Service Life Extension

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Product and service life extension involves continued use of a product and/or service beyond its original design life. Product and service life extension involves assessing the risks and the life cycle cost (LCC) of continuing the use of the product or service versus the cost of a replacement system.

Service life extension (SLE) emphasizes reliability upgrades and component replacement or rebuilding of the system to delay the system's entry into *wear-out* status due to issues such as expensive sustainment, reliability, safety, and/or performance requirements that can no longer be met. The goal is typically to return the system to as new a condition as possible while remaining consistent with the economic constraints of the program.

SLE is regarded as an environmentally friendly way to relieve rampant waste by prolonging the useful life of retiring products and preventing them from being discarded too early when they still have unused value. However, challenged by fast-changing technology and physical deterioration, a major concern in planning a product SLE is considering to what degree a product or service is fit to have its life extended.

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Topic Overview

SLE is typically required in the following circumstances:

- The system no longer meets the system performance or reliability requirements.
- The cost of operation and maintenance exceeds the cost of SLE, or the available budgets.
- Parts are no longer available for repair and maintenance.
- Operation of the system violates rules or regulations, such as environmental or safety regulations.
- Parts of the system are about to reach their operations life limits, which will result in the issue listed above occurring.

It is best if systems engineers use a proactive approach that predicts ahead, so that SLE can be accomplished before the system fails to meet its requirements and before the operations and support costs rise above acceptable limits.

Key factors that must be considered by the systems engineer during service life extension include:

- current life cycle costs of the system
- design life and expected remaining useful life of the system
- software maintenance
- configuration management
- warranty policy
- availability of parts, subsystems, and manufacturing sources
- availability of system documentation to support life extension

System design life is a major consideration for SLE. System design life parameters are established early on during the system design phase and include key assumptions involving safety limits and material life. Safety limits and the properties of material aging are critical to defining system life extension. Jackson emphasizes the importance of architecting for system resiliency in increasing system life. He also points out that a system can be architected to withstand internal and external disruptions (2007, 91-108). Systems that age through use, such as aircraft, bridges, and nuclear power plants, require periodic inspection to ascertain the degree of aging and fatigue. The results of inspections determine the need for actions to extend the product life (Elliot, Chen, and Swanekamp 1998, sec. 6.5).

Software maintenance is a critical aspect of SLE. The legacy system may include multiple computer resources that have been in operation for a period of many years and have essential functions that must not be disrupted during the upgrade or integration process. Typically, legacy systems include a computer resource or application software program that continues to be used because the cost of replacing or redesigning it is prohibitive. The Software Engineering Institute (SEI) has addressed the need for SLE of software products and services and provides useful guidance in the online library for Software Product Lines (SEI 2010, 1). (See Systems Engineering and Software Engineering for additional discussion of software engineering (SwE) factors to consider.)

Systems engineers have found that service life can be extended through the proper selection of materials. For example, transportation system elements such as highway bridges and rail systems are being designed for extended service life by using special epoxy-coated steel (Brown, Weyers, and Spinkel 2006, 13). Diminishing manufacturing sources and diminishing suppliers need to be addressed early in the SLE process. Livingston (2010) in *Diminishing Manufacturing Sources and Material Shortages (DMSMS) Management Practices* provides a method for addressing product life extension when the sources of supply are an issue. He addresses the product life cycle model and describes a variety of methods that can be applied during system design to minimize the impact of future component obsolescence issues.

During product and service life extension, it is often necessary to revisit and challenge the assumptions behind any previous life cycle cost analysis (and constituent analyses) to evaluate their continued validity and/or applicability early in the process.

Application to Product Systems

Product life extension requires an analysis of the LCC associated with continued use of the existing product versus the cost of a replacement product. In the INCOSE Systems Engineering Handbook, Chapter 3.3 points out that the support stage includes service life extension (2012). Chapter 7 provides a framework to determine if a product's life should be extended (INCOSE 2012). In Systems Engineering and Analysis, Chapter 17 provides an LCC methodology and emphasizes the analysis of different alternatives before deciding on product life extension (Blanchard and Fabrycky 2011).

