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2nd International Through-life Engineering Services Conference

Design for obsolescence risk management

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Abstract

Many systems that are required to be manufactured and supported for long time periods lack control over critical portions of their supply chains; these systems include: military, avionics, industrial controls, rail infrastructure. This results in the components and technologies that these products depend on becoming obsolete (and unavailable) long before the system's demand for them is exhausted. Through-life cost models that incorporate obsolescence management are needed so that on sustainment costs can be clearly understood during decision making, and the value of future management actions can be established to support business cases for strategic management.

Selection and peer-review under responsibility of the International Scientific Committee of the "2nd International Through-life Engineering Services Conference" and the Programme Chair – Ashutosh Tiwari.

Keywords: Obsolescence, DMSMS, through-life costing

1. Introduction

Obsolescence is defined as the loss or impending loss of original manufacturers of items or suppliers of items or raw materials [1]. The type of obsolescence addressed in this paper is known as DMSMS (Diminishing Manufacturing Sources and Material Shortages), which is caused by the unavailability of technologies or parts[1] that are necessary to manufacture or sustain a system. Due to the length of the system's manufacturing and support life, and unforeseen life extensions to the support of the system longer than its planned end of support date, the parts and other resources necessary to support the system become unavailable before the system's demand for them ends. Part unavailability from the original manufacturer means an end of support for the part and end of production of new instances of the part.[2] Although parts may remain available from aftermarket sources, the use of aftermarket sources entails risks that may be unacceptable to some types of systems.[3] The most significant DMSMS problems are for electronic parts where the amount of time a part is available from its original manufacturer (i.e., its procurement life) can be less than a year in some cases.

The DMSMS obsolescence problem is especially problematic for "sustainment-dominated" systems where the cost of sustaining (maintaining) the system over its support life exceeds the cost of manufacturing or procuring the system [4]. In many cases the design cycles for many sustainment-dominated systems are long enough that a significant portion of the electronics becomes obsolete prior to the system being fielded, e.g., Figure 1. Once these systems are fielded, their support can last for 20 additional years or more. An even more significant issue is that the end of support date for systems like the one shown in Figure 1 is not known and will

[1] In this paper, "part" refers to the lowest management (manufacturing, sparing, repairing) level for the system.

[2] Inventory (also called "sudden") obsolescence is the opposite of DMSMS obsolescence. Inventory obsolescence occurs when the product design or system specifications change and as a result existing inventories of parts are no longer needed, e.g., [2].

[3] For example, the risk of obtaining counterfeit parts, [3].

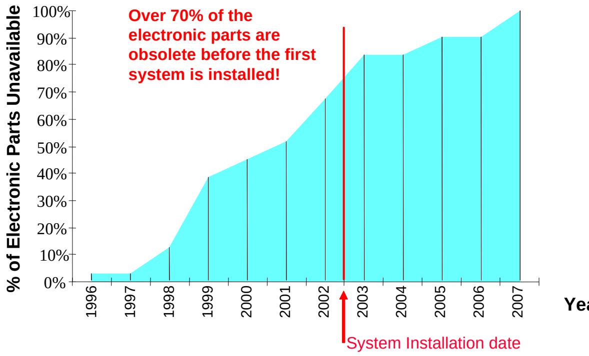

Fig. 1. Portion of the Commercial Off The Shelf (COTS) electronic parts that become un-procurable in the first 10 years of a surface ship sonar system's life cycle (Courtesy of NAVSURFWARCENDIV Crane, [5]).

likely be extended from its original plan one or more times before the system is retired.

For systems like the one shown in Figure 1, replacing obsolete parts with newer non-obsolete parts many not be a viable solution because of high re-engineering costs, and the potentially prohibitively high cost of system re-qualification and re-certification. For example, if an electronic part in the 25-year old control system of a nuclear power plant fails, an instance of the original part may have to be used to replace it because replacement with a part with the same form, fit, function and interface that isn't an instance of the original part could jeopardize the "grandfathered" certification of the plant.

