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Embedding Affordability and Producibility (AP) in Systems Engineering: Cost, Complexity and Readiness as Prime Drivers for Integrated Design

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ABSTRACT

It is time for Affordability and Producibility (AP) to take a more dominant role in Systems Engineering (SE). Functional design is no longer good enough. Cost, complexity and readiness must be drivers for optimum integrated design. Without focusing more on AP, we will continuously fuel the "design, re-spin, re-spin again" problem that drives significant cost and time into a system where the pace for delivery to theatre is moving as fast as ever.

This paper describes the SE approach from an AP focus. Decisions and challenges that were encountered during the DRS OBVP design will be presented as a "real world" example. This paper will present the high level considerations to put AP up front in SE to drive decisions so that safe, reliable, cost effective products are delivered to the Warfighter in this tough, fast paced military environment.

Introduction

Today's competitive environment is changing rapidly. The Military's procurement processes and contracts are focusing heavily on COTS equipment in an environment where cost is king. In order to stay competitive in this economy and this dynamic environment, companies need to focus on reducing cost and development time to ensure products are ready to be provided to the Warfighter in a cost effective, timely manner. In order to accomplish this, companies need to reduce reiterative process and learn how to overcome obstacles such as geography, culture and process. The ability to change the mentality of Systems Engineering by focusing on up-front cost and price to win will allow companies to reduce design spins and incorporate parts that put the company in a position to meet the price to win. Often, bringing in a talented third party can help a project team "think outside of the box" and, working as a team, can help the program focus on the price to win.

One example of this system engineering approach is the On-Board Vehicle Power (OBVP) program at DRS. DRS has long realized the importance of power on the battlefield and after a number of successes with the HMMWV OBVP program [1] realized that teaming with a third party that focuses on cost and producibility will allow the design team to take the system to the next step and provide the Warfighter with a robust, affordable solution in a quick and timely manner.

This paper will discuss the OBVP system and how Munro and Associates was employed as a "third party" to help the program develop a strategy to drive cost down while reducing delivery time. It will discuss the tools and methods used by Munro and Associates to help the OBVP team focus on producibility and price to win early in the program. Since this effort, the OBVP program at DRS has grown to not only a successful program, but the knowledge learned in the light vehicle effort were expanded to develop successful programs for the medium and heavy vehicle markets.

On-Board Vehicle Power

The DRS on-board vehicle power system provides a comprehensive power subsystem that provides generation, power conditioning (AC or DC) and power distribution. These elements thereby provide a fully integrated equipment set that produces the level and quality of power needed in stationary or mobile operations that fully meet the requirements of the Warfighter operating on the battlefield. Figure 1 shows the basic architecture of a typical OBVP system. Various vehicle sizes and platforms can use this common architecture, often with common Line Replaceable Units to provide power at various levels as needed by the platform or the Warfighter on the ground. The basic approach is to identify the LRUs that can be common to multiple platforms and use as much existing hardware as possible as a springboard for the upgraded design. This eliminates costly design reiterations, costly and time consuming "white sheet of paper" designs and breeds commonality as a cornerstone for design. This commonality improves producibility and increases the overall robustness of each system as the designs are realized. This section will give a description of the common OBVP architecture to show the reader the various opportunities and system engineering challenges that OBVP designers are faced with.

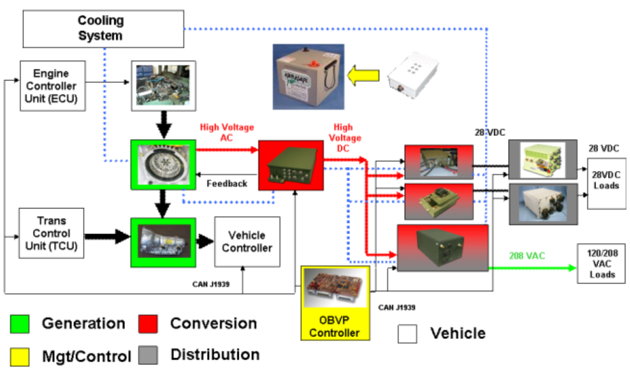

Figure 1. Typical On-Board Vehicle Power Architecture.

