Defense Standardization Program

Case Study

Aircraft Batteries and Components

Design Improvements and Standardization Yield Savings and Reliability

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This case study illustrates how the Naval Surface Warfare Center (NSWC), Crane Division, achieved cost avoidances throughout the Military Services by applying design improvements across several aircraft battery systems and related equipment. At the same time, this effort contributed to aircraft reliability and mission readiness.

Background

The NSWC, Crane Division, provides design, testing, and engineering support for electrochemical power sources—batteries and fuel cells—for nearly all major Department of Defense (DoD) weapon systems and for myriad types of equipment. Applications encompass submarines, surface vessels, aircraft and avionics, surveillance and intelligence systems, satellites and missiles, communications systems, ground support equipment, and other electronic devices. As essential and critical components for the operation of these systems, military batteries must operate reliably and perform well in adverse environments.

The types of batteries in military inventories are as diverse as their uses. Batteries range in size and power from small button cells (0.03 ampere hours) to launch facility batteries (10,000 ampere hours), and span the entire gamut of chemistries (e.g., alkaline, lead-acid, lithium, nickel-cadmium, nickel-iron, seawater). Each type has unique life-cycle requirements for shelf life, service life, transportation, handling, and environmentally sound manufacturing and disposal. All told, there are about 3,800 different types of military batteries, some costing more than tens of thousands of dollars each.

To a degree, this diversity is a necessary consequence of the varying requirements of the systems that use the batteries; however, part of the diversity is an inadvertent result of processes for development and acquisition. Traditionally, when a DoD activity acquired a new system, the system often used a newly designed battery that the contractor supplied specifically for that application. This approach led to a proliferation of battery types beyond what was required by different applications or environments.

Problems

Beginning in 1979, Crane began to address two interrelated issues that arose from the development and acquisition process.

- First, the inefficiency of the process meant that procurement costs for batteries were higher than necessary.
- Second, many of the batteries that resulted from this process were poorly designed. This problem was particularly evident in military aircraft, whose batteries required extensive maintenance and frequent replacement. Moreover, other flaws in these batteries were causing damage to the surrounding battery compartment and other aircraft components.

Under the previous system, specialized engineering support was required for each unique battery type, and the development cycle didn't necessarily reflect the latest trends.

Procurement

Each unique battery type entailed costs for engineering design support. The lack of standardization meant that even if a new battery was similar to others already in use, designing it involved a learning curve and required its own costs for prototyping, testing, evaluation, and design correction when necessary. Different batteries would commonly require different documentation and equipment kits for testing, recharging, or other maintenance. These costs ultimately were expressed in the cost of the battery.

Furthermore, the lack of standardization hindered opportunities for economies of scale. Because numerous systems used unique batteries, the acquisition and production volume for each battery was lower.

Inadequate Design

The problems, however, went beyond just higher procurement costs. When a contractor designed a unique battery for a specific application, the process was akin to reinventing the wheel. The development cycle often overlooked available technological improvements in industry at large and allowed design shortcomings to be repeated in batteries for new applications.

These design deficiencies meant that batteries often required more frequent and costlier testing, recharging, cleaning, repair, or replacement. The main batteries on F/A-18 aircraft, for example, had to be removed for maintenance every 18 flight hours, and battery failures requiring outright replacement occurred every 56 flight hours. Even worse, the main batteries on AV-8B aircraft had to be removed for maintenance every 15 flight hours, and failed systems had to be replaced every 39 flight hours. The sealed nickel-cadmium batteries used on these aircraft were susceptible to high temperature degradation and also needed to be charged by a separate, expensive charger.

In some cases, inadequate components on the batteries also caused unanticipated wear or damage to the systems that used them. Crane's attention focused especially on the vent caps for aircraft batteries. Vent caps are supposed to retain the corrosive electrolyte, allow a controlled release of pressure, and prevent contaminants from entering the cells. Two basic types of vent caps are required—one for aerobatic and one for non-aerobatic applications. The aerobatic version should retain the battery electrolyte in cells when fighter aircraft fly inverted or at extreme flight attitudes. The non-aerobatic version is designed for high-vibration helicopter environments or other aircraft such as transports that are supposed to remain in level flight.

Despite the requirements, the design and materials of the vent caps on the original equipment manufacturer (OEM) batteries allowed the electrolyte to leak out during operation. The CH-46, H-60, P3 group, C-130, and C-141 aircraft were using flooded lead-acid or nickel-cadmium batteries that spilled electrolyte onto the airframe structure. The leakage not only deteriorated the battery and shortened its service life, but also corroded the battery compartment and other aircraft parts. The failure of vent caps to perform properly led to more than half of the battery failures and maintenance actions.

