC. If the result of the Table 2.2 test puts the SSC in the GREEN condition, the test should be repeated every few years (about two refuel cycles) to assure that the condition has not changed, because obsolescence is time dependent.

If the obsolescence test gives a YELLOW or RED condition, plans need to be put in place to deal with obsolescence and contingencies need to be established and scheduled. The options available for managing obsolescence will likely result in the identification of LCM Planning Alternatives due its normally high cost impact. The SSC specific Sourcebook identifies potential obsolescence concerns and discusses generic options for managing obsolescence.

EPRI is currently developing a more rigorous methodology to evaluate and plan for obsolescence. This EPRI-Lite program [16] will provide more detailed guidance to the utility for SSC specific obsolescence assessment and scoring. In addition, the various plant owners groups may have addressed the obsolescence of and availability of spares for specific SSCs, the results of which should be evaluated for plant-specific application.

3.7 Establishing Plant Unique Variations to Generic LCM Alternatives

In the SSC specific Sourcebook, the generic LCM Planning Alternatives relevant to the SSC are discussed. It is important to understand the key drivers for the LCM Alternatives. A plant that has a poor availability, as indicated by a high UCLF when compared to the fleet average and that shows a much higher SSC specific contribution to lost power generation when compared to the generic value, will show a large cost for lost power generation, which in turn will drive the decision process by justifying major SSC improvements. Similarly, plant specific increased failure projections for the SSC result in higher lost power generation cost. The timing of implementing corrective action is therefore an important consideration when defining plant-specific LCM Planning Alternatives.

If the plant SSC performance history (unavailability) and failure rates are substantially below (i.e. by a factor of 3 or more) the industry average and preventive/predictive maintenance is exercised, further performance improvements will be difficult to achieve and fine tuning of the current maintenance plan may be the LCM alternative with the best chance of being optimum. It is also possible that excessive resources are expended to maintain a high performance level, so that a significantly lower O&M cost would be appropriate to evaluate.

On the other hand, if the plant SSC failure rates exceed the industry average by a substantial margin, say by a factor of 3 or more, aggressive maintenance enhancement will likely be a successful and economical alternative.

The financial assumptions, particularly the assumed inflation and discount rates, can significantly influence the economic results and may drive the decision process. Using a set of assumptions to perform a sensitivity analysis often results in selecting different optimum solutions. The nature of the Net Present Value concept favors delay of major capital expenditures (when discount rate is higher than inflation, you have to set less and less money aside today to pay for future capital investments) and therefore a strategy that times large expenditures late in life will be favored. This effect can only be overcome if reductions in lost power generation cost can offset the early capital expenditure.

Plant specific attributes, such as plant age, type, size, number of units and ownership (federal, state, municipal, operating company, subsidiary or publicly traded) will also have an impact on the financial parameters and the results of LCM Planning.

Lastly, it is of utmost significance that the important cost components for each of the available LCM Alternatives be captured, including the consequences of SSC failures, increased UCLF, SSC reliability changes, regulatory costs and the need for materials and parts. The LCM planning report [1] provides some insights regarding the quantification of regulatory costs and business risk.

3.8 Collecting Data for Economic Evaluation

In this overview report, no cost data are presented because generic data would be of little use to individual plants, given their specific needs and accounting practices and the significant variations in equipment types and sizes. Clearly, however, the cost data used should be consistent with the plant's normal practices for accounting and financial analysis. However, some general guidance can be provided with respect to various types and sources of cost information.

The economic evaluation of LCM alternatives relies on a determination of the net present values of all costs incurred as a result of the implementation of a specific strategy and LCM plan. These costs may be expressed either in total or as a differential from a base case. The costs to be considered should include the following:

- Both direct and indirect maintenance costs for labor and materials. Indirect costs may include decontamination, disposal, transport, rigging, scaffolding, staging, removal and installation of insulation, coatings/painting, security, health physics, fluid draining/disposal/reclamation and similar costs associated with the implementation of the activity.
- Costs associated with regulatory action, including preparation of LERs, MPFF reporting, additional inspections (including those associated with the assignment of (a)(1) status under the Maintenance Rule to SSCs), team inspections, justification for continued operation, self imposed outages or temporary shutdown and similar regulatory consequences.

- Costs resulting from a forced or voluntary plant shut down or extended outages
- Costs resulting from the clean-up of accidents, spills, contamination, damage and restoration
- Capital and training costs associated with any replacement of equipment.
- Cost for lost power generation as a result of expected component failure rates and associated loss of system function (if any)
- Cost of additional or new spare parts and maintenance thereof

Again, these bullets are generic. Our intention was to make them specific to IAS to the extent possible.