Power Generation

Typical power generation technology places the generator unit between the engine and transmission of a vehicle. There are numerous ways to do it; in-line generator applications used by DRS have often been selected as the best solution and are described as an example. Requirements for design modifications to support the torque for auxiliary drive shafts, pulleys, etc. are eliminated by this approach. Solutions using this approach are targeted for various vehicle implementations and have the ability of generating power from 30 to 260+kW.

A typical OBVP HMMWV in-line generator installation is shown in Figure 2. Also shown in the figure are the power lines (orange) and the hoses for coolant (black). The unit described in Figure 2 (30+kW – HMMWV) requires no lubrication, is cooled with 8gpm engine coolant (at 96C) and weighs only 54kg. This LRU produces variable AC Voltage with a variable frequency power output that needs to be converted to a regulated high Voltage bus.

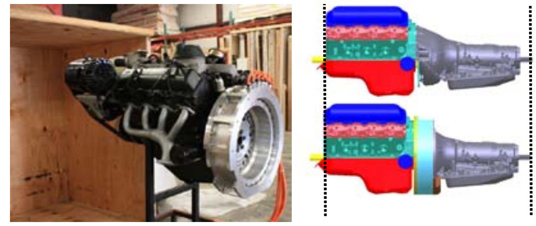
Figure 2. Typical HMMWVOBVP Application

High Voltage Regulation

To convert the variable voltage variable frequency AC power from a typical generator, a bus regulation system needs to be incorporated into the overall power management system. The bus regulation system uses field oriented control to actively rectify the variable frequency/voltage AC output from the Generator. The input to this LRU is the raw output of the in-line generator. Like any permanent magnet generator, the variable voltage over the speed range of the machine results in the inability to passively regulate a DC bus over the wide speed range of the engine. The bus regulation system uses field enhancement techniques at low generator speeds and field weakening techniques at high generator speed to regulate the DC high voltage bus. The high voltage bus is tightly regulated better than 5% during steady state operation and during transient loading and unloading of the system. By regulating the high voltage bus within 5%, as demonstrated on vehicle, the other system's conversion electronics LRUs are reduced in size and weight by eliminating inefficient conversion typically needed to accommodate wide input voltages. The performance described allows tight regulation across the entire speed range of the engine from idle to over-speed.


Figure 3. DRS Generator/System Controller

When the vehicle is at idle, the speed controller has the ability to slightly increase the idle speed and maintain it so that the desired power can be provided during steady state and transient loading. In stationary operation, the controller will increase the engine speed to accommodate the efficient operating point of the generator where it provides its maximum power. During electrical loading of the system, the engine's speed will typically dip due to increased torque demand on the engine. The speed controller will regulate the desired mobile or stationary speed and work hand in hand with the OBVP system controller to ensure power is not interrupted and remains clean during the event.

Figure 4. DRS Motor controller

DC/DC Conversion

The purpose of the high Voltage DC/DC converter is to convert the high Voltage bus created by the bus regulation system to a managed, programmable low direct current (DC) Voltage. The DC/DC converter is liquid or air cooled, isolated and maintains stability throughout the various environmental conditions and loading conditions required on today's battlefield. The LRU enables operator, diagnostic and reprogramming interface with the system via a J1939 bus.

Figure 5. DRS-TEM 10kW High Voltage to 28VDC Converter

If more distribution is required, in more of a "point of use" application, a similar LRU that is air-cooled with similar specifications can be used. This LRU is approximately 3kW and is much easier to mount in locations inside or outside of the vehicle depending on the desired architecture. The 3kW and 10kW DC/DC converter LRUs are shown in Figures 5 and 6. These LRUs are also considered part of the distribution system because they have the ability to remove themselves from the high Voltage bus due to a fault, load shedding, or in a "smart" power algorithm.

