Engineering and Implementing RMS Engineering's DTC Metric

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Abstract

Architecting a product requires a defined set of requirements for the finished product; e.g. size, weight, volume, range, power, color, cost, payload, etc. One very necessary requirement is the anticipated product production cost. Failure to set the production cost requirements at design kick-off allows for unexpected and unacceptable production costs. Previously, all too often, programs were allowing establishment of the production cost goal to slip, or they would wait for their customer to establish it for them. Raytheon Missile Systems' (RMS) Engineering Directorate has specified that all development programs will now establish a production cost goal using the Design-To-Cost (DTC) metric described within this paper and will monitor their design progress towards meeting this goal. Each program's DTC metric is now collected monthly and reviewed by senior management.

This paper will focus on the creation of the Design-To-Cost Metric (DTC), its purpose and use at RMS. The DTC metric is designed to allow business unit management to quickly review the status of their programs as to how well the various program designs are progressing as to their ability to be produced at the specified value.

Background

The Engineering Effectiveness Metrics initiative grew out of RMS's desire to reduce the costs and cycle times necessary to design, develop and build products that work right the first time. As such, we were challenged to measure factors that lead to our products costing too much, taking too long to reach the user, and, admittedly, sometimes not initially working right. To support these goals, an Engineering Effectiveness Metrics Team developed three primary metrics:

- On-Time Delivery Performance, which involves deliveries of Engineering data, documentation, requirements, hardware and software
- First-Presentation Yield, which covers technical data package change rates and identifies out-of-phase defects on all design, development and production programs
- Design To Cost, which uses affordability principles to drive all architecture, design and development activities.

Design to Cost

The traditional definition of Design to Cost (DTC) emphasizes meeting specific cost targets at various stages in a product's life cycle. To meet customer affordability objectives, we must go beyond the traditional definition and create a culture that guides every development and manufacturing decision to eliminate non-value added activity.

DTC is not a stand-alone process, and early attempts to apply it as such produced marginal results. DTC must be an over-arching philosophy that permeates the entire development environment and dominates all major design decisions. DTC must treat cost as a firm program requirement, applying the principals of Cost As an Independent Variable, or as the Department of Defense (DoD) calls it, CAIV.

Design to Cost drives engineering, manufacturing, materiel, finance, and others to find and eradicate extra cost. The DTC approach leverages lean practices and processes and uses rigorous cost target allocation together with successive cost/performance tradeoffs at all levels in the product hierarchy to achieve affordable designs offering best customer value.

The goal of the Design-to-Cost approach is to meet production and Life Cycle Cost targets for products that meet well-established cost targets and provide best customer value. By integrating Design-to-Cost with Six Sigma quality techniques the Product Development Process (PDP) offers the combined benefits of reduced production cost and improved quality/yield.

DTC embraces and leverages the concept of CAIV. As such, cost is treated as a primary requirement that may only be traded for performance or other technical attributes if the customer determines that doing so will provide overall best value and establishes a new cost target that reflects that determination.

DoD customers are focusing on affordability through Acquisition Reform and the best-value concepts of Cost As an Independent Variable (CAIV). In response to these and related initiatives, industry must simplify designs, focus on best customer value, and eliminate non-value-added activity to drive costs down. This objective is possible if we, industry, focus on a best-value balance among cost, performance, and supportability with the same intensity that we once devoted to performance alone.

To provide our customers with superior products at affordable cost, we must embed intensive cost and quality focuses into the product development process (PDP). Cost focus needs to be formalized and institutionalized as an integral part of the PDP. Cost assessment and management begin long before the product takes on a specific form and continue iteration with supportability, performance, and risk until a best-value balanced design is achieved. (HAC DTC Handbook 1996)

DTC and CAIV

In MIL-STD-337, DOD once defined DTC as follows:

> "Design to Cost is an acquisition management technique to achieve defense system designs that meet stated cost requirements. Cost is addressed on a continuing basis as part of a systems development and production process. The technique embodies early establishment of realistic but rigorous cost targets and a determined effort to achieve them."

In more recent documentation such as DOD Instruction 5000.2, DTC can not be found, but is inferred to be under CAIV. Over the years, this has caused some confusion and a blending of terms. To clarify somewhat and to try to keep CAIV and DTC clear:

- CAIV is architectural in nature and asks the question: "Given a fixed budget, how much performance can I get when I need it with maximum acceptable risk?"
- While DTC is engineering oriented and attempts to solve the mystery: "Given the budget and performance requirements, what do I design and build?"

CAIV evolved from and expanded on the basic DTC concept. DTC was, and still is, concerned primarily with production costs and was focused on the lowest cost solution within a given requirements/performance set. CAIV is interested in costs from the total ownership point of view. The acquisition community, including technology and logistics, and the requirements community uses the CAIV process to develop total ownership cost (TOC), schedule, and performance thresholds and objectives. They address cost in Operational Requirements Documents (ORDs), and balance mission needs with projected out-year resources, taking into account anticipated process improvements in both DOD and defense industries. Thus, one can see how DTC became a part of CAIV.

