# De-Risking Long-term Aero/Defense Programs through an Innovative Approach to Sustainment

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***Abstract*—For original equipment manufacturers (OEMs) of test equipment, the product lifecycle is generally much shorter than that of a typical aerospace or defense program. As a result, OEMs have struggled to support the requirements of multi-decade aero/defense programs. This paper will examine the challenges that OEMs face when implementing long-term service and support programs. It will also introduce a Keysight-developed approach that reduces the costs and risks associated with long-term aero/defense programs.**

***Keywords—sustainment, maintenance, support** (key words)*

## I. Introduction

The typical aerospace/defense (A/D) program can last decades, whereas the lifecycle of a commercial project is normally no more than a few years, or even less in the fast-evolving wireless industry. See Fig. 1 [1]. This contrast creates a multitude of challenges, amplified by the fact that each stage of the A/D lifecycle can be much longer compared to the equivalent commercial stage. For example, in the time it takes for the latest wireless technology to break into the market, peak, and then ramp back down, a new A/D program may still be in the prototyping stage. In addition, the long phase post-deployment where demand is typically stable or in a slow decline is called sustainment, which contributes up to 90% of the program lifecycle. This program stage can make up 70% of the program's lifetime cost [2], but it is also underappreciated and undervalued when key decisions are made during the early stages of the program [3].

These milestone decisions made during the early stages incur upfront costs that are relatively high compared to the rest of the program's per incident costs. It can be easy to focus on reducing these costs as much as possible to reduce overall program costs. However, these key decisions also define the rest of the program,

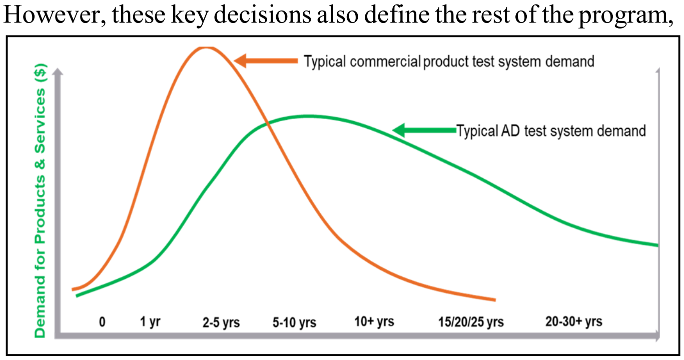


Fig. 1. Typical A/D demand for products is much longer than wireless

including the long-term costs during the sustainment phase. It is therefore vital to consider sustainment challenges and costs in the early stages of the program, and the associated requirements and consequences for program suppliers.

## II. Sustainment: Definition and Requirements

### A. *How the Aero/Defense Community Defines Sustainment*

The term "sustainment" is used to refer to many different applications, based upon the varying perspectives of roles within the aerospace/defense ecosystem. For example, a government program lead has a different goal for sustaining the program compared to the government contractor's perspective and goals. Similarly, a test equipment supplier often talks about sustainment in relation to long-term support of test equipment hardware. Though supporting test equipment long-term does influence overall program sustainment costs, it is normally not the end user's main concern. Therefore, it is necessary to consider the end user's perspective of sustainment in relation to overall program cost and success.

Let's consider the concept of sustainment according to the government. Reference [4], for example, lists several key goals for sustainment activities. The first is to maximize the chance of mission success through guaranteed availability to meet mission needs. This is measured through parameters that quantify operational availability and probability of success of the given mission. Second, unit self-sufficiency during the mission is a goal that is measured by the length of time a unit can maintain self-sufficiency. Self-sufficiency must be balanced by the total number of forces required. The goal is to minimize the number of additional forces dedicated to sustainment while maximizing the length of time a unit can be self-sufficient. Of course, all of this must be achieved at the lowest possible lifecycle cost. Total sustainment cost is measured by the total annual operational cost and normalized per hour and per mile traveled. Total annual operation cost includes the cost of investments in spare parts and in improved reliability.