Sustainment-dominated products suffer particularly severe consequences of electronic part obsolescence because they have no control over their supply chain for electronic parts due to their low production volumes. DMSMS type obsolescence occurs when long field life systems must depend on a supply chain that is organized to support high-volume products, [6]. Obsolescence becomes a problem for an organization when the organization is forced to involuntarily make a change to the system that it manufactures, supports or uses.[4]

1.1. The Need for Business Cases

Engineers complain to program-level management daily that the "sky is falling" due to a range of technical and logistical issues (for electronics systems these include: lead-free parts, tin whiskers, counterfeit parts, obsolete parts, etc.). Management is often not moved to action until a catastrophic event has occurred or a detailed quantitative demonstration of the risks associated with the issue has been performed. To determine how resources should be allocated, management asks the following questions: 1) Has a serious event occurred as a result of this problem (loss of life, loss of equipment or loss of mission)? and 2) What is the likely future impact of this problem on me if I don't take action (e.g., in terms of cost and/or availability)?

If a serious problem has not occurred, it is likely that a business case will be necessary before management takes action. Often engineers have vast and valuable experience managing systems and a good understanding of the risks that exist, but they lack the ability to articulate those risks and their impact on sustaining systems in terms of the through-life cost and availability measures that management will understand. As a result, sustaining systems (in particular managing obsolescence) remains a largely reactive activity.

2. Obsolescence Management

Effective management of obsolescence in systems requires three different management levels: reactive, pro-active and strategic, Figure 2. Reactive management determines the immediate resolution to the problem of an obsolete part, executes the resolution process and tracks the action(s) taken.

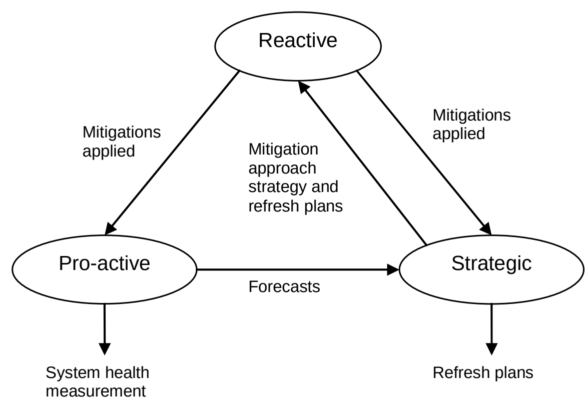

Fig. 2. Three obsolescence management levels [8]

Pro-active management of obsolescence requires the identification of critical parts that: a) are at risk of going obsolete, b) will have an insufficient quantity available after obsolescence to satisfy expected demand, and c) will represent a problem to manage if/when they become obsolete. Once parts are identified they are managed prior to their actual obsolescence event. Pro-active management requires an ability to forecast the obsolescence risk for parts.

Strategic management of obsolescence means using obsolescence data, logistics data, technology forecasting, and business trending (demand forecasting) to enable strategic planning, life-cycle optimization, and long-term business case development for system support. The most common approach to strategic management of obsolescence is design refresh planning (DRP), i.e., determining the set of refreshes that maximizes future cost avoidance (see Section 4.2).

[4] The dynamic nature of an industry is referred to as "clockspeed," [7]. The industry types that generally have to manage DMSMS-type obsolescence problems are slow clockspeed industries. For these industries, because of the expense of sustainment-dominated systems the customers can't afford to replace them with newer systems very often (i.e., slow clockspeed customers). DMSMS-type obsolescence occurs when slow clockspeed industries must depend on a supply chain that is organized to support fast clockspeed industries, [6].

3. Designing Systems (and the Management of Systems) to Mitigate the Risk of Involuntary Obsolescence

For low-volume systems that are supported for long periods of time and have significant electronics content, avoiding obsolescence is not possible. Designing an electronics-rich system that can be supported for 20+ years so that none of its constitute parts become obsolete is generally not practical. Therefore, design for involuntary obsolescence becomes an exercise in making the problem manageable (or minimizing the through-life cost of sustaining the system).