CAIV and DTC at RMS

At RMS, CAIV and DTC are blended into both the business culture and the development process under the heading of Affordability. To work effectively, CAIV must be a part of the business culture, seeking cost reduction and best value at every turn, while DTC must be an integral part of the design and development process. Within this process at RMS, well-defined cost targets are assigned to each sub-product in a product's hierarchy; cost drivers are identified and focused on; cost/performance tradeoffs that lead to affordable, best-value solutions are conducted; and metrics are determined and reported on.

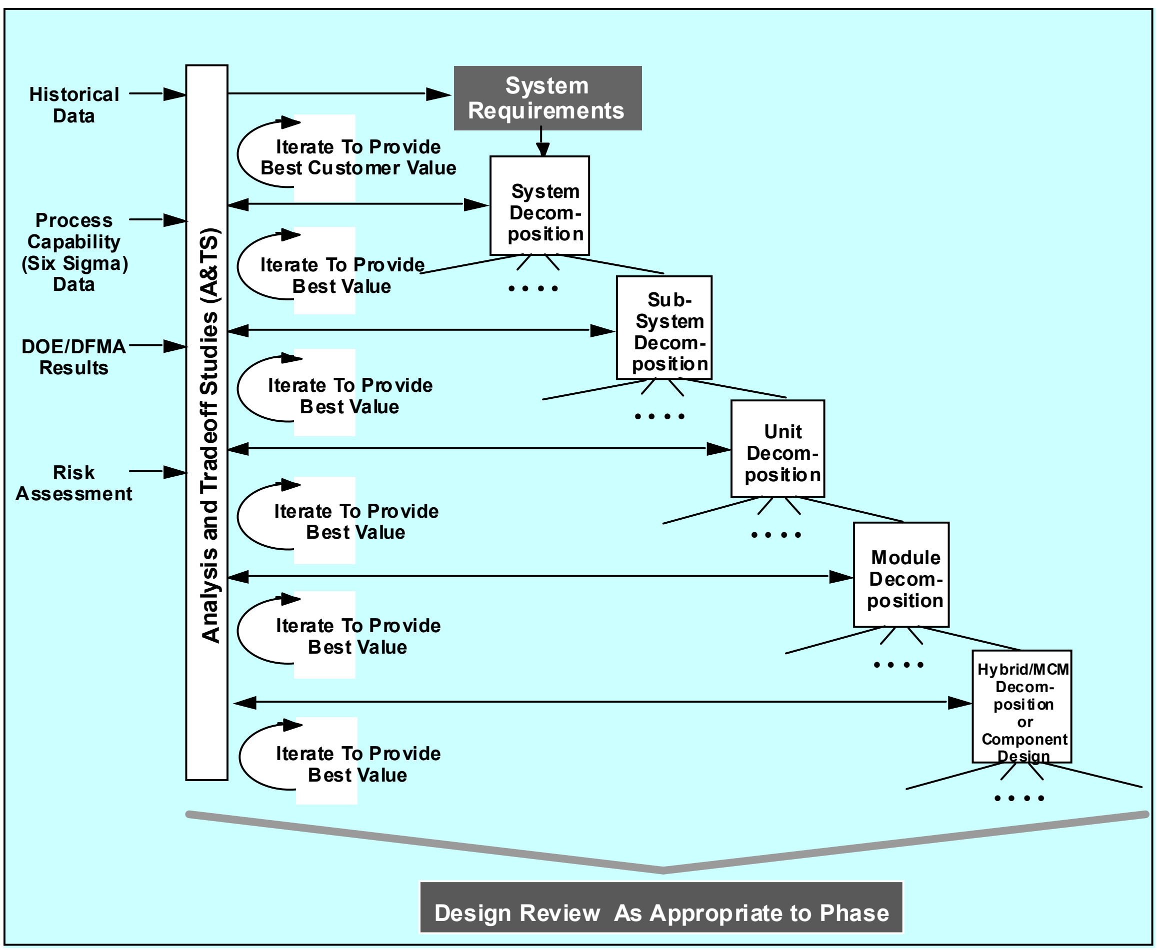
With this approach, each design choice is evaluated simultaneously for both cost and benefit. This process begins before Concept Exploration and remains vigorous throughout product development. Focus is on minimizing cost, identifying and eliminating non-value-added activity, reducing cost risk, and achieving well-defined product cost objectives by optimizing the entire product to provide best customer value. Affordability is interactive, creating a multi-tier Virtual IPT that integrates design engineering, process engineering, manufacturing, materiel, quality, and business across all IPT levels to develop manufacturable products that meet well-defined cost targets while balancing cost, performance, supportability, and risk.

DTC Process

DTC, when taken in its most basic form, is very simple, concentrating only on meeting well-defined cost objectives. In the real world, many requirements must be satisfied simultaneously, requiring thorough analysis and tradeoff among viable alternatives through an iterative design process to achieve a balanced affordable design.