Thus, you can see how sustainment is an essential component of mission success. In addition, expenses due to ongoing operational and maintenance activities are becoming an increasingly larger part of total expenditures. This is shown in Fig. 2, which depicts total expenditures by category for A/D programs [3]. In the chart, the operations and maintenance category has increased by 10% from the 1980's to the 2000's. It is projected to increase further to 44% of total expenditures by 2029. Personnel expenditures have also increased, likely due in

part to increased demand to meet sustainment goals. Unfortunately, although sustainment costs are becoming more significant, it continues to be undervalued and underappreciated during the key decision phases.

### *B. Program Sustainment and Consequences for Suppliers*

Now that we have established what the goals are for sustainment and that it is becoming increasingly important to manage sustainment related expenses, let's consider an example of what the A/D community is doing to model and sustain programs, and the associated consequences for the suppliers of those programs. Fig. 3 depicts the program model of a hardware-intensive A/D program such as a major weapons platform [5]. This is taken from the DoDI 5000.02 procedures. Enclosure 6 from the DoDI 5000.02 document highlights the requirements for life-cycle sustainment for such a program. From the first key decision stages, the product support strategy must be developed. This support strategy is the basis for all sustainment efforts to maintain the requirements of the program. Included in the product support strategy are:

- Sustainment metrics that are continually monitored and managed to minimize cost and risk
- A program to improve reliability based upon failure modes and critical analysis. Data is captured during the engineering development phase and through systems health info that is available through on-board and off-board technologies
- The ability for competition at the prime and subcontract levels for both system and subsystem levels

The sustainment plan is not fixed. Throughout the lifecycle, the plan performance will be assessed and modified as necessary to reduce cost and risk.

What, then, is the impact to suppliers? Ongoing assessment of a supplier's ability to provide support is part of the overall management of sustainment for the program. It is therefore imperative for the supplier to provide products and product support for the length of the program. It also means that consistent yields over the long-term are required. In addition, for the supplier to continue to provide the lowest possible cost and remain competitive, predictable costs are required. For example, if the supplier's own costs are at risk of increasing over time, this increases prices for long-term programs and reduces the supplier's competitiveness. And finally, to improve sustainment metrics and manage long-term cost, contracts are often re-bid at later program stages. When a supplier can maintain consistent costs and continue to improve efficiency, the chances of winning the re-bid are significantly higher.

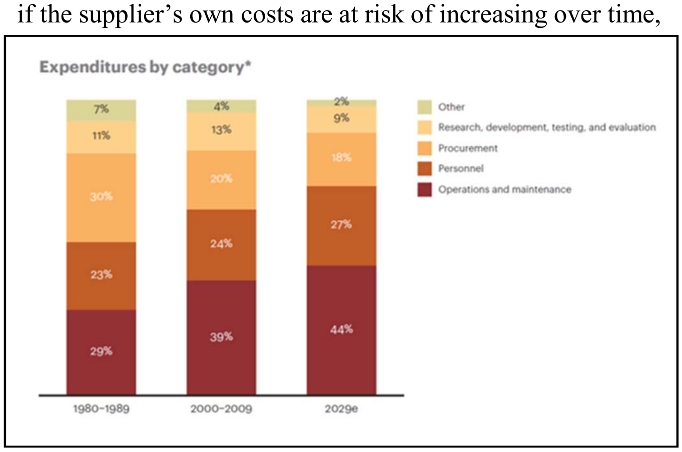


Fig. 2. Total expenditures by category for A/D programs

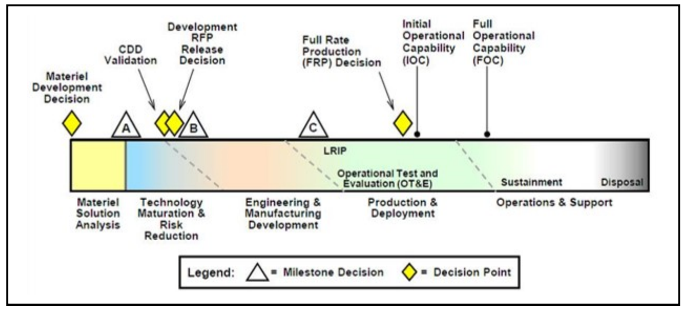


Fig. 3. Classic program model used for military weapon systems

### *C. Current Efforts to Support Program Sustainment*

Consider which trends are driving the challenges of sustaining long-term programs and the actions that program contractors are taking to mitigate these challenges. Increasingly, program contractors are focused on outsourcing unnecessary tasks and using more commercial, off-the-shelf (COTS) equipment. This enables the contractor to focus on core expertise, which drives both innovation and competitiveness. In addition to outsourcing, programs are looking at strategies for reducing total lifecycle costs rather than immediate expenditures. Also, the business model is moving from cost-plus to fixed-price, meaning budget controls are becoming more essential for ensuring program profitability.