3.1. Obsolescence Forecasting

In order to manage obsolescence, we first need to be able to predict it. The majority of electronic part obsolescence forecasting involves the development of models for the part's life cycle. Traditional methods of forecasting used in commercially available databases and services are based on the use of ordinal scales, that determine the life-cycle stage of the part from a set of technological attributes, e.g., [9,10] – this type of forecasting is available in commercial tools such as TACTRAC™, Total Parts Plus™, and Q-Star™. Models based on technology trends also exist including a methodology based on forecasting part sales curves [11], and data mining the historical electronic parts record [6,12]. A few efforts have appeared that address non-electronic part obsolescence forecasting including [13]. Most obsolescence management organizations perform obsolescence forecasting on their Bills Of Materials (BOM) to avoid selecting parts that are close to obsolescence

3.2. Obsolescence Mitigation

When parts become obsolete there are various mitigation approaches that can be employed, [14]. Replacement of obsolete parts with non-obsolete substitute or alternative parts is common for simple parts where the requirement for re-qualification of the system is not unreasonable. Lifetime buys of parts are also commonly used, i.e., buying and storing enough parts to last through a system's remaining manufacturing and sustainment life. There are also a many aftermarket electronic part sources that range from original manufacturer authorized aftermarket sources that fulfill part orders with a mixture of finished parts (manufactured by the original manufacturer) and new fabrication in original manufacturer qualified facilities (e.g., Rochester Electronics), to brokers and eBay. David Sarnoff Laboratories operates GEM and AME, [15] that are electronic part emulation foundries that fabricate, using newer technologies, replacements for obsolete parts that meet the original part qualification standards. Thermal uprating of available parts to meet the extended temperature range requirements of an obsolete Mil-Spec part can also be performed for some parts, [16].

3.3. Strategic Planning

When information regarding the expected procurement lifetimes[5] of parts is available strategic approaches that enable the estimation of through-life sustainment costs are possible. Even with data that is incomplete and/or uncertain, the opportunity for through-life sustainment cost avoidance is significant if appropriate decision making methods are used.

Several types of strategic planning approaches have been used to manage obsolescence: material risk indices and design refresh planning. Material Risk Index (MRI) approaches analyze a product's bill of materials and scores each part within the context of the application and the enterprise using the part, e.g., [17]. The idea of an MRI is to evaluate the time-dependent risk of a particular function or subsystem within a system being impacted by obsolescence to specific degrees that require specific actions. The evaluated risk can then be mapped to through-life cost. An MRI is easy to use once it exists, but creating it can be burdensome – a catalog of relevant functions for an organization must be created and the probability of risk (of obsolescence precipitated actions) must be calibrated.

Because of the very long manufacturing and field lives associated with sustainment-dominated systems, it is not uncommon for the systems to be refreshed or redesigned one or more times during their lives to manage obsolescence and to update functionality. Technology "refresh" refers to system changes that "Have To Be Done" in order for the system functionality to remain useable. Redesign or technology insertion is a term used to identify the "Want To Be Done" system changes that include both new technologies to accommodate system functional growth and to replace and improve the existing functionality of the system, [18]. Improvements in manufacturing, equipment and/or technology drive redesign of high-volume commercial products. Alternatively, design refresh of sustainment-dominated systems is usually driven by obsolescence that would otherwise render the system un-producible and/or un-sustainable. The goal of design refresh planning (DRP) is to determine when to design refresh (on what dates) and what obsolete system parts should be replaced at each design refresh (versus managing the obsolescence event with a reactive obsolescence mitigation approach).

Design refreshing a system solely to manage obsolescence is not practical for every system. Technology insertion roadmaps are commonly developed for systems in order to dictate changes in the system's functionality and performance over time. Technology roadmaps reflect an organization's internal goals and budgeting cycles, or may be dictated by the needs of the customer. Integrating technology roadmap information into design refresh planning ensures that the refresh plans that are selected will meet roadmap imposed timing and budget constraints, and that the costs of roadmap-specified actions are accommodated within relevant refreshes [19].