The iterative design process begins at the top level of Figure 1 (HAC DTC Handbook 1996) with a product requirement that includes cost as a major priority. The ensuing requirements flowdown and associated design process are merged into a continuous multi-tiered interactive process that seeks to optimize the entire product by allocating all requirements at all levels in the product hierarchy to produce best customer value.

Figure 1: Requirements Flowdown



The generic seven steps shown in Figure 2 (HAC DTC Handbook p. 4-6) summarize a single tier of the iterative decomposition of a product into its sub-products. This representation of the iterative development process is referred to as the “Seven Steps to an Affordable Design”.

The engineer must use the following steps to execute DTC:

- Understand Requirements (Cost Goal is a key requirement)
- Analyze Functions
- ID Physical Alternatives/Allocate Requirements/Plan Task
- Design Synthesis
- Cost Modeling - Estimation & Rollup
- Evaluate – Meet or change Requirements?
- Select/Formalize Design

Plus, an added step that is rarely mentioned and often overlooked: the engineer must document and report progress towards meeting the cost goal.

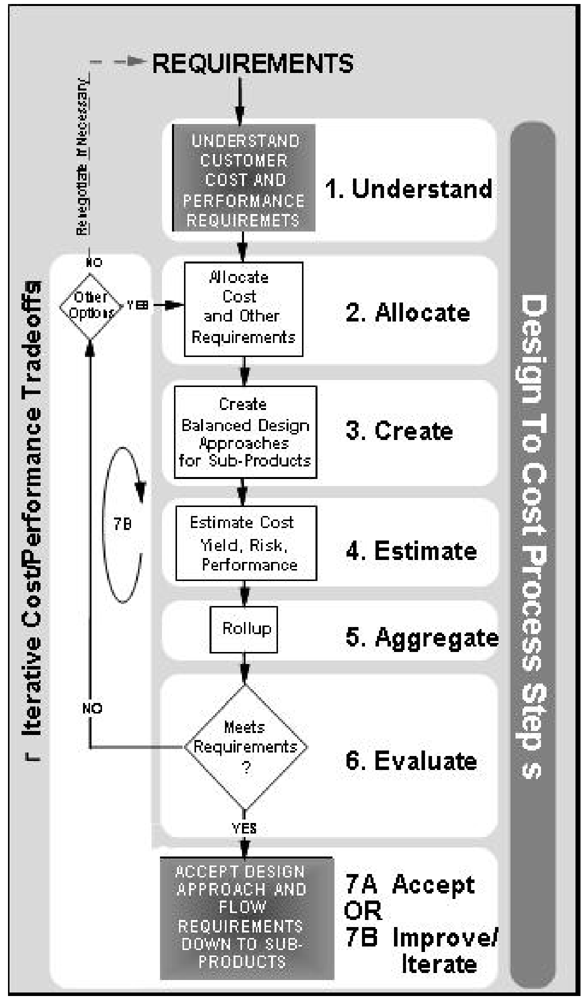


Figure 2 Seven Steps to an Affordable Design

A product-tailored derivative of these steps is applied to every sub-product at each level in the hierarchy beginning in the preconcept phase and continuing throughout detailed design. For multi-tier decompositions, the seven steps are applied at each sub-product level until no further decomposition is needed, so that initial design approaches and assessments can be used to steer each level of requirements flowdown toward a product-global optimum. Cost target allocations are a crucial part of this flowdown sequence. The iterative development process relies on open and ongoing communication among all IPT disciplines and among IPTs at all levels of the product hierarchy. This communication is a powerful benefit of IPD and is essential to the development process.

The design is complete when the customer/contractor team has accomplished the following:

- Performed detailed cost, performance, supportability, and risk assessments that indicate that all final requirements will be met with levels of cost, schedule and technical risk acceptable to both the customer and the company.
- Allocated all requirements to NDI items or specific custom components.
- Completed the detailed design of all custom components.

- Successfully modeled/prototyped custom components and assemblies that can drive cost, performance, or schedule.
- Completed a thorough manufacturing plan defining the approach to the fabrication or procurement of all components and the assembly, integration, and test of the product and each significant subproduct.
- Complied with all customer and company requirements for ILS, support, review, documentation, verification, scheduling, warranty, and the like.

Earlier, we mentioned that DTC is engineering oriented and attempts to solve the mystery: "Given the budget and performance requirements, what do I design and build?" If it were left up to only the engineers, then DTC would be simply one of many engineering processes and largely ignored, but DTC has another role within the CAIV framework as a management control system for production costs.

DTC as a Management Control System

Management control systems for human systems are equivalent to electronic control systems for electro-mechanical systems. They are put in place to direct the targeted activity toward achievement of desired results.

The Cybernetic Paradigm and the Control Process is one theory behind management control systems. Comparing the Cybernetic Paradigm and Control Process from management control system theory (Maciariello, 1984) to the DTC process, we can easy add DTC meaning to the Control Process diagram (Figure 3). Further comparison yields Table 1.