Sustainment requirements are addressed by program contractors through:

- Implementing a zero-defect policy for suppliers to ensure uncompromising quality; this means that suppliers' parts must always meet their specifications
- Intolerance for schedule delays: unplanned downtime must be minimized
- Demanding consistent performance and yields while the margins between instrument performance and product specifications continue to decrease

As a result, understanding the limits of test system performance and maintenance is essential for sustainment purposes.

## III. Taking a Total Cost of Sustainment Approach

### *A. Key Challenges and Risks for Long-Term Programs*

Based upon the definition of sustainment efforts and requirements, it is possible to identify some of the key risks associated with maintaining long-term programs. First, programs are not always fixed for life. At multiple stages, re-bids put profits and all previous work on the program at risk. Therefore, maximizing the probability of a successful re-bid is essential. Second, maintaining the lowest possible costs ensures profitability. However, it is important not to focus solely on

upfront costs. When accounting for long-term program costs, it is important to account for the total cost of sustainment for the life of the program. Third, downtime, especially during production runs, can put a program budget and schedule at high risk. Having a flexible and dynamic solution for uptime support is therefore essential. On the other hand, unplanned downtime is often a significant issue. Not putting a plan in place, such as acquiring spares, can put the schedule at serious risk. Still, having spares available may not be enough. If spares are not properly maintained and tracked, they may not be usable when needed. Or, even worse, if that spare is not being calibrated at regular intervals, it may appear to solve the immediate challenge of a broken instrument but in fact be contributing to yield problems.

Finally, support costs become significant when a commercial product is reaching its end of life. There are many reasons for this, and we will discuss them in the next section. Unfortunately, not only are costs higher at the product's end of life, but failures tend to occur more often. These risks are more apparent for long-term programs because the lifecycle of most commercial products is shorter than that of most A/D programs.

An underlying issue becomes clear when analyzing the various challenges of sustaining long-term programs: all these risks require time and effort to manage and mitigate. The real goal, then, is not just to mitigate these risks. Instead, it is to eliminate the need to think about them at all. If all these risks are addressed by a third party with the appropriate expertise, then a defense contractor can truly focus on its core proficiencies, and this in turn increases its competitiveness, profitability, and longevity in the market.

### *B. Total Cost of Sustainment Example*

Consider Fig. 4, which depicts two different methods for addressing program sustainment and costs. The first is the traditional approach, which will be called the per-incident method. In general, this will save the most money at the beginning of the program because all support costs are paid per incident, and support is typically required less often. In this case support costs include everything required to maintain the system: repair, calibration, training, etc. This can also include the cost of buying and maintaining spares or periodically paying for onsite services, if needed. The other method is equivalent to paying for an annual agreement that covers all required support. A single annual price is charged by the provider of support services, and this price increases each year by only the inflation rate. With a long-term agreement, the service provider can plan ahead, control costs, and ensure that consistent price even when repairs and other services are required more often at the end of the program.