Regardless of the costs involved and their grouping for analytical and presentation purposes, it will probably be useful to tabulate the data required for LCM maintenance planning on a maintenance activity worksheet. A sample of such a work sheet is illustrated in Table 3.8.

3.8.1 Plant Outage Data

- Cost data for a forced plant outage (i.e., production and revenue losses, replacement power costs and duration).
- Cost data for the prolongation of a scheduled outage.
- Data pertaining to plant reduced power production or availability
- The anticipated cost to the plant of enhanced regulatory scrutiny should that be precipitated by equipment failures or additional plant outages

3.8.2 Data on Existing Preventive or Predictive Maintenance Programs

- The current or anticipated frequency of the scheduled or planned preventive maintenance task.
- The hours required for crafts and other labor to perform the scheduled preventive maintenance task(s).
- Supervisory and engineering hours associated with initiating and overseeing preventive maintenance and interpreting and trending any data derived from this maintenance activity.
- The costs of any parts or consumables required for each task.
- Any fixed costs associated with the implementation of a work order or request if it is normal plant practice to allocate these separately to each maintenance item.
- Plant outage extension costs, if this preventive maintenance lies on the plant outage critical path or might prolong an outage.
- Possible costs associated with the removal of an SSC or train or component from service (e.g., the impact on the predicted frequency of plant shutdown or severe accidents and the plant's ability to perform other maintenance given the risk profile). Include impact of LCO and or exceeding LCO (AOT).

3.8.3 Data on Corrective Maintenance Tasks

- The anticipated frequency of the scheduled or unscheduled task. This should normally be one of the SSC failure rates.
- Costs associated with the response of operating staff to the failure (e.g., the posting of watches).
- The hours required for crafts and other labor to perform the maintenance
- Supervisory and engineering hours associated with initiating and overseeing the maintenance and interpreting and trending any data derived from it.
- The costs of any parts or consumables required for each task. The cost of spare parts should include whatever amount is normally allocated in the plant's accounting practices for warehousing parts.
- Any fixed costs associated with the implementation of a work order or request if it is normal plant practice to allocate these separately to each maintenance item.
- Possible costs associated with the removal of an SSC, train or component from service (e.g., the impact on the predicted frequency of plant shutdown or severe accidents and the plant's ability to perform other maintenance given the risk profile).
- Maintenance Rule costs should the SSC, as a result of this failure, exceed its performance criteria and thus be assigned (a)(1) status under the Rule.

3.8.4 Data for Proposed Preventive and Predictive Maintenance Tasks

- The anticipated frequency of the scheduled maintenance task.
- The hours required for crafts and other labor to perform the scheduled maintenance task(s).
- Supervisory and engineering hours associated with initiating and overseeing maintenance and interpreting and trending any data derived from this maintenance activity. The hours required to generate and implement new procedures, programs, guidelines and training.
- The costs of any parts (or allocated diagnostic equipment costs or new tools) or consumables required for each task.
- Any fixed costs associated with the implementation of a work order or request if it is normal plant practice to allocate these separately to each maintenance item.
- Plant outage extension costs, if this proposed preventive maintenance lies on the plant outage critical path or might prolong an outage. These costs may be handled in a probabilistic fashion if appropriate.
- Data with which to characterize the impact of the proposed task on equipment failure rates (including the ability to substitute planned repairs or replacements for corrective maintenance) and on the anticipated need for, and timing of, equipment replacement as a result of wear out.

3.8.5 Data for Proposed Equipment Replacement Tasks

- The capital cost for the equipment including delivery and installation costs. The latter may comprise labor hours and hourly rates for labor if the work is to be performed by plant staff.
- For major repairs and replacements, the estimators should be consulted or the vendors should be contacted for reasonable estimates. Costs should be acquired in present day Dollars. If repair or replacement costs are based on past experience, the cost needs to be adjusted to present value by escalating at the historic average inflation rate.
- Plant outage extension costs, if this proposed equipment replacement lies on the plant outage critical path or might prolong an outage.
- Such labor and engineering costs for procurement, planning, installation and start up as are appropriate, (including interchangeability studies, interface engineering, support services for electric supply, cooling water, drains, supports and foundations, etc).
- When making design changes or operational changes, the costs need to consider licensing and FSAR and /or Tech Spec changes, updating or revising drawings, logic diagrams, specifications, procedures, functional descriptions or DBDs.
- Training costs for maintenance and operating personnel should replacement equipment represent new technology or require new skills.
- Removal, disposition and disposal of the old equipment
- When stocking spare parts for future replacement (as a contingency to obsolescence), purchase of the new inventory and the warehousing must be estimated. If the components are replaced later, sale of the inventory should be considered (as a negative cost).