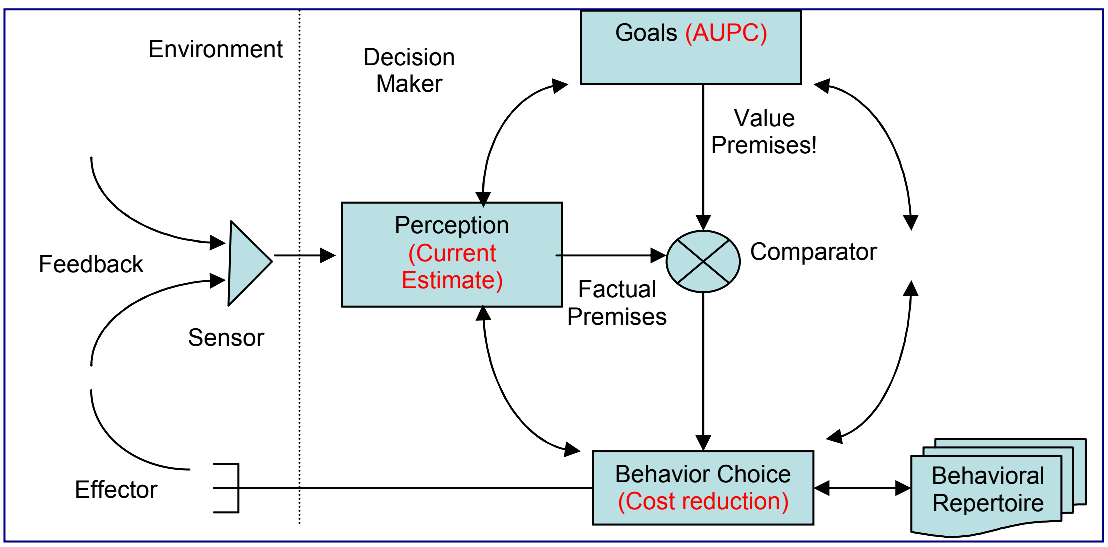


Figure 3 The Control Process with DTC comments

Cybernetic Paradigm and Control Process	DTC Process
Set Goals and performance measures	Set AUPC Goal as part of DTC Plan
Measure achievement	Prepare current cost estimate
Compare achievement with goals	Current estimate vs. DTC Goal
Compute the variances as the result of the preceding comparison	Estimate System and subsystem variances
Report the variances	Report $ Delta
Determine cause(s) of the variances	Cost Drivers, spec. risk, etc.
Take action to eliminate the variances	Action Plan: Changes
Follow-up to ensure that the goals are met	Repeat at interval per plan

Table 1. Applying the DTC Process to Management Control System Theory.

Converting the DTC Process into a management control system, we arrive at the process shown in Figure 4 which brings us to the topic of metrics. One of the main functions of proper management is to monitor and control a process; to ensure that proper decisions are made; and to act in a timely manner to mitigate risk. To do so, a manager needs reliable and accurate information. Information comes in many forms and metrics, if properly applied, are invaluable sources of information.

Both, the DTC process and management control system theory require establishment of goals, measurement of achievement of those goals, measurement of variances from the goals, feed back actions to the process to attempt to eliminate the variances, and follow up to ensure that the goals are met. We also know from theories on human behavior and organizations that when individuals or organizations are measured then those individuals tend to redirect their effort towards achieving a level of performance within the functionally being measured that will be at or above the desired measurement grading level. We built this aspect of human behavior into our metric reporting system as the organizations being measured know that they are being measured and what they are being measured against and that the results of these measurements will be reported to executive management. For this to be successfully applied as it has been at RMS, those organizations that are being measured must see the proactive loop closure that says "I'm making a positive change to do better." Beyond identifying shortcomings, measurements should be used to help engineer centers/ program IPTs replicate their successes.

> To quote Sun Tsu, The Art of War, "the wise general in his deliberations must consider both favourable and unfavourable factors. By taking into account the favourable factors, he makes his plan feasible; by taking into account the unfavourable, he may resolve the difficulties."