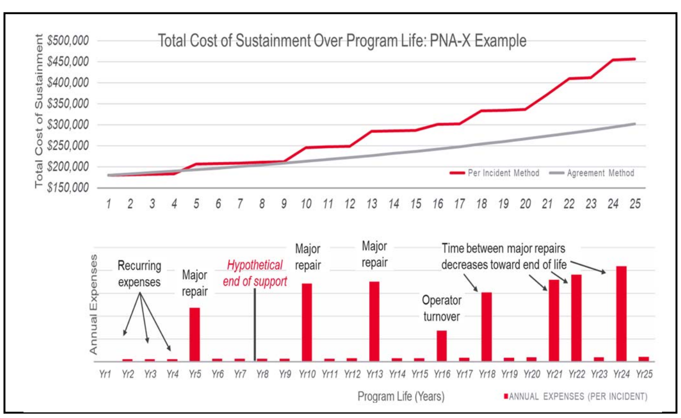


Fig. 4. Total cost of sustainment example for a network analyzer

The upper plot in Fig. 4 shows the total cost of sustainment as a cumulative total from years 1 to 25. For simplicity, the figure shows the repair and calibration costs for a Keysight vector network analyzer. The lower plot in Fig. 4 shows the annual support costs for the per-incident method. The agreement price grows at a 3% inflation rate, so it was not included in the lower plot. Until about year 5, the two methods have similar prices (red and gray lines). But, the cost of each major repair is significantly higher than the agreement price. In general, the agreement price for the entire year can be as much as 70% lower than the per-incident price of one major repair. Therefore, by year 10, the agreement method becomes the lower-cost option. As the program reaches its long-term sustainment phase, the mean time between major repairs starts decreasing. This creates a major difference in total cost by year 25, the end of the program. In this case, the total cost of sustainment of the agreement method is only 66% of the total cost of paying per-incident.

Furthermore, it is important to note that it does not take many failures to justify using the agreement method. In fact, to maintain an approximately equal total cost between the methods, no more than two major repairs can occur within the 25-year span. This is highly unlikely, even for a high-performance instrument that has stabilized at a low annualized failure rate.

A consistent cost is clearly the winner when it comes to achieving the lowest total overall cost. Predictable costs help in other ways, too. For one, knowing the cost to maintain a test system for the entire program life means the true costs are already known if a program must be re-bid. This makes a significant difference compared to the risks of the per-incident method. As insurance, the re-bid is often padded to account for the per-incident costs that may arise. This can significantly reduce the chances of winning the re-bid.

Consider a slightly modified example. In Fig. 5, support for the instrument is hypothetically set to end at year 9. After that, the cost of parts and labor for repairs becomes significant, and the number of repairs is likely to increase. At this point, it is common to consider upgrading to a new platform. Of course,

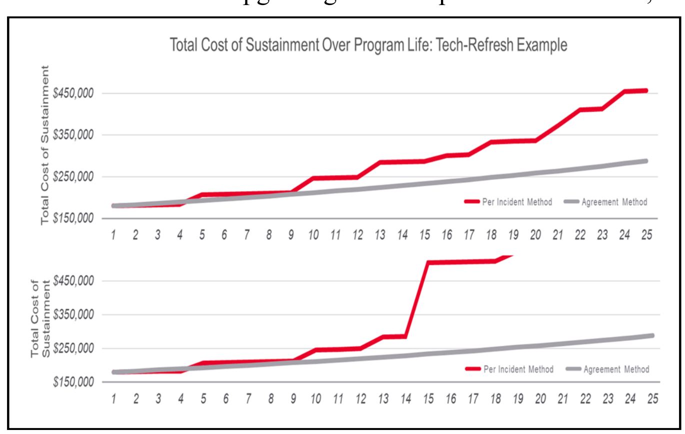


Fig. 5. Total cost of sustainment versus equipment upgrade

this is only relevant if upgrading to a new platform is possible within the constraints of the program.

Fig. 5 compares the total costs of the per incident method, including the purchase of the next-generation instrument, with the agreement method and the decision to keep the old equipment running throughout the program. For the example, the cost of this new instrument is 20% higher than the legacy unit, although this example would be equally valid if the costs were the same. Both examples show that extending the life of the instrument using the agreement method provides the lowest total cost.

## IV. Support Challenges for Instrumentation OEM's

In this section we will discuss some of the key challenges that original equipment manufacturers (OEM's) face when supporting legacy platforms. Traditionally, OEM's have not been able to support platforms for as long as A/D programs require. Multiple reasons for this exist to be able to provide long-term support, and we will discuss these reasons and hurdles to overcome.

To keep pace with emerging requirements and technologies, instrumentation OEM's are consistently developing new products. Eventually, the OEM must choose between supporting their older products or focusing manufacturing lines, parts, and technical resources on the latest generation technologies. Supporting older products can be very expensive, and the return on investment is usually lower. In addition, future profits are put at risk because limited resources are available to pursue the next technology wave. On the other hand, getting to market to meet the latest technology wave can often lead to much higher returns. Thus, the risk and cost factors demonstrate that the return on developing new products far outweighs that of supporting legacy models.