[5] Procurement life is the amount of time that a part is available from its original manufacturer, i.e., obsolescence date minus the introduction date, [6].

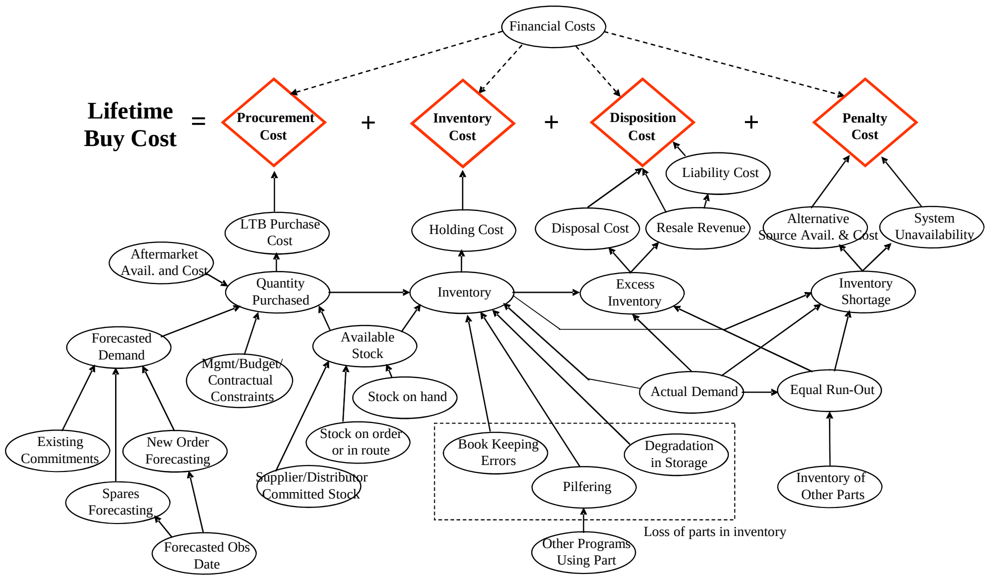

Fig. 3. Lifetime buy costs, [20].

4. Understanding Through-Life Costs

Obsolescence management and risk mitigation approaches cost money to perform. The ability to predict the through-life cost of managing obsolescence within a system is important for two reasons. First it allows an estimation of the cost associated with managing a system in a specific way (for use in the budgeting or bidding process for supporting the system). Secondly, it enables optimization of the management of a system by measuring and trading off the cost impact of multiple management approaches.

In this section we briefly review the cost analysis for several common obsolescence management approaches.

4.1. Lifetime Buy Optimization

Semiconductor manufactures generally notify their customers and distributors when a part is about to be discontinued by providing customers 6-12 months of warning and providing them the opportunity to place a final order for parts, i.e., a “lifetime buy”. Users of the part determine how many parts will be needed to satisfy manufacturing and sustainment of the system until the end of the system’s life and place a last order for parts. Alternatively, bridge buys (last time buys) mean purchasing enough parts to last until a planned design refresh point in the future where the part will be designed out of the system. Lifetime and bridge buys play a role in nearly every part obsolescence management portfolio no matter what other reactive, pro-active or strategic management plans are being used.

Purchasing sufficient parts to meet current and future demands is simpler in theory than in practice due to many interacting influences and the complexity of multiple concurrent buys as shown in Figure 3. Fundamentally, the lifetime buy problem can be divided into two activities: 1) demand forecasting and 2) optimizing the buy quantities based on the demand forecasted.

Forecasted demand depends on manufacturing (sales) forecasts and sustainment expectations (spares) for fielded systems – this paper does not address the demand forecasting portion of the problem. The second portion of the problem is given the demand and its uncertainties, determine the number of parts that should be purchased (buy quantity).