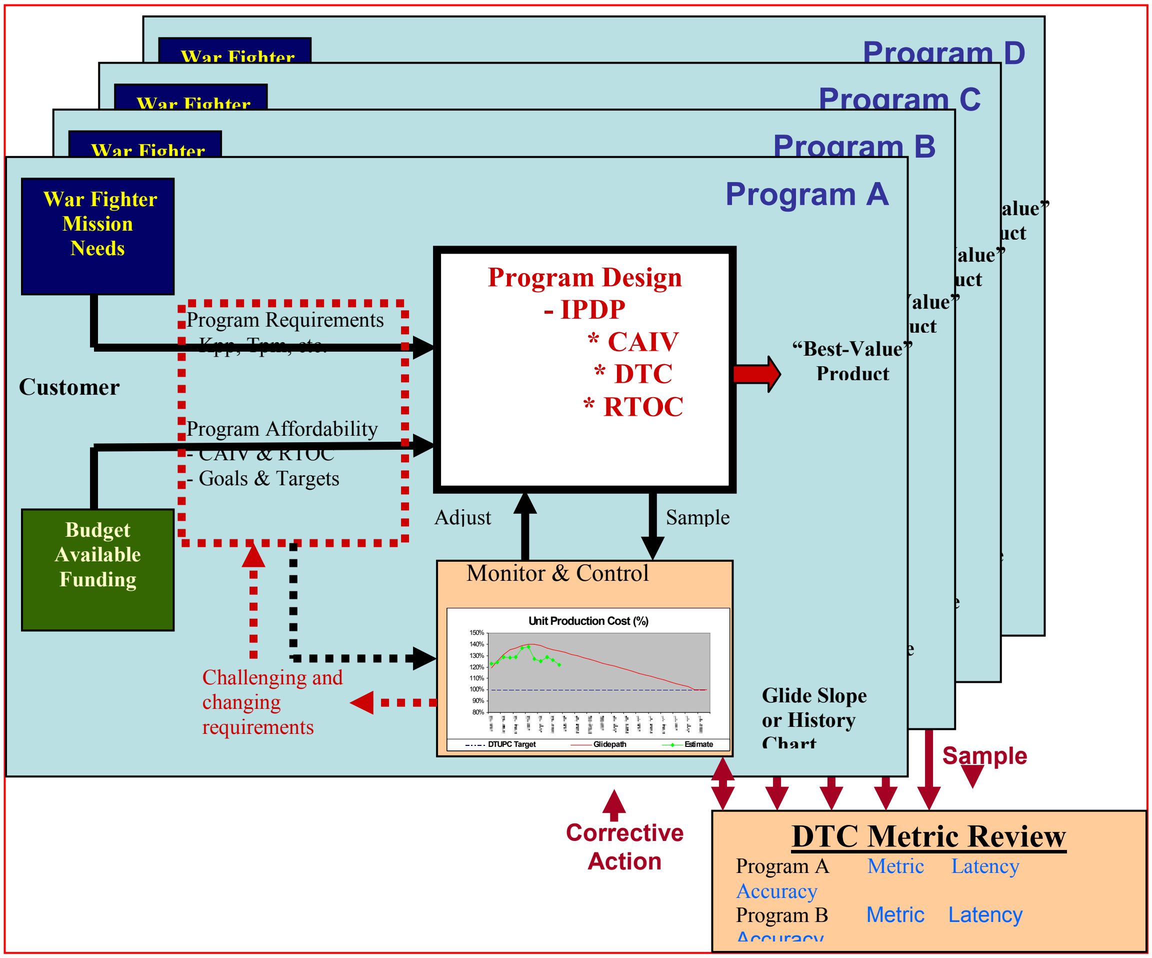


Figure 4, The DTC Process in Terms of a Management Control System

The purpose of any metric is to drive proper behavior and the purpose of the DTC Metric is no different. The DTC Metric, by providing information to both the program manager and the program manager's superiors, drives proper behavior. The program manager is aware of a program's cost status and can make decisions based on that status. The program manager's superiors can use the DTC Metric as is part of a higher level monitoring function over individual programs, across a line of similar programs, or across a business area. To be of value, it is required that this metric be reported to a level significantly above the program in order for the feed back to carry force of action to the program. It is this force of action that provides an additional monitor and control function to verify and drive the program to conduct a successful DTC program.

Establishing a DTC Metric at RMS

Raytheon Missile Systems' Engineering Directorate needed to have a few simple metrics they could use to track and report development program future design production costs, quality, and timeliness on a number of different programs. The Engineering Effectiveness Metrics (EEM) initiative grew out of RMS' desire to reduce the costs and cycle times necessary to design, develop and build products that work right the first time.

Early in 2003, RMS announced the formation of the Engineering Effectiveness Metrics Council and its development of metrics designed to help the directorate measure its performance, identify problem areas and quantify its progress in eliminating them. Selection of the appropriate measurements would help focus future efforts towards meeting and improvements in these measured areas. To support these goals, the team developed three primary metrics:

- On-Time Delivery Performance, which involves deliveries of Engineering data, documentation, requirements, hardware and software,
- First-Presentation Yield, which covers technical data package change rates and identifies out-of-phase defects on all design, development and production programs, and
- Design To Cost (DTC), which uses affordability principles to drive architecture, design and development activities

The Engineering Effectiveness Metrics reporting organizational structure (Figure 5) was set up to facilitate executive level portfolio management of RMS programs for their achievement of selected goals. RMS' Engineering Accountability Review Council, under which the EEM group functions, reports its metrics monthly at the Engineering level "Accountability" reviews.

