Component Obsolescence Risk Assessment

Craig Josias and Janis P. Terpenny*
Department of Mechanical and Industrial Engineering
University of Massachusetts
Amherst, MA 01003-9265

Kenneth J. McLean
Kollmorgen Electro-Optical
Northampton, MA 01060-2390

Abstract

Custom low volume products and systems, such as those utilized by military and avionics applications; often make use of commercial high-tech components. In the past decade, technology has advanced very rapidly causing such components to have a shortened life span. Newer and better technologies are being introduced frequently, rendering components obsolete. Yet, custom low volume products and systems such as ships, submarines and aircraft can be in use for decades. Being proactive about obsolescence is critical to maintaining fully capable products and systems and satisfied customers. This paper presents an obsolescence risk measurement tool that is being developed to better predict and manage component obsolescence. Critical variables in this assessment that are precursors to a component becoming obsolete are described. A multiple regression model developed for forecasting obsolescence is presented. An industrial case study with Kollmorgen, an international manufacturer of motion control systems, is also presented.

Keywords
Obsolescence, sustainability, commercial off the shelf (COTS), diminishing manufacturing sources and material shortages (DMSMS), risk management

1. Introduction
The electronics industry has grown rapidly over the past decade; three times that of the overall economy in the United States [1]. Consequently, this rapid growth has led to intense competition among manufacturers spurring quicker introductions of superior consumer electronic products. This rapid introduction of superior components has led manufacturers to discontinue production of older components that are no longer economical to produce due to declining demand and lower economies of scale. This quick pace of new product introductions is difficult for manufacturers to keep up with.

Manufacturers and system users of low volume complex electronic systems and products are especially vulnerable to obsolescence. These products or systems typically are designed for system life cycles spanning many decades. As the service life of the sub-components is much shorter than the overall system, the risks and challenges of maintainability and sustainability become an enormous task. This is, of course, in addition to the challenges of delivering advanced, high quality, safe, and reliable products and systems to customers. System failures are considered unacceptable and could have extremely costly consequences.

While the impact and pervasiveness of obsolescence is a growing problem, much work has yet to be done to predict, assess, actively manage, and mitigate obsolescence. This paper addresses these issues and describes a risk measurement tool that is being developed to better predict and manage component obsolescence. The next section provides motivation for this work. An industrial case study with Kollmorgen, an international manufacturer of motion control systems, is then presented to illustrate how critical variables that are precursors to a component becoming obsolete can be identified. A proposed multiple regression model developed for forecasting obsolescence is also presented. Finally, conclusions and future work are presented.

2. Motivation
As shown in Figure 1, weapon systems can have long system life cycles (40-90+ years). Consider for instance, the B-52 bomber, with planned service until 2040. This is over 90 years of service life! As one would expect, obsolescence is a major factor due to technology changes that have brought new opportunities for achieving functionality. Perhaps less anticipated for the military was the plague of obsolescence issues since migrating away from the use of military specification components (custom) to commercial off-the-shelf (COTS) components. Rapid

growth of the commercial sector due to increased technology content in consumer products has caused many manufacturers to stop producing low volume products for the military as they shift their production to the high volume consumer electronics markets.

Accordingly, systems designers…"*can no longer predict a component's performance and reliability in the Air Force environment*" [2]. Why the military has migrated from military specification to commercial components is important to understand. The USAir Force was one of the first to use integrated circuits (ICs) as far back as 1961 and in 1962 it used ICs in its Minuteman missile program [2]. Throughout the 1960s and 1970s the Department of Defense (DOD) and NASA were among the largest consumers of electronic components. Thus, they were able to determine and control design specifications and requirements. This was possible as manufacturers produced mainly low volume products and systems for DOD and NASA. Thus military systems evaded issues of obsolescence in the 1960s and 1970s, as there was always a manufacturer ready to produce just for the military. However, the 1980s were a turning point as consumer electronics boomed. Personal computers, cell phones, audio and visual equipment are among the consumer electronic equipment that revolutionized the semi conductor industry.