3.8.6 Data for Proposed Elimination of Existing Maintenance Tasks

- Should the elimination of existing maintenance tasks be one of the alternatives to be considered under LCM maintenance planning, the impact of the proposed task on equipment failure rates, on anticipated availability and /or reliability changes and on the anticipated need for, and timing of, equipment replacement as a result of wearout should be considered.

3.8.7 Regulatory, Licensing and Administrative Cost Data

In addition to the business and regulatory risk discussed in the LCM Demonstration Report, other regulatory and administrative cost may be associated with the SSC performance. For instance:

- If unacceptable performance causes the SSC to be treated as A1 under the Maintenance Rule, such action may cost $20,000 or more
- If a safety related component failure causes a loss of function, processing the LER, performing cause determination, preparing justification for continued operation, tracking LCO limits, making a PRA run, etc, may cost as much as $50,000 or more.

- A repetitive problem at the plant that triggers an NRC special inspection or investigation may consume $100,000 or more in plant resources over a 6-week period.
- An engineering study to facilitate the replacement of an obsolete component with a new and different model may cost $15,000 or more.

3.9 How to Draw Conclusions for Planning Decisions

The comparison of LCM Planning Alternatives is made on the basis of NPV, such that the least cost alternative (viewing lost revenues as a cost) would normally be the clear favorite. This presumes that all affected cost components have been considered and the assumed (projected) failure rates are realistic. The decision is normally driven by one of the three principal cost components, PM, Corrective Maintenance and Lost Power. Of these, the Corrective Maintenance cycle is based on a projected failure rate or assumed improvement of performance and availability. It is therefore prudent to vary these assumptions and test the sensitivity on the results.

When modeling lost power production, another decision driver, care must be taken to avoid "Double Dipping", that is, assuming the cost of planned power generation more than once in various LCM plans. In reality, more than one major activity will be scheduled during a prolonged planned outage. This may not always be the case for unplanned outages.

To estimate the cost lost power production (i.e. lost rercaues), it is important to use electricity price projections appropriate for a competitive industry. This is not a straightforward task. Engineers preparing LCM plans should consult with the company's financial specialists. A single average value has been used in the twelve LCM plans prepared to date. EPRI has an R&D program for projecting electricity price (contact the project manager, V. Niemeyer).

Lastly, one has to consider the timing of major planned activities, because of the NPV effect. Discount and inflation rate assumptions can vary widely with time (note that the 75-year historical average is 3.5% inflation and 5.3% discount rate).

3.10 SSC-Level Versus Plant-Level LCM Planning

Currently, as described in the LCM report and LCM sourcebook reports, detailed LCM planning is performed at the SSC level. It is recognized that ultimately the results of the SSC level LCM plans must be combined at the plant level to assure that individual SSC level LCM plans are optimized with respect to plant strategies. This optimization must address the unavoidable potential of counting the cost of lost power generation more than once at the SSC level (e.g. more than one SSC may be repaired during a forced outage, or more than one major SSC may be replaced during an extended outage). Furthermore, the SSC level LCM plans must be optimized by integrating the schedules of major tasks at the plant level to avoid multiple extended outages. System interactions at the plant level must be integrated to assure maximum economic benefit (e.g. a condenser tube replacement would be integrated with a steam generator replacement and a change in water chemistry). Until EPRI plans for developing plant-level

LCM tools are carried out, SSC level LCM plans need to be integrated manually, using engineering experience and judgment.

In addition, it is almost certain that the total O&M expense needed to implement the system-level optimum LCM plans for all SSCs would exceed approved annual O&M budgets. Only plant-level LCM planning and optimization can identify the optimum set of SSC LCM plans constrained by a given budget amount. EPRI has plans to provide tools for plant-level planning. The ultimate goal is to achieve (1) acceptably safe plant operation over the remaining plant licensed term. (2) maximum financial gain for a given investment in improved plant operation.

4
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A
STANDARD TABLE OF CONTENTS FOR AN LCM SOURCEBOOK

EPRI Report Summary

1 MANAGEMENT SUMMARY

2 INTRODUCTION
- 2.1 Purpose of LCM Sourcebook
- 2.2 Relationship of Sourcebook to LCM Process
- 2.3 Basis for Selection of SSC for LCM Sourcebook

3 BACKGROUND INFORMATION
- 3.1 Safety and Operational Significance
- 3.2 Functions
- 3.3 System and Component Boundaries
- 3.4 Scope of Equipment Covered by Sourcebook

4 INDUSTRY OPERATING EXPERIENCE AND PERFORMANCE HISTORY
- 4.1 Nuclear Industry Experience
- 4.2 NRC Generic Communications and Other Reports
- 4.3 Experience in Fossil, Industrial Applications
- 4.4 Potential Use of Generic Performance Data