Figure 6. DRS-TEM 3.3kW High Voltage to 28VDC Converter

DC/AC Conversion

Often it is desired to have AC export power from the vehicle to power AC loads from a 120/208VAC source. This makes the distribution and management of power even more important, because the probability of a fault occurring when cabling and loads are drawn from the vehicle is higher. It would not be desired to have an overload or fault condition that would cause all of the other systems on the vehicle (IED Jammers, etc.) to be removed.

Typical inverters operate from high Voltage input power provided by the bus regulation system, and produce three-phase output power at 120/208VAC. The output frequency is often user-selectable for 50 or 60Hz and is compliant with MIL-STD-1332B Class 2B power quality requirements for utility power applications. The user can manually adjust both the inverter's output Voltage and frequency allowing the inverter to be synchronized to an external power source such as a Tactical Quiet Generator (TQG). In this manner, an uninterrupted transfer of power can be accomplished between the vehicle and a stationary power source.

The inverter provides ground fault monitoring and input power disconnect for unbalanced currents flowing into the inverter. This function enhances the overall system safety, fault clearing capabilities, load prioritization and load shedding. The inverter monitors the input DC Voltage and protects the inverter during conditions where the input power is connected in reverse polarity. A typical DC/AC inverter used in combat vehicle applications is shown in Figure 7.

Figure 7. DRS-TEM DC/AC inverter used in On-Board Vehicle Power applications

Power Management/Control

A final capability that is required in an OBVP system is power management, protection and control. These typically include a family of solutions based on a scalable, adaptable technology for the low-Voltage power management function. The Digital Vehicle Distribution Box (DVDB) is a power management system currently applied to multiple U.S. Combat platforms. The Power Management Diagnostics Controller (PMDC) is an enhanced power distribution LRU, while a Tactical Vehicle Power Distribution Unit is a power distribution LRU designed to support tactical trucks. All three of the power management solutions are based on similar technology and provide a proven power management capability.

Applying cost reduction and producibility using Munro and Associates' Design Profit tools

Most product development efforts focus on meeting functional goals first with other requirements such as cost, complexity, manufacturability and quality being viewed as downstream requirements, secondary at best, and usually as resultants of the design. After all, if the system doesn't meet the mission objectives, the rest doesn't matter, right?

Typical development approaches are reactive and iterative with design spin followed by design spin sequentially solving functional issues. A functional prototype is quickly produced and tested, establishing an arbitrary design path that evolves over time into "the system design" as issues are resolved. Suddenly significant time and resources have been invested into this particular concept and it's viewed as too risky for significant design changes.

Most engineers aren't as concerned with cost and manufacturability during early concept and design phases, seeing them as something "we'll address later, when manufacturing gets involved." Even a BOM seems to be difficult to obtain during early concept and design phases, let alone one with cost information, even though the majority of components have been identified or modeled in CAD.

When cost and producibility do become important, it is usually late in the program and well after the design has been approved and perhaps qualified. At this point, it becomes difficult to address cost and producibility because it requires major design changes to accomplish with any significance. Some design changes do occur but they are usually minor tweaks to the design to avoid requalification, reduced price negotiations with suppliers, or alternate sources identified for lower costs. But the results are often less than desired.

Manufacturing has the enviable task of determining how the product will be produced and often finds issues with the design that compromise producibility. Special equipment, processes and tools are often developed to accomplish the task adding more time and cost to the overall program. A cost reduction effort typically follows once manufacturing has commenced and the system clearly costs too much to produce.

The biggest issue in all of this is that 70% or more of the total cost of a product is determined and locked in during the early concept phases of the program when no one was concerned about cost and producibility, typically during the bid phase of most programs. Early design decisions drive cost and complexity determining every element of the product and how it's produced – the system's structure, what materials are used, how many parts and components are needed, how they will be produced, labor content, tools & equipment, facility requirements, etc. Our early decisions will establish how easily or difficult a system will be to produce as well as the total cost of that system. In other words, all downstream elements are determined when the concept is generated.