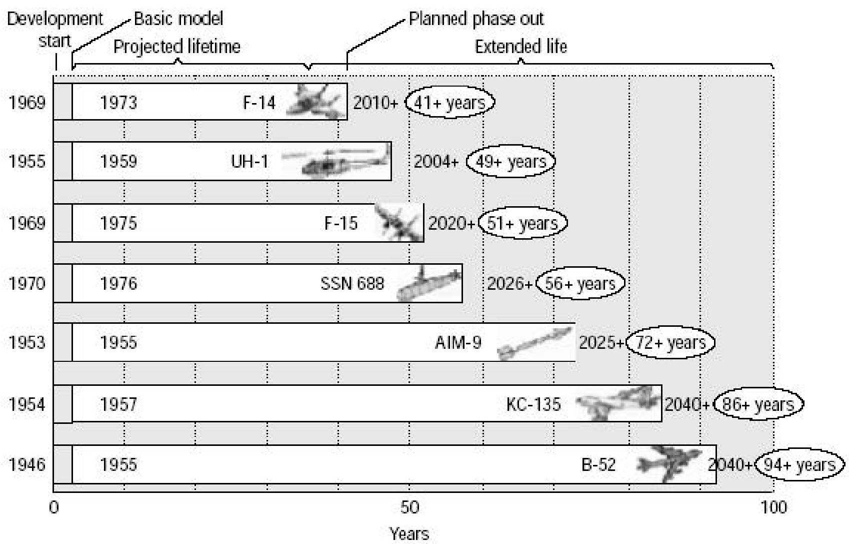

Figure 1. Weapon system life cycles [2].

As shown in Figure 2, the military market share declined drastically in the 1980s and 1990s. From 1975 to 1985 the military's IC market share decreased by more than double. It further decreased from 7% to just 1% from 1985 to 1995, which is extremely significant.

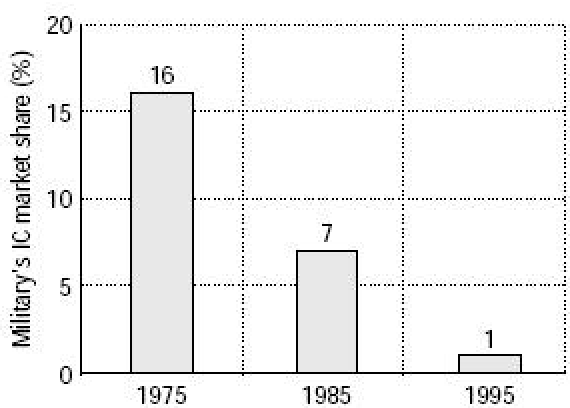

Figure 2: The military's decreasing share of total IC market [2].

With this sharp decline in the IC market share of the military, manufacturers have migrated away from producing just for the military as the low volume industry is not profitable and thus manufacturers produce mainly high volume products to remain competitive in the marketplace. Many low volume military manufacturers have stopped producing military parts altogether further exacerbating the component obsolescence issues for the military as they react to changing markets and the need to incorporate commercial components into their designs.

The military has traditionally dealt with obsolescence in a reactive mode [3]. Reacting to obsolescence when it occurs has been expensive for the military since finding solutions in a short period to remain operable is costly. The need for the military and supporting manufacturers to change from reactive to proactive approaches regarding obsolescence is widely acknowledged [2, 3, 10]. Proactive approaches would allow for management of programs more effectively by being cognizant of changing dynamics in the market place.

3. Case Study

Kollmorgen, an international manufacturer of motion control systems started producing periscopes for the US Navy as far back as World War I. In 1916 Kollmorgen Optical Company produced their first two periscopes commissioned for the SS-32, a US Navy submarine [4]. Today Kollmorgen is the foremost producer of periscopes for submarines. Kollmorgen's designs have evolved over the years to include the latest technologies. However, as Kollmorgen's periscopes have a long manufacturing and system life cycle, the constant pace of new component introductions is difficult to keep up with. In many cases, components are rendered obsolete before the development cycle is complete. In the past, Kollmorgen dealt with issues of obsolescence in a reactive mode, fighting fires as necessary. Reacting to obsolescence when it occurs has been expensive for Kollmorgen with changes that may propagate changes to surrounding subsystems and parts that lead to longer development times.

To satisfy its customers, Kollmorgen not only has to provide the best functional systems, but also systems that are maintainable and sustainable over a long life cycle. Thus Kollmorgen has set up a task team to study the problem of obsolescence on their systems and to find pro-active management and engineering approaches to mitigate obsolescence. This team collaborated with counterparts at the Navy in what is called an "Integrated Product Team" for the Virginia Class design. Kollmorgen drafted an obsolescence management plan to ensure that obsolescence will be anticipated, identified, analyzed, and mitigated. The objective of this plan is to establish a process that [5]:

1. *ensures continuous supportability while maintaining operational capability,*
2. *minimizes total ownership cost (TOC),*
3. *makes financial management more predictable, and*
4. *monitors and reports on obsolescence management effectiveness.*

The Electro-Optical division of Kollmorgen is collaborating with the University of Massachusetts to develop a tool that will aid in predicting obsolescence of components. This prediction tool will aid in making proactive management decisions for obsolescence planning. Components types identified for initial investigation and proof of concept testing, include: computer processors, cameras, power supplies, and connectors. In the section that follows, computer processors are used to illustrate how component characteristics can be used to predict obsolescence.