In practice today, the common wisdom usually used to determine buy sizes is a best guess (forecast) of demand based on projected manufacturing needs (if manufacturing is still occurring) and spares needed (based on observed or predicted failure rates) to the planned end of support date; then buffer that quantity by 10%-50%.[6] In most organizations, the buffers are based on “institutional knowledge” and there is little understanding of the statistical meaning or ramifications of the lifetime/bridge buy buffer sizes that are used.

Quantitative approaches to the lifetime/bridge buy problem are also possible - given a demand forecast one can calculate the quantities of parts necessary to minimize through-life cost, which, depending on how you are penalized for running short or running long on parts could be substantially different than what simple demand forecasting tells you to purchase. In general, lifetime buy is an asymmetric problem where the penalty for underbuying parts and overbuying parts are not the same – if they were the same, and then the optimum quantity to purchase would be exactly the forecasted demand. For example, the penalty for underbuying parts is the cost to acquire additional parts long after they became obsolete or redesign the system to use a newer part; while the penalty for overbuying parts is paying for extra parts and paying the

[6] The buffers are put in place to mitigate “life extension” risk. Life extensions may take the form of: a) manufacturing the product that the part is in for longer than anticipated, b) supporting the fielded products for longer than planned, or c) design refreshes (that designed out the obsolete part) happening less frequently than planned or taking longer than planned.

inventory (holding) cost for those parts for a long period of time and then losing all or some of that investment. In general, for sustainment-dominated systems, the penalty for underbuying parts is significantly larger than the penalty for overbuying parts.

In the operations research domain, lifetime buy optimization is a special case of the of the newsvendor problem. [7] Many extensions to the classical newsvendor problem solution exist that accommodate many different situations, but these solutions fall well short of solving real lifetime and bridge buy problems because they generally lack time dependence, i.e., they do not include cost of money and holding cost. In addition, a "must support" assumption is implicit in lifetime buy problems that is not generally present in simple newsvendor problems - you cannot choose not to support the system, i.e., you are not allowed to fail to fulfill the demand and therefore you must pay the penalty to purchase extra parts from a broker or redesign the system if you run out (the newsvendor is not required to do this). A discussion of the application of newsvendor problem solutions to lifetime buys appears in [17].

Some treatments of the "final order" problem applicable to lifetime buy also exist in the operations research literature. Existing final order models are intended for systems like complex manufacturing machinery that have long-term service contracts. To be able to provide long-term service, a manufacturer must be able to supply parts throughout the service period. The period after the machine has been taken out of production is called the end-of-life service period (EOL). To avoid out-of-stock situations during the EOL, an initial stock of spare parts is ordered at the beginning of the EOL. This initial stock is called the final order. Some final order problem solutions exist, [22,23], but simplifying assumptions about demand profiles and fixed end of support dates make these solutions non-viable for the treatment of DMSMS problems in real applications.

Most real world rigorous treatments of lifetime buys use discrete event simulation that follows the time history of a population of parts applying demands and associated penalties until an end of support date for the use of the part is reached. Such solutions can be used to determine the through-life cost of the buys and the optimum quantities (the quantity that minimizes the through-life cost).

4.2. Design Refresh Planning (DRP)

Reactive obsolescence mitigation approaches are *reactive* in nature, focused on minimizing the costs of obsolescence mitigation, i.e., minimizing the cost of resolving the problem after it has occurred. While reactive solutions always play a major role in obsolescence management, ultimately, higher payoff is be possible through *strategic* management approaches.

Ideally, a methodology that determines the best dates for design refreshes and the optimum reactive management approaches to use between the refreshes in needed.

The simplest model for performing life-cycle planning associated with technology obsolescence (explicitly electronic part obsolescence) was developed by Porter [24]. Porter's approach focuses on calculating the Net Present Value (NPV) of last time (bridge) buys and design refreshes as a function of future date. As a design refresh is delayed, its NPV decreases and the quantity (and thereby cost) of parts that must be purchased in the bridge buy required to sustain the system until the design refresh takes place increases. Alternatively, if design refresh is scheduled relatively early, then last time buy cost is lower, but the NPV of the design refresh is higher.