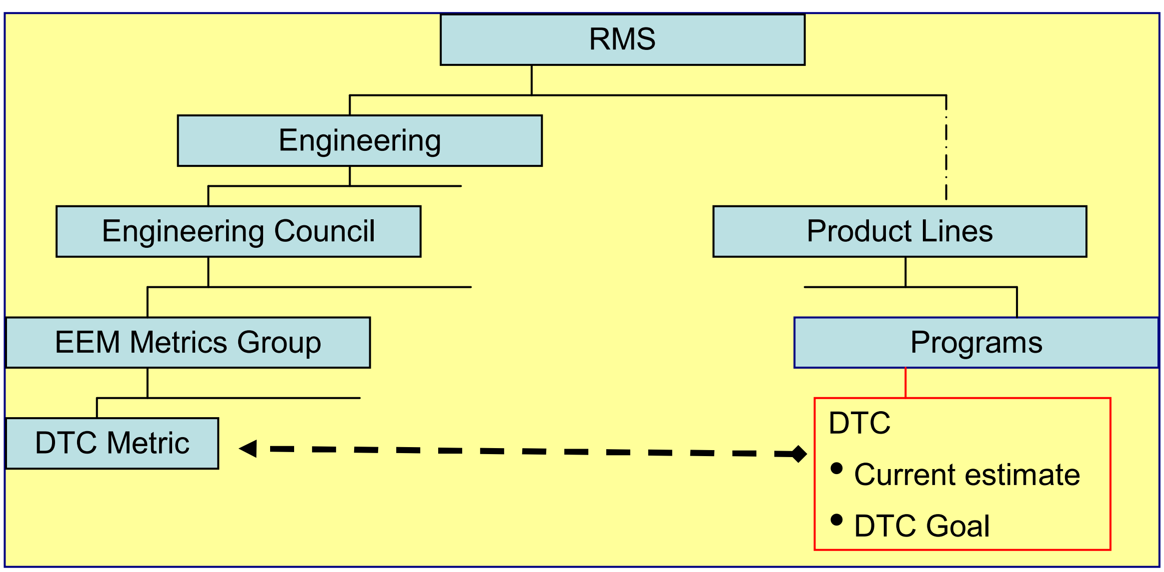


Figure 5. DTC Metric reporting Structure

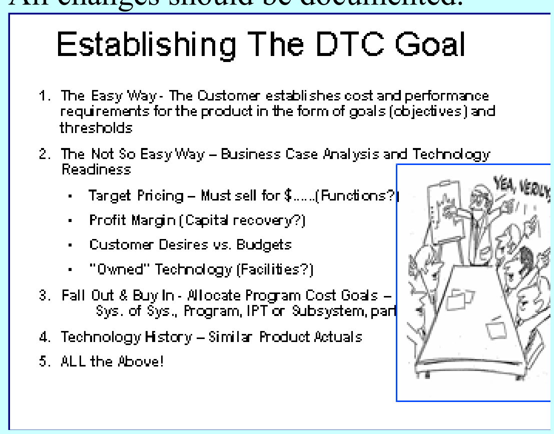
DTC Metric Definition

The DTC Metric was created to allow management to quickly access a program's progress as to how well its design, as it stands today, meets the cost target developed using the DTC process. In order to do this we must take snap shots of the design at regular intervals. For RMS' DTC Metric, the appropriate interval was determined to be monthly. For each snap shot, a cost estimate is prepared using the same set of Ground Rules and Assumptions used to create the cost target. These estimates are then compared to the target and evaluated. The formula for the DTC metric is:

DTC Metric = Current Cost Estimate / DTC Target

Of note, the current cost estimate and the DTC cost target need to be like in nature. The definition allows for targets and current estimates to be defined appropriately for the need of each individual program. However, the intent of and management's goal in establishing the DTC Metric (unless customer intentions dictate otherwise) was for the DTC Metric to measure the average unit production cost (AUPC) of the product. The production cost is defined as the total manufacturing recurring cost with appropriate overheads divided by the total production quantity. Often, the DTC Target represents a contractual cost, although it could be set lower. Again, this would be based on the ground rules and assumptions. When the DTC Metric is greater than one, the current cost is greater than the cost target and is an indication of a program starting to over run its costs.

Establishing a realistic DTC Goal (or Cost Target) is critical to the DTC Metric. There are several methods that can be used and as the program requirements evolve, the method may change causing the target to also change. All changes should be documented.



The DTC Metric is then color-coded based on severity.

- Green is when the DTC Metric is less than 1.05,
- Yellow is between 1.05 and 1.099, and
- Red is 1.10 or greater.

The color scale allows a quick glance capability to the monthly DTC metric report to ascertain the status of all reporting program across RMS quickly (Table 2). The scale was set to allow early intervention should a program tend toward cost over runs. If a program reports itself in the yellow or red, management will start to ask questions: questions that we'll leave to the reader's imagination.