Next, consider some of the challenges facing OEM's that choose to continue supporting legacy products. According to [1], these challenges increase substantially as products age. Early in a product's life, the OEM has both a large supply of parts and technical expertise available. However, the customers' need for support stays low due to lower equipment failure rates. As the program moves toward volume production and sustainment stages, the products age. Equipment failure rates begin to rise and the need for support increases. Three factors make it difficult for the OEM to provide service at these latter stages: the discontinuance or obsolescence of the product, decreasing part supplies, and dwindling product expertise.

Decreasing part supplies is a big challenge for OEM's that have an established supply chain for genuine parts that ensure the instruments will meet their specifications. Unfortunately, this supply chain is not reliable long-term. The parts themselves have their own lifecycles and become obsolete, causing a break in the supply chain. Additionally, vendors can go out of business for various reasons. One reason that affects both the OEM's quality and conformance processes is the changing of technical, industry, or government standards. As expertise and component availability dwindles, the OEM may stop investing in component level repair and utilize the used market for securing spare instruments. This can save time, money and expertise because the OEM simply needs to swap out a defective assembly for a new one. Finally, an ongoing challenge that can dramatically impact an OEM's costs and reputation is the increasing risk of counterfeit parts. Third parties often stockpile parts and may or may not have quality control processes in place. These providers will sell the parts for profit, which may be significant as components go obsolete and supplies dwindle. Due to the lack of quality control, counterfeit or copy-cat parts can easily be mixed into the supply [1]. In the next section we will introduce a process for supporting older products that involves planning ahead to reduce the high costs that are typically incurred when supporting equipment has gone obsolete or passed its support end of life (EOL) date.

## V. An Innovative Approach to Sustainment

### A. *Ensuring Predictable Costs for Long-Term Support*

Consider a test system made up of many elements, including instruments, components, signal routing and switching elements, and control and computation elements such as CPU's and others. This normally includes elements from many manufacturers, as well as custom designed components from third parties or by the program contractor itself. Every element of the system will be at a different point in its lifecycle. In addition, each element's lifecycle may be shorter or longer based upon the type of element and its associated demand cycle, parts availability, industry's pace of evolution, etc. One approach used by OEM's that is normally expensive and usually cost prohibitive is to look at expected failure rates for all components in the system and stockpile enough spares to cover the entire life of the program. This creates an enormous cost upfront and does not consider the evolving failure rates and requirements of the program itself.

Here we introduce an innovative alternative approach to providing long-term support that dramatically reduces upfront costs while managing ongoing expenses appropriately. An OEM that chooses to adopt this approach can achieve consistent costs that translate to predictable sustainment costs for program contractors. This alternative approach utilizes a key role that must be created called the "project success manager." The project success manager is responsible for ensuring that support is available, provided only as needed, and delivered at the lowest possible cost to the OEM, which translates to a low, predictable cost for the program contractor.

There are four key aspects of this approach that are implemented by the project success manager. First, for system elements that are manufactured by the OEM service provider and have not been discontinued yet, the project success manager works with product planners to ensure that parts are available throughout the life of the program. Product planners then make lifetime buys when necessary to ensure that parts are available for standard support purposes and any existing sustainment contracts. Second, the project success manager continually audits the system bill of materials to determine when obsolescence is imminent and secures the appropriate parts or spares. For example, a CPU often has a much shorter lifecycle than a typical A/D program. The project success manager must ensure that enough spare CPU's are available, which are compatible with the system and meet program requirements.

As a system element approaches obsolescence, the correct approach for managing parts varies based upon the type of component. In many cases, it is necessary to stockpile parts accordingly. The availability of parts depends heavily upon where the system element is in its lifecycle, the manufacturer's strategy for supporting elements, and the overall demand for that element's parts and components. The third task implemented by the project success manager is to ensure that each element has enough supply of parts using any means available. A system element that is past its obsolescence period, for example, may be only available at a marketplace for used equipment. Or, due to the risk of counterfeit parts, there may not be any parts available from trustworthy sources. In this case, utilizing in-house expertise in component level repairs can ensure parts are available for decades beyond obsolescence.