For military systems, service life extension is considered a subset of modification or modernization. Military systems use well-developed and detailed guidance for SLE programs (SLEP). The Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (OSD AT&L) provides an online reference for policies, procedures, planning guidance, and whitepapers for military product service life extension (DAU 2011). Continuous military system modernization is a process by which state-of-the-art technologies are inserted continuously into weapon systems to increase reliability, lower sustainment costs, and increase the war fighting capability of a military system to meet evolving customer requirements throughout an indefinite service life.

Aircraft service life can be extended by reducing the dynamic loads which lead to structural fatigue. The Boeing B-52 military aircraft and the Boeing 737 commercial aircraft are prime examples of system life extension. The B-52 was first fielded in 1955 and the Boeing 737 has been fielded since 1967; both aircraft are still in use today.

For nuclear reactors, system safety is the most important precondition for service life extension. System safety must be maintained while extending the service life (Paks 2010). Built-in tests, automated fault reporting and prognostics, analysis of failure modes, and the detection of early signs of wear and aging may be applied to predict the time when maintenance actions will be required to extend the service life of the product. (For additional discussion, see Safety Engineering.)

Application to Service Systems

For systems that provide services to a larger consumer base, SLE involves continued delivery of the service without disrupting consumer use. This involves capital investment and financial planning, as well as a phased deployment of changes. Examples of these concepts can be seen in transportation systems, water treatment facilities, energy generation and delivery systems, and the health care industry. As new technologies are introduced, service delivery can be improved while reducing LCC's. Service systems must continuously assess delivery costs based upon the use of newer technologies.

Water handling systems provide a good example of a service system that undergoes life extension. Water handling systems have been in existence since early civilization. Since water handling systems are in use as long as a site is occupied (e.g., the Roman aqueducts) and upgrades are required as the population expands, such systems are a good example of "systems that live forever." For example, there are still U.S. water systems that use a few wooden pipes since there has been no reason to replace them. Water system life extension must deal with the issue of water quality and the capacity for future users (Mays 2000). Water quality requirements can be further understood from the AWWA Manuals of Water Supply Practices (AWWA 2010).

Application to Enterprises

SLE of a large enterprise, such as the National Astronautics and Space Administration's (NASA) national space transportation system, involves SLE on the elements of the enterprise, such as the space vehicle (shuttle), ground processing systems for launch operations and mission control, and space-based communication systems that support space vehicle tracking and status monitoring. SLE of an enterprise requires a holistic look across the entire enterprise. A balanced approach is required to address the cost of operating older system components versus the cost required to implement service life improvements.

Large enterprise systems, such as oil and natural gas reservoirs which span broad geographical areas, can use advanced technology to increase their service life. The economic extraction of oil and natural gas resources from previously established reservoirs can extend their system life. One such life extension method is to pump special liquids or gases into the reservoir to push the remaining oil or natural gas to the surface for extraction (Office of Natural Gas & Oil Technology 1999).

Other Topics

Commercial product developers have been required to retain information for extended periods of time after the last operational product or unit leaves active service (for up to twenty years). Regulatory requirements should be considered when extending service life (INCOSE 2012).

Practical Considerations

The cost associated with life extension is one of the main inputs in the decision to extend service life of a product or a service. The cost of SLE must be compared to the cost of developing and deploying a new system, as well as the functional utility the user will obtain from each of the alternatives. It is often the case that the funding required for SLE of large complex systems is spread over several fiscal planning cycles and is therefore subject to changes in attitude by the elected officials that appropriate the funding.

The challenges with upgrading a system while it is still being used, which is often the case with SLE, must be understood and planned to avoid serious disruptions to the services the systems provide.

Any SLE must also consider the obsolescence of the systems parts, (e.g., software, amount of system redesign that is required to eliminate the obsolete parts, etc.).

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