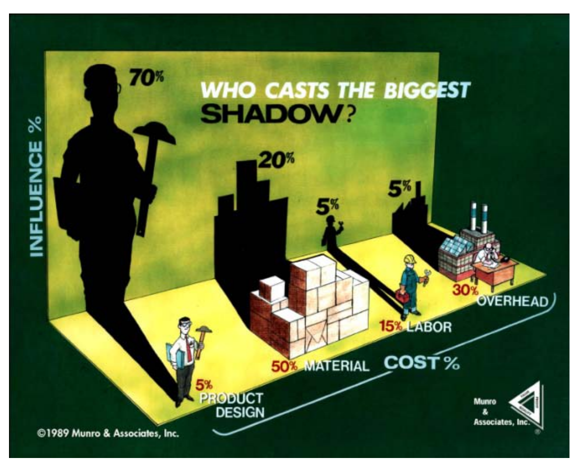

Figure 8. Cost and Producibility influences

Understanding cost and producibility early in the program has significant benefits. Our ability to influence the result of these attributes is highest during the early stages and drops off considerably as we move through the detail design and prototype phases and beyond. Opportunity is greatest early in the program to set the stage for a producible, cost effective system design. This also gives us the opportunity to evaluate multiple design alternatives and make design changes while it is still easy and inexpensive. Performed early it is Cost Avoidance instead of Cost Reduction.

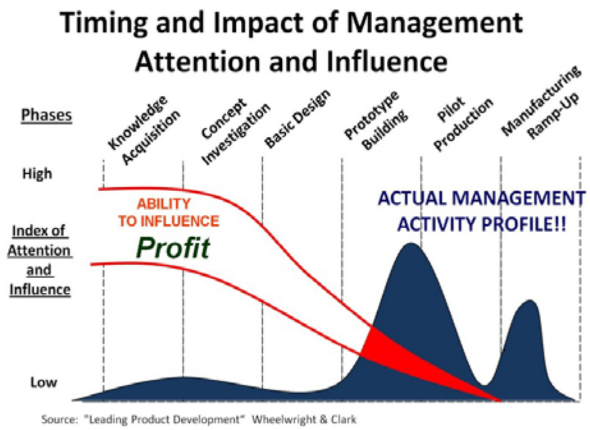

Figure 9. Timing and Impact

But the tools, methods and processes to effectively evaluate system design costs and producibility along with developing alternative concepts for comparison have lacked significant deployment on DoD programs. More importantly, product development processes haven't supported their use, especially early in the program. But they do exist and have been in significant use throughout industry for over twenty years. Engaging a third party industry expert with the experience, proven track record and technical capabilities can provide Systems Engineering programs the tools, processes, methods and, most importantly, the guidance and facilitation needed to implement early cost and producibility initiatives. As objective outside entities, they can see opportunities for improvement that others miss. They are not tied to the ways of the past nor caught in the corporate politics. They bring a fresh perspective, new eyes and the experience to identify and quantify solutions that have a positive effect on cost and producibility.

An organization such as Munro and Associates, Inc. has the experience and track record of guiding companies of all industries, including Defense, in this very task. It is what Munro & Associates does and have been doing for twenty-two years. Munro has developed the tools, techniques, and processes that address cost and producibility while working as an extended member of the development team. **Design Profit®** (DP) is a suite of analytical tools developed by Munro to model the design structure, processes, cost and quality. Mapping the design & process structure becomes a discovery process for the team uncovering the complexity and costliness of a given design. This DP model is a character representation of a design that consists of a set of symbols to represent parts, subassemblies, tools, fastening steps & other operations, in logical sequence. Various characteristics are then selected that develop a score for each part, subassembly and operation that highlight design issues to be addressed. A set of metrics including part costs, labor costs, quality costs, design complexity, part count, and other metrics, provide a relative set of data for comparison and rating of multiple alternative designs.