3.1. Prediction Model

Table 1 lists computer processors in chronological order from when they were first introduced in 1971 through 2003. Three key attributes, which have revolutionized computer technology, as we know it today, include the clock speed, number of transistors and size of the processors. As can be seen, the first processor was the 4004 introduced in 1971, which had a clock speed of 400 KHz, 2,300 transistors, and 10 microns in size. Today's processors have clock speeds of ~ 7,500 times quicker with ~ 25,000 times more transistors and have decreased in size by approximately 77 times. Figures 3, 4, and 5 show graphically the dramatic change in processor capabilities when considering processor size versus date introduced, number of transistors versus date introduced, and clock speed versus date introduced. In each case it is clear that there is a relationship, however non-linear, between the three technologies over time. Figure 3 shows the processor size decreasing constantly from 10 microns in 1971 to 0.13 microns in 2003, which is a decrease in size of approximately 77 times. This is remarkable, bearing in mind that 0.13 microns is approximately 770 times smaller than the width of a human hair. Figure 4 depicts the steady increase in the number of transistors over time from 2,300 in 1971 to 55,000,000 in 2003, an approximate increase

Table 1. Introduction dates of computer processors [6, 7, 8]

Processor Model	Date Introduced	ClockSpeed (MHz)	Mfg Process (Microns)	Transistors (Number)
4004	1971	0.40	10	2,300
8008	1972	0.80	10	3,500
8008	1973	0.80	10	3,500
8080	1974	2	6	4,500
8080	1975	2	6	4,500
8085	1976	5	3	6,500
8085	1977	5	3	6,500
8086	1978	8	3	29,000
8088	1979	8	3	29,000
8088	1980	8	3	29,000
8088	1981	8	3	29,000
80286	1982	12	1.5	134,000
80286	1983	12	1.5	134,000
80286	1984	12	1.5	134,000
80386	1985	16	1.5	275,000
80386	1986	16	1.5	275,000
80386	1987	16	1.5	275,000
80386	1988	16	1.5	275,000
80486	1989	25	0.8	1,200,000
80486	1990	25	0.8	1,200,000
80486	1991	25	0.8	1,200,000
80486	1992	25	0.8	1,200,000
Pentium	1993	66	0.8	3,100,000
Pentium	1994	66	0.8	3,100,000
Pentium	1995	133	0.35	3,300,000
Pentium	1996	166	0.35	3,300,000
PentiumII	1997	300	0.25	7,500,000
PentiumII	1998	400	0.25	7,500,000
PentiumIII	1999	733	0.18	28,000,000
Pentium4	2000	1,500	0.18	42,000,000
Pentium4	2001	2,000	0.13	55,000,000
Pentium4	2002	2,530	0.13	55,000,000
Pentium4 w/HP Tech	2003	3,000	0.13	55,000,000

by 25,000 times. Figure 5 depicts the constant increase in the clock speed over time from 400 KHz in 1971 to 3 GHz in 2003, a whopping 7,500 times quicker.

The three factors were further explored in a regression model to determine whether they are predictors of the time of introduction of a new and better computer processor. The model is derived from the data listed in Table 1. The response variable, or dependent variable, is the date introduced. The independent variable is the size, clock speed and number of transistors. The model also incorporates 2-way interaction which includes size*clock speed, size*number of transistors, and clock speed*number of transistors. The regression model is as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_1 X_2 + \beta_5 X_1 X_3 + \beta_6 X_2 X_3 + \varepsilon;$$

where Y = year of introduction, β_k = regressor coefficients for $k = 0,1,\ldots 6$, and X_1 = clock speed, X_2 = manufacturing process (microns), X_3 = number of transistors.