The optimum refresh year from the Porter model can be solved for directly for a simplified case [17]. Assuming that the demand quantity is the same in every year ($Q = Q_i$ for all $i = 1$ to Y_R) and continuous compounding, the total through-life cost becomes,[8]

$$C_{Total} = P_0 \sum_{i=1}^{Y_R} Q_i + \frac{C_{DR_0}}{(1+r)^{Y_R}} = P_0 Q Y_R + C_{DR_0} e^{-rY_R} \quad (1)$$

where

- P_0 = price of the obsolete part in the year of the last time buy (year 0 in this case)
- Y_R = year of the design refresh (0 = year of the last time buy, 1 = one year after the last time buy, etc.)
- Q_i = number of parts needed in year i
- C_{DR_0} = design refresh cost in year 0
- r = discount rate on money

Equation (1) assumes that the part becomes obsolete at the beginning of year 0 and that the last time buy is made at the beginning of year 0. The minimum value of C_{Total} can be found, [16],

$$Y_R = \frac{1}{-r} \ln\left(\frac{P_0 Q}{r C_{DR_0}}\right) \quad (2)$$

An example of the Porter model is shown in Figure 4.

The Porter model performs its tradeoff of last time buy costs and design refresh costs on a part-by-part basis. While the simple Porter approach can be extended to treat multiple parts, and a version of Porter's model has been used to plan refreshes in conjunction with lifetime buy quantity optimization in [25], it only considers a single design refresh at a time. In order to treat multiple refreshes in a product's lifetime, Porter's analysis can be reapplied after a design refresh to predict the next design refresh, effectively optimizing each individual design refresh, but the coupled effects of multiple design refreshes (coupling of decisions about multiple parts and coupling of multiple refreshes) in the lifetime of a product are not accounted for, which is a

[7] The newsvendor problem seeks to find the optimal inventory level for an asset given an uncertain demand and unequal costs for overstock and understock. This problem dates back to an 1888 paper by Edgeworth [21].

[8] C_{Total} is actually only the portion of the through-life cost that is specifically associated with obsolescence management. All other contributions to the through-life cost are assumed to be a wash between management cases and therefore not modeled.

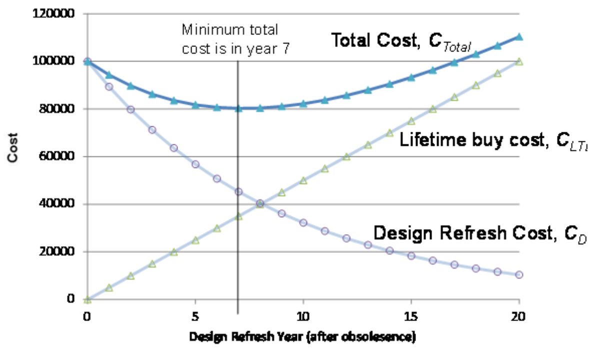

Fig. 4. Example application of Porter's refresh costing model [17].

significant limitation for the application of the Porter approach to real systems.

A more complete optimization approach to refresh planning called MOCA has been developed that optimizes over multiple refreshes and multiple obsolescence mitigation approaches (the Porter model only considers last time buys), [5]. Using a detailed cost analysis model, the MOCA methodology determines the optimum design refresh plan during the field-support-life of the product. The design refresh plan consists of the number of design refresh activities, their content and respective calendar dates that minimize the through-life sustainment cost of the product.

The general DRP problem can be formulated as

$$C_{Total} = \sum_{i=1}^{n} \frac{S_i C_i + s_i c_i}{\left(1+\frac{r}{100}\right)^{d_i}} + \sum_{j=1}^{R} \frac{NRE_j}{\left(1+\frac{r}{100}\right)^{d_j}} \quad (3)$$

where,

S_i = quantity of systems to be manufactured at the ith manufacturing event

s_i = quantity of spare components to be manufacturing at the i^{th} manufacturing event

C_i = recurring cost of manufacturing a system instance at the i^{th} manufacturing event

c_i = recurring cost of manufacturing a spare component instance at the i^{th} manufacturing event

NRE_j = non-recurring cost of the j^{th} design refresh

n = number of manufacturing events

R = number of design refreshes in the plan

d = difference in years between the event date and the net present value calculation date.