This quantifies the design, cost and quality and provides the means for understanding the issues facing cost and producibility upfront during the earliest concept and design phases. Utilizing **DP** starts when the program starts, as soon as there is some idea of the system intent with conceptual ideas or sketches as starting points. The ability to quantify the design early highlights producibility and cost opportunities aiding in decision making and focusing the team toward a common goal that will result in better products and systems from the start of the program.

The objective of DP is to find an optimum, balanced design that is simple, elegant and producible. It enables rapid design trades for competing concepts. It works in the front end concept space to expose problems, cost drivers and issues that are often overlooked until after detailed designs are complete and we begin to assemble. It forces the team to consider the assembly, manufacturing and serviceability in the concept planning stage. It enables the team to review every aspect of the design in a systematic fashion revealing missing design elements, design conflicts, inelegant interfaces and opportunities that cross defined IPT boundaries.

The symbolic, character representation divorces us from detailed constraints in order to allow creativity and innovation to be tried and analyzed. Symbolic mapping provides objective, meaningful metrics with less "pride of ownership" than detailed designs. Symbols are rapidly moved and reconfigured to represent new design schemes. This enables integrated teams to investigate technology, processing, supply chain, quality, risks and total accounted cost for many more design alternatives. Reports from the symbolic concept models reveal and expose drivers of poor quality, complexity and cost so that the team can innovate for elegant or more optimized, integrated solutions.

The DP model progresses in detail as development progresses. It is designed to enable rapid concept modeling early so that complexity and risks are exposed and mitigated while costs are at their lowest. As development validates assumptions, the DP model is refined with more discrete steps, tools and operations. Since it captures manufacturing and assembly elements, the DP model can generate line balancing, process sheets and work instructions as a direct output of the process.

The DP method plugs into and works in concert with Systems Engineering. Early concept evaluations for producibility using the DP methods provide metrics and direction for a more elegant integrated solution. This early activity provides a mainstream point of departure (POD) design plan that kicks off functional SE. The traditional functional SE activities will validate assumptions and provide refined data back to the DP model. A defined method with a series of PODs where the development team moves between the producibility domain and the functional domain several times during development will ensure that we design a product that is functional and cost effective.

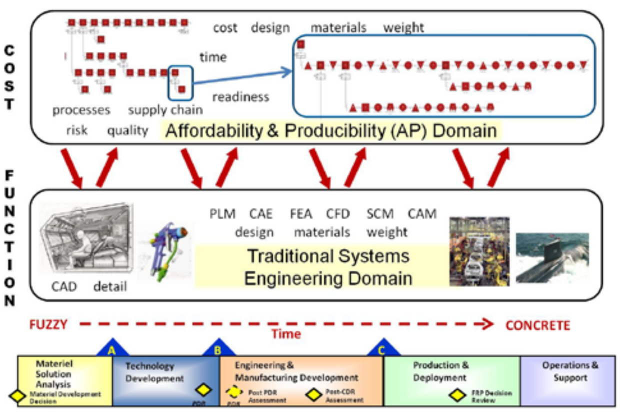

Figure 10. Cost function for affordability and producibility.

Reducing design time and cost through an AP focused SE approach

Given a set of requirements there are typically multiple viable technical solutions, however, none of them may result in a product with a unit cost that meets the market demands. In order to achieve the best overall solution in the initial development cycle, cost must be considered as a requirement from the beginning. This was the situation encountered by DRS on the On-Board Vehicle Power (OBVP) development. While an initial solution was identified that leveraged existing designs to reduce time to market and technical risk, it did not meet the cost objective. So to address a total solution it was determined that alternative designs must be evaluated.

It was decided to engage a third party with experience and the necessary tools to analyze a complex system such as this. Munro & Associates, Inc. was selected to join the DRS team and utilize their 'Design Profit' tool. The approach was to model the baseline system of known technical maturity and cost in 'Design Profit' as a basis of comparison with alternative solutions that resulted from team brainstorming sessions. The alternative designs resulted from consideration of vehicle packaging constraints, reduction of components, distribution of key processing functions, minimizing cabling and cooling complexity as well as other factors.