5 GUIDANCE FOR PLANT-SPECIFIC SSC CONDITION AND PERFORMANCE ASSESSMENT
- 5.1 SSC Condition Reviews
- 5.2 Condition Monitoring Technologies
- 5.3 Review of Current Maintenance Plans

6 GENERIC AGING AND OBSOLESCENCE ASSESSMENT
- 6.1 Aging Mechanism Review
- 6.2 Expected Lifetimes of Major Components
- 6.3 Technical Obsolescence

7 GENERIC ALTERNATIVE LCM PLANS
- 7.1 Plant Operating Strategies and Types of LCM Planning Alternatives
- 7.2 Development of Detailed Alternative LCM Plans

7.3 Hypothetical Illustration of Assembling LCM Planning Alternatives

8 GUIDANCE FOR ESTIMATING FUTURE FAILURE RATES

9 GUIDANCE FOR PLANT-SPECIFIC ECONOMIC EVALUATION

10 REFERENCES AND INFORMATION SOURCES

B
TYPICAL TABLE OF CONTENTS FOR AN LCM PLAN

Table of Contents

1 INTRODUCTION

2 BACKGROUND INFORMATION
- 2.1 Basis for Selection
- 2.2 LCM Planning Strategies
- 2.3 System Description

3 OPERATING AND MAINTENANCE EXPERIENCE
- 3.1 Plant Operating and Maintenance Experience
- 3.2 Industry Operating and Maintenance Experience

4 CURRENT MAINTENANCE ACTIVITIES
- 4.1 Preventive Maintenance Activities
- 4.2 Surveillance Activities
- 4.3 Testing Activities
- 4.4 Corrective Activities

5 SYSTEM PERFORMANCE ISSUES AND FAILURE DATA

6 AGING AND OBSOLESCENCE ISSUES

7 LCM PLANNING ALTERNATIVES

8 ECONOMIC COMPARISON OF LCM ALTERNATIVES

9 LCM PLANNING RESULTS AND RECOMMENDATIONS

10 REFERENCES

C
ACRONYMS

AE	Architect-Engineering firm
AMG	Aging Management Guide, a Sandia product
ASME	American Society of Mechanical Engineers
BOP	Balance of Plant
BWR	Boiling Water Reactor
CC	Component/Commodity
CCW	Component Cooling Water
CLB	Current Licensing Basis
CM	Corrective Maintenance
DBD	Design Basis Documents
DOE	Department of Energy
ECCS	Emergency Core Cooling System
EHC	Electro Hydraulic Control
EPIX	Equipment Performance Information Exchange, a database maintained by INPO
EPRI-Lite	An EPRI Equipment Reliability and Obsolescence Evaluation Tool
EQ	Equipment Qualification or Environmental Qualification
ESF	Engineered Safety Feature
FSD	Functional System Description
GALL	Generic Aging Lessons Learned, NUREG-1801
GC	Generic Communications, NRC publications
IAS	Instrument Air System
I&C	Instrumentation & Control
INPO	Institute of Nuclear Power Operations
ISI	In-service Inspection
IST	In-service Testing

LCM	Life Cycle Management
LCMT	LCM Technology, L.C.
LcmPLATO	Life Cycle Management Planning Tool
LcmTEMPLATE	Life Cycle Management Template
LcmVALUE	Life Cycle Management Value
LCO	Limited Condition of Operation
LP	Low Pressure
LR	License Renewal
MCC	Motor Control Center
MOV	Motor Operated Valve
MPFF	Maintenance Preventable Functional Failure as defined by the MR
MR	Maintenance Rule
MWh	Megawatt hour
NEI	Nuclear Energy Institute
NIS	Nuclear Instrumentation System
NMAC	Nuclear Maintenance Analysis Center, an EPRI organization
NPAR	Nuclear Plant Aging Research, an NRC program
NPRDS	Nuclear Power Reliability Data System, a discontinued database maintained by INPO
NPV	Net Present Value
NRC	Nuclear Regulatory Commission
NSSS	Nuclear Steam Supply System
NUREG	NRC report designator
OEM	Original Equipment Manufacturer
O&M	Operations & Maintenance
PM	Preventive Maintenance
PdM	Predictive Maintenance
PRA	Probabilistic Risk Assessment
PSA	Probabilistic Safety Analysis (synonymous with PRA)
PWR	Pressurized Water Reactor
RCM	Reliability Centered Maintenance

RMPFF	Repetitive Maintenance Preventable Functional Failure
SAR	Safety Analysis Report
SS	System/Structure
SSC	System, Structure, or Component
SYSMON	System Monitoring for System Engineers, an EPRI Tool
UCLF	Unplanned Capability Loss Factor
UGP	Underground Piping
WO	Work Order
WOG	Westinghouse Owners Group

Target:
Nuclear Power

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