Figure 5 shows the MOCA design refresh planning timeline. Fundamentally, the model supports a design through periods of time when no parts are obsolete, followed by multiple part-specific obsolescence events. When a part becomes obsolete, some type of mitigation approach must take effect immediately: either sufficient inventory exists, a lifetime buy of the part is made or some other short-term mitigation strategy that only applies until the next design refresh. Next there are periods of time when one or more parts are obsolete, and short-term mitigation approaches are in place on a part-specific basis. When design refreshes are encountered the change in the design at the refresh must be determined and the costs associated with performing the design refresh are computed. At a design refresh, a long-term obsolescence mitigation solution is applied (until the end of the product life or possibly until some future design refresh), and non-recurring, recurring, and re-qualification costs are computed. Re-qualification may be required depending on the impact of the design change on the application – the necessity for re-qualification depends on the role that the particular part(s) play and/or the quantity of non-critical changes made. The last activity appearing on the timeline is production. Systems often have to be produced after parts begin to go obsolete due to the length of the initial design/manufacturing process, additional orders for the system, and replenishment of spares.

The MOCA methodology can be used during either: a) the original product design process, or b) to make decisions during system sustainment, i.e., when a design refresh is underway, determine what the best set of changes to make given an existing history of the product and forecasted future obsolescence and future design refreshes. See [5] for a description of refresh planning analyses using MOCA.

Several efforts have addressed optimal redesign of

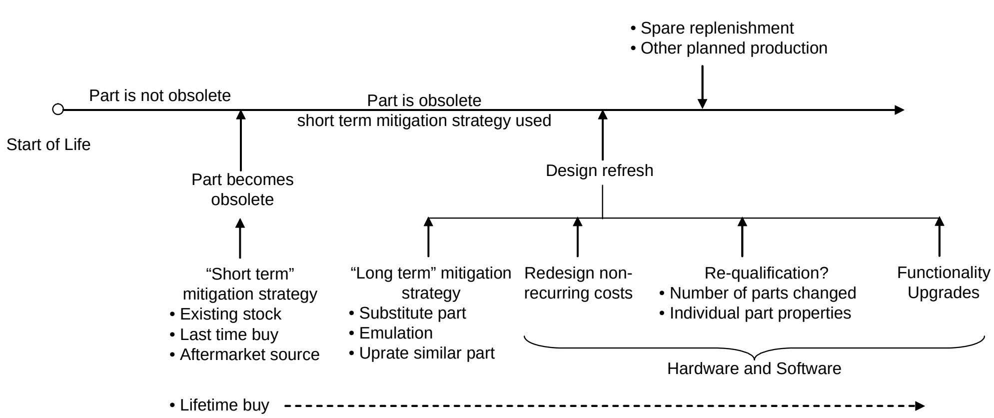

Fig. 5. Design refresh planning analysis timeline (presented for one part only, for simplicity, however in reality, there are coupled parallel timelines for many parts, and design refreshes and production events can occur multiple times and in any order), [5].

systems subject to obsolescence, [26]. These efforts focus on understanding when new components/technologies will be available for replacing obsolete ones (the DRP models discussed above implicitly assume that the appropriate parts are available to refresh the system when needed). Real options analysis has also been used to assess the value of waiting to invest in new technology to mitigate obsolescence [27].

4.3. Budgeting and Bidding Support

Methods have been developed in [28] to facilitate accurate budgeting and bidding. These methods perform two actions, first they determine the probabilities of using specific resolution activities, and then they predict an application-specific cost of performing the predicted group of resolution activities. Both actions are performed based on practitioner surveys, expert opinion and other historical information. The result is an estimation of the obsolescence management costs for a defined contract period using commonly defined resolution approaches. For organizations that wish to estimate management costs for systems based on their own or the industry's prior system management history, this approach is valuable. It may also be possible to use this approach to perform tradeoffs associated with shifting the resolution approach focus within organizations.