A symbolic characterization diagram was created for each alternative system design to account for cabling and cooling components in addition the main power electronics. Then a Bill-of-Material was provided along with an assessment of the assembly procedure for each component on the symbolic characterization diagram, so that a cost could be predicted. The known cost of the baseline system power electronics was used as a means of validating the model by comparing the predictions of material costs and assembly labor times to known data. After the baseline system was validated the alternative system designs were then modeled. A prediction of system cost was then determined for each alternative along with an assessment of risk. After comparing all of the data the team selected a system design that would meet the technical and cost requirements with an acceptable risk. Once the system design was selected a detailed evaluation of the individual power electronics was conducted using the same approach as used at the system level to determine the places where parts could be reduced to include circuit card, internal harnesses, and fasteners as well as construction techniques such as castings and integrated mounting features.

AP Focus

Often when performing internal research and development, we fall in the trap of finding parts or making custom parts to meet the demanding schedule needs. There is always the good intention of revisiting this on later "respins" or upgrades and making an effort to find the most reasonable priced part. Often, this is too late. If we wait until after the initial proof of concept design to think about the affordability and producibility of the unit, often it is difficult to find the affordable "drop-in" parts and more design is required to use these parts, thus increasing time and money required during the respin. A focus on affordability and producibility during the initial proof of concept will result in less redesign during a respin, or even eliminate a respin, which results in driving the schedule to the left and the cost down.

The OBVP system described previously is the perfect example for this SE approach. There are typically at least 3 to 4 different LRUs in the complete system that share a significant amount of commonality. Looking at Figures 2-7, it is apparent that the potential cost drivers for these types of

LRUs will include military grade connectors, busbars, capacitors, interconnects inside the box, power switches and a number of circuit card assemblies. Often, there is quite a bit of commonality of components for each of these LRUs that can be leveraged to get bulk pricing and eliminate costly design that would be required if each LRU is built individually.

Another tactic that needs to be applied when performing an SE focused task is a real look at "do we really need these" features. Often engineers fall into the trap of focusing on "the customer probably wants this" (even though they have not made it a requirement) or "here is a difficult requirement we know the customer wants, but let's just include this later during a respin." Performing detailed peer reviews with a third party that focuses on AP during the incubation process ensures the designers do not have to have multiple solutions over multiple iterations. It is far better to take a small amount of time during the initial design process, rather than taking a significant amount of time trying to make something work later, because having to modify multiple parts to make one part work during a respin often takes a significant amount of time and money.

A total system view of the entire OBVP system was envisioned as installed on the target vehicle. The initial objective was to optimize the entire system from a top level perspective first, then to optimize individual subsystems and LRUs. Block diagrams were developed showing subsystem interfaces (LRU to LRU) as well as functional block diagrams showing functional interfaces, communications and controls, power, I/O, etc. in order to clearly communicate system intent. Installation of each LRU, cable harness, mounting bracket, cover, as well as the generator/transmission swap, were identified and modeled within the Design Profit software. This allowed the team to gain a full, cross-functional perspective of the system, potential difficulties associated with the initial concept as well as a cost basis from which to compare alternative approaches.

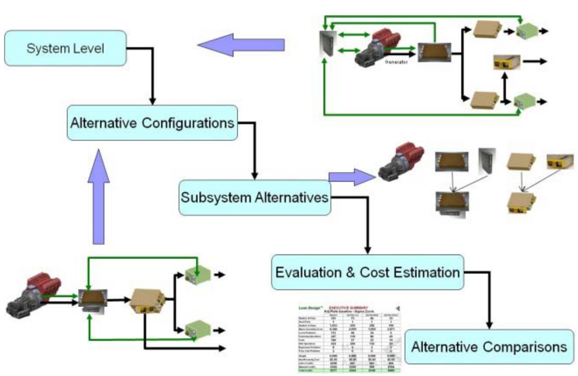

Figure 11. Design Profit approach for OBVP.