Program	Jan	Feb	Mar	Apr	May	Jun	Jul
Program A	1.33	1.11	1.11	1.11	1.13	1.13	1.13
Program J	1.58	1.58	1.58	1.58	1.58	1.42	1.42
Program C				1.11	1.11	1.09	1.07
Program F	1.01	1.01	1.01	1.01	1.01	1.08	1.06
Program B							0.99
Program D	0.99	0.99	0.99	0.99	0.99	1.04	1.04
Program E	0.89	0.89	0.89	0.89	0.89	0.89	0.89
Program G	0.69	0.69	0.69	0.69	0.69	0.69	0.69
Program H	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Program I	0.90	0.63	0.64	0.64	0.64	0.64	0.64
Program K	0.94	0.94	0.94	0.94	0.94	0.97	0.97
Program L	0.90	0.90	0.90	0.90	0.90	0.90	0.90

Table 2. DTC Summary Chart

Along the same line, latency is also reported. Latency equates to the number of months since completion of last the Current Cost Estimate. While it is desirable to do this monthly, there are occasions when this cannot be done. Latency is also color-coded and as before, varying levels of interest follow each color.

- Green is latency of 2 months or less,
- Yellow is latency between 2 and 4 months, and
- Red is latency greater than 4 months old.
-

Accuracy of the cost estimate is also reported and represents the relative possible cost range (cost risk) associated with the current cost estimate. This is expressed as a plus and minus percent. Phase and Gate represent where in a program's life-cycle the program current is and room for comments in the DTC report exists.

A hypothetical example is shown in Table 3.

PROGRAM	Phase	Gate	Metric	Latency	Accuracy	Comment
One A	SDD	3	1.12	1	+15 -10	High Subcontractor cost for motor assembly
Two B	SDD	3	1.55	9	+25 -15	Program undergoing major corrections and rebaselining.
Three C	SDD	2	1.04	4	+10 -5	Lower FPA Cost

Table 3: DTC Metric Report Including Accuracy

DTC METRIC Reporting Frequency and Initial Results

RMS's Engineering Effectiveness Metrics Council reports its metrics monthly at the Engineering Accountability Reviews for the previous month (trailing indicators). All engineering metrics are distilled into a series of color-coded stoplight charts that show current status in relation to goals for the year.

Data is collected during the first week of the month and areas of concern are pinpointed. Product lines, programs and functional organizations are informed when the data indicates problems exist. Process reviews are held the third week of the month, so those areas of concern should have enough time to prepare for the review and to come up with a proposed solution. If solutions are not available by review time, the issue becomes an action item, with follow-up slated for the following month or sooner depending on severity. When product lines and programs are involved, the council informs the Engineering Centers' IPTs to find a solution.

> Six months after the DTC Metric was put in place, analysis shows substantial improvement. Data shows that 65 percent of the programs that the council is tracking have met their DTC goals, in contrast to only 33 percent six months earlier, with the trend toward reducing costs existing for the majority of programs that have yet to reach their DTC targets.

Variances are measured and reported at design team meetings and program reviews. Efforts to eliminate cost variances (the proper behavior) become part of the IPT design effort when tradeoffs are made between cost, risk, performance, and cycle time.

Implementation and Evolution – Lessons Learned

American companies have long been accused by foreign partners of wanting to close the deal in a short period of time, but taking forever to implement the decisions. "Americans are quick to sign a contract or make a decision. But try to get them to implement it---it takes forever." (Ouchi) Institutionalizing the DTC Metrics at Raytheon Missile Systems has met with some resistance. Common excuses include: "The customer does not require DTC," "We didn't fund for DTC," "We don't have time to track DTC and make reports," "We received a waiver from doing DTC," "We've never had to do this before," and "This is a very small program, so we don't need to do DTC."

Top management at Raytheon Missile Systems is now closely watching our DTC metrics and placing heavy emphasis on successfully capturing and reporting the DTC metrics. Answers to the above comments include: "While the customer may not require it, this is an internal RMS management requirement." "Tracking the current estimate is something that a well-managed program is doing already, and it is extremely easy and quick to compare the current estimate to the known cost goal." "We are doing many things that we have never had to do before to shorten our cycle times, to assure the quality of our products at initial delivery, and to stay within or under budget. These things we do to remain competitive, which in turn safeguards employment and positively impacts our bottom line." "Even though this is a very small program, it is of strategic importance, and offers lucrative follow-on contracts." With top management emphasis, programs are now more willing to report their DTC metrics (for design and development programs) and are embracing affordability metrics (for production programs) as well.

Currently, the council is continuing to refine, systematize and institutionalize its data-gathering activities. When programs transition from "green" to "yellow" and from "yellow" to "red," they are required to provide "Root Causes/Corrective Actions" explanations at the Engineering Accountability Reviews. As mentioned previously, the various RMS Engineering centers become involved to assist in identifying solutions to programs' challenges. Should programs not exhibit improvement right away, a "Five Whys" exercise is conducted, drilling down at least five levels to assure that the true root causes have been identified so that they can be corrected. Simply put, it's about improvement. The Council is also analyzing the data to spot emerging trends, assess their significance and address problems on a case-by-case basis. Now that the basic process is up and running, we are looking more closely at long-term, systemic obstacles and solutions.

Adopting the correct metrics and using them appropriately can add tremendous value to a program, allow program managers increased ability to control their programs vice being controlled by their programs, and allow senior management an earlier opportunity to assist programs heading toward problems.