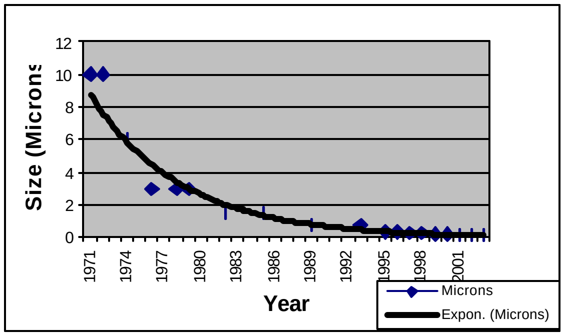

Figure 3. Processor size versus date introduced

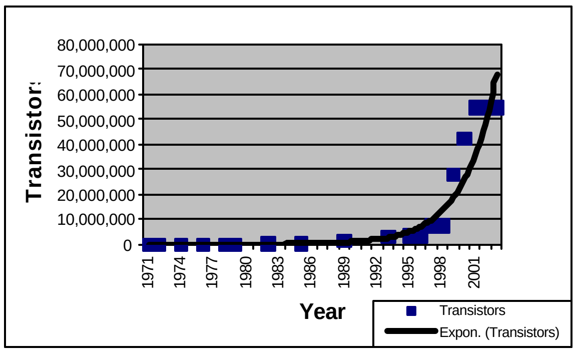

Figure 4. Number of transistors versus date introduced

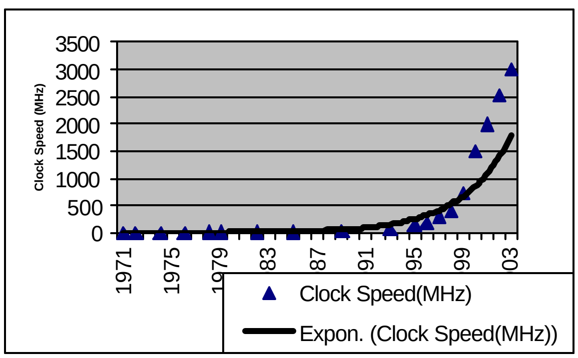

Figure 5. Clock speed versus date introduced

The analysis below shows the results of the regression model with the date as the response variable. The p-values of all the variables are less than 0.05 indicating that all the variables are significant predictors of the response variable, the Introduction Date. The model has an R_Square of 93.9% indicating that 93.9% of the variability is accounted for by the model. Additional analyses, not shown herein, indicate that the residuals are normally distributed, which is a good indicator that the model is valid. Thus, the model presented can estimate the date of introduction of a new processor.

The regression equation is:

```
DATE = 32773 + 25.2 ClockSpeed(MHz) A - 658 Microns B -0.000372 Transistors C
- 86.8 AxB -0.000000 AxC + 0.00246 BxC
```

Predictor	**Coef**	**StDev**	**T**	**P**
Constant	32772.9	528.3	62.04	0.000
ClockSpeed(A)	25.175	6.177	4.08	0.000

Predictor	Coef	StDev	T	P
Microns(B)	-658.40	73.86	-8.91	0.000
Transistors(C)	-0.00037154	0.00009535	-3.90	0.001
AxB	-86.76	27.14	-3.20	0.004
AxC	-0.00000020	0.00000005	-3.77	0.001
BxC	0.0024563	0.0005182	4.74	0.000

S = 969.4 R-Sq = 93.9% R-Sq(adj) = 92.5%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	6	374725532	62454255	66.46	0.000
Residual Error	26	24432820	939724		
Total	32	399158352			

Conclusions and Future Work

The regression model for predicting personal computer processor introduction using the three factors (processor size, number of transistors, and clock speed) account for 94% of the variability. We can thus conclude that the model above is a predictor of processor introduction dates. Further modeling to determine the introduction rates of cameras, power systems, and connectors, will be explored and the zones of obsolescence estimated. This information will be helpful to manufacturers of low volume complex electronic systems and products in estimating the time to obsolescence of its products with reasonable confidence. This is an important first step in the development of models and tools that can help to predict, assess, actively manage, and mitigate obsolescence.

Acknowledgement

The authors gratefully acknowledge the participation and funding provided for this work by Kollmorgen Electro-Optical of Northampton, Massachusetts.

References:

1. Singh, P., Sandborn, P., "Electronic Part Obsolescence Driven Product Redesign Optimization" 6th joint FAA/DoD/NASA Aging Aircraft Conference, Sept 16-19, 2002, pp. 1-13
2. Stogdill, C. R., Wright-Patterson Air Force Base, "Dealing with Obsolete Parts" IEEE Design & Test of Computers, April-June 1999
3. Livington, Henry, "GEB1: Diminishing Manufacturing Sources and Material Shortages (DMSMS) Management Practices," (Government Electronics & Information Technology Association G-12 Solid State Devices Committee.
4. Merrill, J., "Looking Ahead – A short history of Submarine Periscopes", 2002
5. "Obsolescence Management Plan – Virginia Class Tech Refresh IPT", May 2003, Revised Oct. 2003
6. Pecht, M., Sandborn, P., Solomon, R., Wilkinson, Chris ., Das, D., "Life Cycle Forecasting, Mitigation Assessment and Obsolescence Strategies" CALCE EPSC Press, 2000.
7. Scott Mueler, "Upgrading and repairing PCs" 2003
8. "How Microprocessors Work" http://www.howstuffworks.com/microprocessor1.htm
9. Singh, P., Sandborn, P., Geiser T., Lorenson, D., "Electronic Part Obsolescence Driven Product Redesign Optimization" 6th Joint FAA/DoD/NASA Aging Aircraft Conference, Sept. 16-19, 2002
10. Dasgupta, A., Magrab, E., Anand, D., Eisenger, K., McLeish, J., Torres, M., Lall, T., Dishongh, T., "Perspectives to understanding risks in the Electronic Industry" IEEE Transactions on Component, Packaging, and Manufacturing Technology – Part A, vol. 20, no. 4, December 1997.