Having the full system laid out and modeled in front of the team allowed everyone to see the potential of new design alternatives, different combinations of subsystems, redundant components that could be eliminated, subsystem integration opportunities and functional consolidation. Through discussions and brainstorming with the core, cross-functional team, several alternative concepts emerged that were less complex, had fewer individual components, LRUs, cabling and interconnects. The entire system was therefore simplified, eliminating individual components that represented significant cost, complexity and design time in themselves, before any significant resources were invested.

Each concept was modeled and evaluated for complexity, producibility and total cost using DP software. System functions and features were reviewed against requirements ensuring no loss or compromise in mission objectives. Risk and technology deployment were also reviewed and all concepts were compared to each other and the original concept. Having early system level metrics provided the team with valid information on AP as well as functionality for comparison and decision making purposes. Optimizing at the system level prior to detail design improved the system architecture, eliminating waste in the design and reducing overall level of effort and development time.

Design Profit®

EXECUTIVE SUMMARY
OBVP Kit - Alt 0

Munro & Associates, Inc.

	OBVP Kit - Alt 0	OBVP Kit - Alt 1	%↓	OBVP Kit Alt2	%↓
Parts	1789	1656	7%	1636	9%
Steps	5181	4841	7%	4800	7%
Fasteners	1022	867	15%	853	17%
Piece Cost*	$22,738.21	$17,092.79	25%	$16,492.29	27%
Labor Time (min)**	2734	2515	8%	2501	9%
DRS Tooling	85000	85000	0%	85000	0%
Vendor Tooling	141000	141000	0%	141000	0%

Figure 12. Design Profit summary of alternative OBVP system concepts.

Once a concept was selected, the DP process was applied at the subsystem level, or individual LRUs. Each LRU was modeled in DP in detail showing every part, CCA, interconnect and fastener to gain an understanding of complexity and producibility as well as estimated costs. Design alternatives were generated to simplify the designs, reduce CCA's, interconnects, hardware, etc. throughout each box. Through combinations of design consolidation, layout changes, alternative technologies, material and process options, individual LRU designs emerged having fewer components, reduced wire harnesses, smaller lighter weight enclosures, resulting in reduced overall complexity, improved producibility and reduced total costs.

Design Profit® — **EXECUTIVE SUMMARY** GSC 500pc qty — Munro & Associates, Inc.

	GSC 500pc qty	Concept 1	% ↓	Concept 2	% ↓
Parts	1245	997	20%	892	28%
Steps	6094	5647	7%	5252	14%
Fasteners	466	242	48%	176	62%
Score	48,091	44,038	8%	41,347	14%
Piece Cost	$6,746.32	$6,085.98	10%	$4,825.22	28%
Actual Time (hr)	13.36	12.23	8%	11.49	14%
Total Labor Cost	$1,699.05	$1,555.86	8%	$1,460.78	14%
Q Burden	$5,828.10	$5,364.06	8%	$5,019.03	14%
Total Cost	$14,273.47	$13,005.90	9%	$11,305.03	21%
Annual Savings	N/A	$633,785	0%	$1,484,222	0%

Figure 13. Design Profit summary of alternative controller LRU concepts.

Ultimately, this system design was realized in the HMMWV OBVP solution delivered to the USMC in June, 2010. Furthermore, the cost saving concepts that were identified and employed in the initial solution were incorporated in the next evolution of the OBVP family of products currently being designed to target Medium class vehicles (MRAPs, Stryker, GCV) and Heavy Vehicles (such as Bradley and Abrams).

Results from utilizing SE tools to reduce price and development time

It has been established in this paper that the traditional SE domain focused first and foremost on the functional aspects of a product's design. In a global environment with an insatiable thirst for lower cost solutions we must find new age methods to provide solutions within the market budget. The time is now upon us where price will drive solutions. Hitting a price/cost target is paramount, and making it to the finish line with your profit margins intact will be the difference between survival and death.