The final aspect of this novel approach for sustaining test systems is to continually plan ahead, especially earlier in the program's lifecycle. The project success manager therefore ensures that predictable, consistent costs for support are achieved. This translates to an overall predictable cost of sustainment for program contractors.

### B. *Why Plan Ahead for Sustainment?*

When is the best time to start planning for sustainment? As discussed, costs can be reduced when appropriate planning occurs in advance of the product obsolescence period. However, it is not accurate to make the general statement that the limitation is based on where the program is in its cycle. Most often, it is possible to still achieve significant value and savings no matter where the program is in the cycle. At least part of the issue is mitigated by the fact that few if any of the products are on the same cycle. Many of the newest products will likely be free of parts shortages for the majority of the program. For any products built with parts that may be in short supply in the near term, possible solutions include a decision to use a combination of used equipment, parts stockpiling, and component-level repair capabilities.

Consider Fig. 6, which depicts the tradeoff between the value and cost of a sustainment solution based upon which program phase is currently employed. At a high level, this graphic depicts the inverse relationship. The earlier that you plan for sustainment, the more options there are available to achieve the lowest cost. One reason for this, as discussed, is the number of options available to acquire or supply stockpiles of parts. In addition, besides parts supply, sustainment and test costs can be significantly reduced through a combination of services that is tailored according to the program phase and goals.

For example, in the definition phase, consulting to help design the test system and improve test processes reduces long term costs. Later in the lifecycle, there is still time to do significant planning. Onsite services can be utilized, such as providing a dedicated expert to ensure maximum uptime when it is needed and for critical systems that need it most. Better management of assets through available programs and tools can help identify utilization and health of instruments, producing insights into reducing capital expenditures, operational expenditures, or both. By performing analysis regarding timing of obsolescence, actionable insights can be used to determine which instruments are candidates for a technology refresh and the best timing for that process.

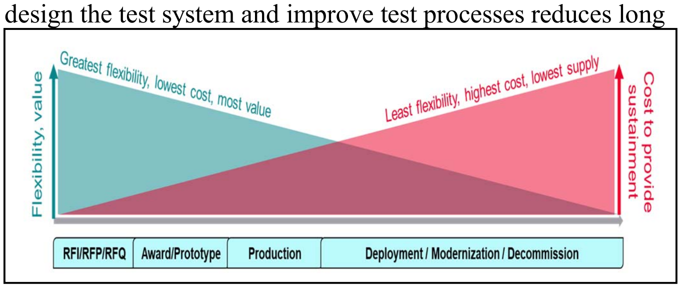


Fig. 6. Tradeoff between value and cost based upon program phase

## VI. Case Studies

### A. *Case Study 1: Test Process Analysis*

This case study shows how planning early to improve test processes can reduce long-term cost of test. A stepwise approach is used to analyze the current test process, get actionable insights and financial benefit projections, and follow-up to assess the impact of changes. The main purpose of analyzing the test process is to drive improved efficiency and efficacy into the entire test process.

Benchmarking relative to industry leaders provides a sense of the current test state, using parameters such as those shown in the spider chart in Fig. 7. The parameters shown include test architecture, test and quality improvements, asset utilization and lifecycle management, reuse and standardization, test data management and usage, and manufacturing test cost and effectiveness. After completing this benchmarking process, analyze the results to create a plan and roadmap for implementation. Once the plan has been implemented, the benchmarking process is performed again to see how the changes are affecting the key parameters. One example of using this process resulted in significant long-term cost reduction through a more efficient automation process and common production line.

### B. *Case Study 2: Reducing Sustainment Costs*

In this case study, we will analyze how an asset management program can help identify opportunities to reduce capital and ongoing operational expenditures. Fig. 8 shows the results of tracking the utilization of an example set of instruments that a typical company could have in their asset pool. The instrument models listed include network analyzers, an oscilloscope, a