Outcome

Crane's general approach to these procurement and design issues was to replace OEM components with government designed equipment that incorporated technological improvements and to apply those improvements across several aircraft systems.

Battery Replacement

Crane addressed the procurement and maintenance problems by replacing contractor provided batteries with standard government designed low maintenance battery types (Figure 1). Many of the battery replacement programs introduced new technologies or materials to enhance performance. Although improved systems often were not available off the shelf for designers to use, the individual components were available through commercial sources or were used in other aviation designs.

Some improvements were not yet being used for commercial aircraft and posed some unknown risk to the military. The risk turned out to be minimal, and the savings have been tremendous.

One such new technology was the “starved electrolyte” battery, which eliminated the need to add electrolyte. It could charge directly from the aircraft’s electrical power instead of needing a special charger. Another battery design change was the use of ultralow maintenance nickel-cadmium batteries that minimized the addition of electrolyte and extended the maintenance interval. These design changes also increased safety in combat situations.

Other changes included materials more resistant to electrolyte damage, materials with higher conductivity and hardness for electrical connectors and receptacles, and tamper-proof hardware to eliminate inappropriate maintenance actions.

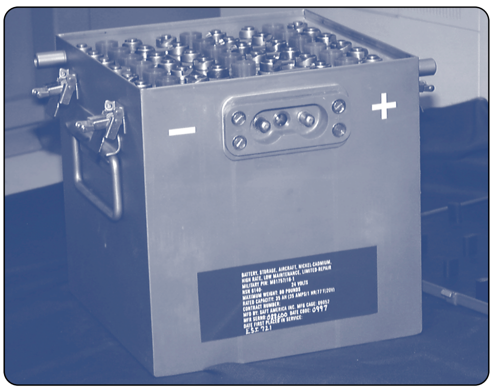

Figure 1 ***Crane developed a family of standardized government designed batteries, such as this nickel-cadmium aircraft unit.***

Reduced Maintenance

The new batteries greatly extended maintenance and replacement intervals for each of the aircraft and reduced the need for spares procurement. The batteries do not need scheduled maintenance. They are removed only if they are mistakenly over discharged or reach their scheduled service life. Table 1 compares the average maintenance and replacement intervals for OEM batteries to those of the new government designed equipment. The difference is expressed as an improvement factor (i.e., how many times longer the new maintenance interval is than the old).

In some cases, the maintenance intervals improved by tens, hundreds, or even thousands of hours. The F/A-18, for example, can now fly more than 40 times longer between battery maintenance actions.

Aircraft	Routine Maintenance Interval (Flight Hours)			Replacement Interval (Flight Hours)		
	OEM	Government-designed	Improvement factor	OEM	Government-designed	Improvement factor
AV-8B	15	69	4.6	39	233	6.0
CH-46	49	169	3.4	85	683	8.0
F/A-18	18	793	44.1	56	2,393	42.6
H-60	—[a]	450	—[a]	158	1,300	8.2
INS	16	169	10.6	51	526	10.3

Table 1 ***Battery Maintenance Intervals***

Source: Compiled from NSWC Crane Productivity Initiative (PII) data sheets. Data for the AH-1W and P3 group were not sufficiently documented to enable direct comparisons.

[a]Not documented.

Lower Unit Costs

The unit costs of batteries generally have fallen. Table 2 compares the unit costs of OEM and government designed batteries, and expresses the difference as an improvement factor (i.e., how many new batteries could be bought for the price of one old battery). The main battery for the F/A-18 now costs less than one-tenth the price of its predecessor. The slightly higher unit costs for the H-60 and inertial navigation system (INS) batteries were more than offset by the improved service life and reduced maintenance costs described above.

Crane cites the following reasons for the lower unit costs:

- Economies of scale—A common battery can be used in multiple applications, thereby reducing engineering, contract, and logistics support costs.
- Introduction of military technologies into commercial applications—Because of larger production volumes, production costs were amortized over a wider customer base.
- Competitive sources of supply—Systems no longer depended on batteries from a sole source. Crane states that the qualification of more than one source of supply reduces cost by 25 to 30 percent.

Aircraft	Replacement Battery Unit Cost ($)		
	OEM	Government-designed	Improvement factor
AH-1W	7,800	3,800	2.1
AV-8B	8,200	1,400	5.9
CH-46	1,180	900	1.3
F/A-18	9,810	900	10.9
H-60	1,100	1,200	0.9
INS	500	600	0.8
P3 group	600	500	1.2

Table 2 ***Battery Unit Costs***

Source: Compiled from NSWC Crane PII data sheets.

In summary:

- The standardized government designed batteries for these systems cost less to acquire.
- Once acquired, those batteries last far longer.