Two significant lessons were taken from this project. One, focusing on meeting cost and complexity early will drive better long term stakeholder value into a product design, and two, cultural and procedural change within corporate functional supporting groups is essential for long term success.

Programs require the support from functional groups inside an organization. Programs rely on these functions to deliver expertise to their particular programs. Corporate functional groups have defined processes and rigor that they must follow. In order for a program to take advantage of new age methods, it is imperative that corporate functions incorporate early cost metrics expertise into their cultures.

Competitive system engineering must embed affordability and producibility analyses capability along with the more traditional tools. This new SE domain will include methods to capture downstream knowledge of production capabilities and costs, operations and support costs, etc. and make it available upstream to the concept development effort. Likewise, downstream looking tools must be made available to the early efforts so that "run out" scenarios can be simulated against design theories and alternatives before detailed development ensues. In the past cost has been a resultant of functional design. In the future, cost will stand as an equal player in driving decisions.

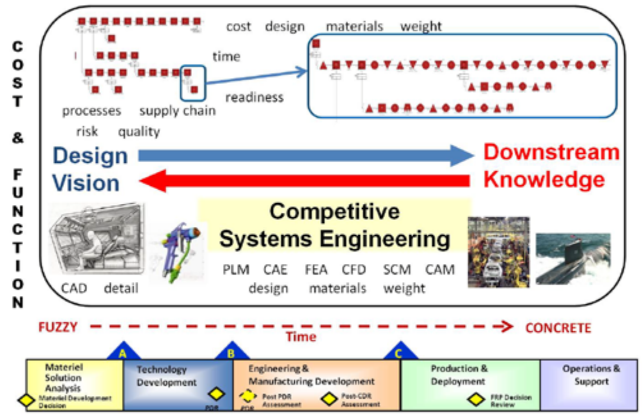

Figure 14. Competitive Systems Engineering design process.

Deploying a DP producibility domain plugged into traditional functional product design development is a step change to traditional SE. Successful implementation involves changes in behavior, activities and tool interoperability. It must be enabled and integrated into an organization's overall development scheme and requires new thinking around how designs are evaluated. This SE step change ensures design issues are identified and resolved earlier in the development. The result is simpler designs and elegant integrated solutions that enable right first time manufacturing and lower lifecycle costs.

Conclusion

Whatever program you may be working, please be assured that no science or capability is so necessary that money will find its way to you. The current global state is too competitive and too overextended to afford anything more than the essential, optimum value solution. Working the problem from a cost viewpoint is the only way to expose hidden costs and maximize value. The DRS OBVP has demonstrated that this is a feasible and more effective way to develop a product system. Engineers must learn that running off to engineer a solution before truly understanding its cost is a lost leader. With a clearer picture of total cost for given concepts, engineering teams can creatively eliminate complexity that in turn reduces development time. As in the movie "The Hunt for Red October," Captain

Ramius had a clear vision and knowledge of the future results. While his crew anxiously worried and wanted to act, Captain Ramius was able to wait calmly until the right time to act swiftly with amazing successful outcome. We engineers must also learn to collect more data and study more scenarios so that we can act swiftly, one time, with amazing successful outcome.

So, do you have time and budget to reorganize and retrain your organization to modernize your ability to analyze cost up front? We submit…you have no choice. Change is here and those who adjust can prosper. On June 28, 2010, Ashton Carter published a memo [2] to defense acquisition professionals that it is their duty to the American tax payer to eliminate waste and deliver high value to the war fighting effort. The war on cost in defense spending has just stepped up to a higher gear. A step change in systems engineering is in order. You must become proactive to reduce waste and cost or the government will do it for you.

REFERENCES

[1] Marcel, M., Schultz, J., Grider, G., "DRS-TEM On-Board Vehicle Power System," Proceedings of the NDIA Ground Automotive Power and Energy Workshop, Warren, MI, Nov 2008.

[2] Memo from Ashton Carter, dated June 28, 2010, "Better Buying Power: Mandate for Restoring Affordability and Productivity in Defense Spending"

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