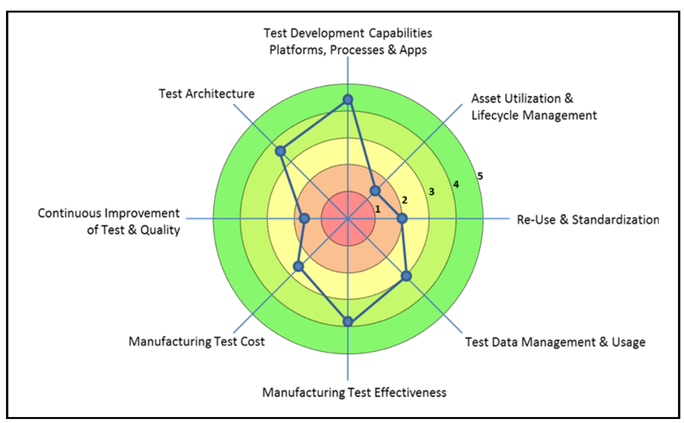


Fig. 7. Benchmarking exercise for analyzing current test processes

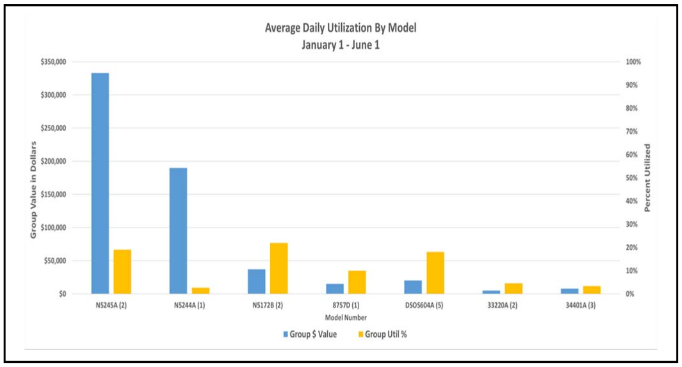


Fig. 8. Equipment utilization versus purchase price

function generator, and a digital multimeter. The blue bars represent the capital purchase price of the instrument, and the gold bars represent the average daily utilization of that instrument over a 5-month period.

The two instrument models with the highest purchase price and performance, the N5245A and the N5244A, have low usage rates relative to the purchase price. Using this information, the following improvements are possible:

- Increase utilization by placing the high-cost instruments into a loan pool so that engineers can share them
- Compare purchase price to the cost of a rental if the use model aligns with renting

Of course, if rental proves to be the ideal option, it may be necessary to also use a loan pool to ensure the instrument can be used efficiently during rental periods. In addition, it may be possible to identify underutilized instruments that can be traded in for ones that are higher priority. Or, if there are requests for more purchases of a given model, the loan pool may allow the requesting groups to efficiently share the equipment, thereby reducing capital expenses.

This example shows many ways in which a program can save capital and operational expenditures over the long term. Improving efficiency lowers the total cost of sustainment, which, of course, improves profitability and competitiveness.

## VII. Conclusion

Sustainment is a major contributor to overall program cost, and in many cases is the leading contributor. This has consequences. For example, long-term supportability is required. Also, it is important to maintain predictable costs and utilize cost-management techniques (e.g., improve efficiency). Not only is sustainment a leading contributor to program cost, most of these costs are locked in by decisions made during the development phase. As shown, managing risk through a planned approach to sustainment can ensure predictability and lower overall costs versus addressing and managing the issues when they arise. Predictable costs ensure maximum probability of success when re-bidding contracts and maximum probability of total program profitability. They also remove the risk of high-cost per-incident support events.

Unfortunately, it has been common to accept the risk of managing issues when they arise. This may seem to be the lowest-cost option, especially in the beginning of the program when support costs are usually low. However, this is not the best long-term option. The costs can be very high, and there is no way to predict the magnitude or timing of those costs as the program ages.

Predictable and consistent costs are achieved by partnering with an OEM that is committed to long-term support. The innovative approach to sustainment solutions discussed ensures test systems are operational and maintained long-term, provides guaranteed uptime support, and minimizes total sustainment costs. Additionally, while incorporating sustainment solutions earlier in the program enables greater value and cost savings long-term, a customized sustainment solution can be created for any phase of the program and set of requirements.

Ultimately, by leveraging a customized solution for sustainment, the program contractor eliminates the excess time and resources previously required and can focus on true core competencies and differentiators. Thus, profits are maximized, schedule is maintained, and long-term success is achieved.

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