Additional undocumented savings have also resulted from a battery help line that Crane established in 1994. The help line links customers, engineers, and commercial battery databases, and helps customers identify standard battery types they could use in their applications.

Vent Caps

Crane addressed the problem of faulty battery vent caps by replacing OEM vent caps with standard government designed vent caps (Figure 2). The new ones included the following improvements:

Figure 2 ***Battery vent caps (from left): OEM, new non-aerobatic, and new aerobatic. The government design for the new vent caps used improved technology.***

- Use o-ring and vent band materials that are impervious to electrolyte.
- Change the physical shape of the battery to redirect the electrolyte away from gas vent paths, thereby eliminating the expulsion of electrolyte as cell pressure increased.
- Apply configuration control through common specifications, which eliminate tolerance issues between rival battery manufacturers and allow one vent cap to be used on products from different companies.

The standard vent caps required less maintenance. In addition, major cost avoidances resulted from reduced damage to the battery compartment and aircraft structure from leaking electrolyte.

These standardized improvements have been applied to several aircraft systems. The initial replacement for non-aerobatic vent caps began in 1990, with the replacement of vent caps for aerobatic application in the T-2 aircraft following in 1992. In 1995, the standard, non-aerobatic vent caps were introduced to additional aircraft types across the Military Services.

Investments and Payoffs

Savings for the battery and vent cap replacements are reflected as cost avoidances and are calculated by comparing the costs of the old systems to the costs for the new ones, including development costs. The calculations take into consideration the number of aircraft, flight hours between maintenance intervals, labor costs, and materials. Development costs include engineering changes, testing, flight evaluation, and conversion costs, and are for the most part a non-recurring expense for the life cycle of a system. Documentation does not report whether any training costs occurred. The cost avoidances are recurring each year as long as the aircraft are in service.

Table 3 shows the savings through FY 1999 that can be attributed to reduced costs for procurement and maintenance. About 45 percent of the savings came from lower procurement costs (i.e., buying fewer and cheaper batteries and vent caps) and about 55 percent from reduced maintenance costs (i.e., less frequent and faster scheduled maintenance, and fewer unscheduled repairs).

Replacement Item	Procurement	Maintenance	Investment Cost	Total
Batteries	137,351	160,869	(8,624)	289,596
Vent caps	74,401	91,436	(717)	165,120
Total	211,752	252,305	(9,341)	454,717

Table 3 ***Summary of Cost Avoidances for Aircraft Batteries and Vent Caps Through FY 1999 ($000)***

Source: Compiled from NSWC Crane PII data sheets.

Notes: "Procurement" category includes savings for batteries, battery repair materials, and aircraft repair materials. "Maintenance" category includes labor costs for scheduled maintenance as well as unscheduled repair and replacement of failed units. "Investment cost" includes system development, engineering, design changes, flight tests, and conversion equipment and labor.

- Through the *battery replacement* programs, Crane reports net cost avoidances of $289,596,000. The documented investment costs for development and conversion were $8,624,000.
- Similarly for the *vent cap* replacements, Crane reports cost avoidances through FY 1999 of $165,120,000. The documented investment costs were $717,000.
- The *total* reported savings and cost avoidances for Crane's battery standardization initiatives amount to $454,717,000, from an investment of $9,341,000—a return ratio of 49 to 1.

Current Status

Cost avoidances will continue to accrue for the aircraft that use the battery improvements introduced by Crane.

Crane typically undertakes two or three battery development efforts each year. Current standardization efforts involve a plan to develop a standard family of thermal batteries. Six different sizes and three different voltages have been selected that cover many of the thermal battery requirements. A challenge will be to convince decision makers to use batteries from the standard family rather than selecting a program unique battery. Occasionally a program may use a slightly over designed battery, but by using a solution shared across multiple programs, the overall total system cost savings should outweigh the slightly increased cost to the individual program.

Standardization of aircraft batteries improves design and performance and lowers cost.

Working with battery manufacturers in response to Navy and Air Force improvement initiatives, Crane has developed an ultralow maintenance nickel-cadmium battery for military use. It will reduce the maintenance performed on aircraft engine starting batteries in the fleet by 50 percent.

Lessons Learned

Following is a summary of the lessons learned in this case:

- NSWC Crane achieved significant cost avoidances by replacing OEM batteries and vent caps with standard government-designed items.
- The government-designed batteries demonstrated longer service life, dramatically extending the number of aircraft flight hours between repair or replacement.
- Standardization afforded an opportunity to improve design and performance, while lowering costs.
- A relatively simple component, such as a vent cap, can have an enormous impact on maintenance and repair costs.
- As a center of expertise for battery design and technology, Crane was able to extend the savings beyond Navy equipment across the Services.

Making Systems Work Together

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