4.4. Establishing the Value of DMSMS Management

In order to justify their existence, groups that manage DMSMS must estimate the value of their management activities. The value of DMSMS management activities is usually quantified as a cost avoidance. A cost avoidance is a reduction in costs that have to be paid in the future to sustain the system. While management can (with a bit of effort) understand cost avoidance, it is not always a "sellable" quantity. Requesting resources to create a cost avoidance is not as persuasive as making a cost savings or a return on investment argument.

The most common cost avoidance calculation used by DMSMS management organizations is based on a bookkeeping approach first articulated in a DMEA report written by ARINC from 1999 [29] and is also articulated in the 2010 versions of the DMEA DMSMS cost resolution numbers [30], SD-22 [31], and UK MOD documents [32]. In this approach, the cost avoidance associated with the chosen mitigation solution is equal to the difference between the cost of your solution and the next most expensive mitigation option. The validity of this approach is questionable.

An ROI-based valuation of DMSMS management organizational value is detailed in Appendix C of [30]. Unlike the conventional cost avoidance calculation, this approach results in the calculation of numbers that have real meanings, are independent of program-specific value of money, and can account for resolutions that treat multiple parts concurrently.

5. Comments

Too often, sustainment organizations become caught up in addressing obsolescence events as they occur, for example, making decisions on a case-by-case basis whether to undertake a lifetime buy of the obsolete part or initiate a design refresh activity to replace the obsolete part with a newer part. This can lead to being caught in a "death by a thousand cuts" system management trap, spending valuable resources making a continuous stream of independent decisions about how to manage parts. However, unfortunately engineers often lack the ability and tools to provide the appropriate business case support more strategic management efforts.

Viable through-life cost modeling is at the core of business case support. Determining the best action to take depends, in large part, on the through-life cost ramifications of the decision. Ideally one should have a method of determining the total cost of ownership of system and part-specific sustainment decisions made.

There are numerous issues that have to be addressed in order to perform viable through-life cost modeling and potentially build actionable business cases to support DMSMS management. Some of these include:

- Not just hardware – DMSMS management is not just a hardware management problem. The cost of managing software obsolescence [33] concurrently with hardware obsolescence must be considered – software is at least as serious a problem as hardware. And, human skills obsolescence can become a very real problem too [34].
- Sourcing disruptions – Obsolescence isn't the only disruption in sourcing parts for long periods of time. Global issues can conspire to complicate sourcing. It is not uncommon for, low-volume customers to go the "back of the line" for their parts (i.e., this is an allocation problem). Some non-obsolete electronic parts can have 18-24 month lead times.
- Constraints – Just because you can model a sustainment approach does not mean that people can actually perform it. The constraints that can be applied in strategic planning of systems include budget, timing and policy. See [19] for a discussion of the inclusion of constraints in the refresh planning process.
- Outcome/availability-based contracts – Outcome-based contracts (also called performance based logistics in the U.S.) are changing how the OEMs for sustainment-dominated products do business. Strategic management concerns will make more sense to the OEMs as real outcome-based contracts are transacted, however, a host of new problems come to the forefront, e.g., how do you make a lifetime buy when your outcome-based contract only pays you quarterly?
- Cost of money – DMSMS management takes place over long periods of time. Therefore, cost of money has to be considered. This is relevant when tradeoffs include lifetime buys of parts that require large outlays of capital early in a program to acquire inventories of parts that will

not be used for many years. The problem is complicated because the cost of money is not a constant, you can't just pick today's number and assume it for the next 20 years or be representative of the risk associated with penalties if one runs short of parts.

- Relative versus absolute costs – Absolute costs are much more difficult to accurately determine than relative costs. For example, calculating the difference between the cases need not include the "wash" costs (costs that are the same for both cases).
- Availability – Just like cost and yield cannot be separated in manufacturing assessment; cost and availability are coupled together when the sustainment of systems is considered.

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