Key lessons learned are as follows:

- Affordability is the primary driver in all architecture design and development activities.
- DTC requires mandatory cost requirements be assigned to all programs down to the lowest levels.
- Programs must track and measure their current design to cost status against their goals at periodic intervals.
- Cost must be an independent design requirement with importance equal to or greater than performance (i.e., the process must address CAIV as its primary focus).
- DTC focus must begin as early as possible in a program (pre-RFQ) for early cost driver identification.
- Lean practices and processes must be effectively leveraged.
- Cost estimation can be approximate in early program phases, progressively better during Engineering and Manufacturing Development (E&MD).
- Cost estimation cycle time must be near real-time by the detailed design phase.
- Design, manufacturing and product life cycle cost data must be readily accessible.
- DTC tools must be user friendly and accessible from the IPT's desktop.
- Manufacturing process costs must be understood.
- DTC training deployment, and data collection must be given high priority.
- Proper CAIV behavior is achieved by setting, striving for, and ultimately reaching goals. A CAIV metric is therefore one that keeps cost and cost reduction in the forefront of IPT activity.
- By establishing cost and TOC goals for a program (and its subsystems) that are time phased, and constantly decreasing, a program is able to measure its cost reduction effort toward the ultimate program cost goal.

A Path Forward

With the Design to Cost Metric in place and positive results being shown, it is time to consider expanding DTC into CAIV and implementing a series of metrics more in tune with CAIV principles.

CAIV seeks to find the optimum balance between Cost, Performance, Schedule and Risk, this a set of CAIV Metrics should encompass these areas. Table 3 shows how the DTC Metric can be enlarged and enriched with Performance, Schedule and a Risk Assessment.

CAIV Metric	Threshold	Goal	Current	Current/Goal	Risk Assess	Cost Driver	Latency	Plan of Action
Cost - System	$ 32,775.00	$ 31,500.00	$ 37,790.00	1.20				
Sub-System	$ 5,000.00	$ 4,500.00	$ 6,200.00	1.38			2	no
Sub-System	$ 1,500.00	$ 1,500.00	$ 1,400.00	0.93			4	no
Sub-System	$ 12,275.00	$ 12,000.00	$ 17,890.00	1.49			1	yes
Sub-System	$ 8,000.00	$ 7,500.00	$ 6,000.00	0.80			3	yes
Sub-System	$ 2,500.00	$ 2,500.00	$ 2,700.00	1.08			3	yes
Sub-System	3500	3500	3600	1.03			2	yes
Sub-System								
Sub-System								
Performance	**Requirement**	**Goal**	**Current**	**Req/Current**	**Risk Assess**	**Cost Driver**	**Latency**	**Plan of Action**
speed mph	200	220	180	1.11			1	no
range nm	500	550	525	0.95			1	yes
load lbs	750	750	800	0.94			1	yes
KPP-4								
Schedule	**Contract**	**Goal**	**Expected**	**Exp/Con**	**Risk Assess**	**Cost Driver**	**Latency**	**Plan of Action**
Dates								
Months to Go	18	15	15	0.83			2	no
				Red Yellow Green Blue Violet	Red Yellow Green	What is/are the major cost driver(s)	Red Yellow Green	Is there a plan of action - yes/no Comment

Table 4: CAIV Metrics

As a management enabler, this chart, at a glance would disclose a program's status in the areas of cost, performance and schedule. From the above sample chart one can quickly see:

- The program is projected to over-run costs by 20%.
    - Two of the sub-systems are in the red; one with a high risk of failing.
    - The PM has no plan of action to fix one of the red areas
    - One sub-system is in the "violet" with low risk of failure so perhaps cost goals ought to be re-allocated.
    - The others are close to goals on one-side or the other
- Two of the performance areas have superseded requirements while one area, without a plan of action and at high risk of failure is in the red.
- And, the program is planning on an early delivery.

From the above information, management can key in on areas to get involved with. If a program, like the example, is in the "red" in cost but ahead of schedule and over-achieving in some area of performance, then perhaps adjustments can be made to lower costs while still meeting requirements. Likewise, if a program was under cost but not quite meeting a key performance parameter (KPP) then that area can be targeted appropriately. The color coding helps key in on specific areas of concern.

Of course, should a Program Manager not have a plan of action for an area lacking, then his or her management would become aware of this and can make the appropriate recommendations to ensure correction. One would hope that at the next level up, all areas lacking would have an action plan.

Going yet the next step, the proper metric for CAIV is one that establishes a system cost goal for the design and that requires attainment of estimated development, production, and operation and support costs (Total Ownership Cost) at specified points along a program timeline. It is still too early for this step, but not to early to considering how to incorporate it and when. In addition, other metrics can be included that reflect on program costs and system performance and can be used by management to enable an informed decision.

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Author's Biographies

F. Quentin Redman is a Senior Department Manager and Engineer Fellow in the Systems Engineering laboratory of Raytheon Missile Systems in Tucson Arizona. He is responsible for Total Ownership Cost, Design and Life Cycle Cost, Risk Analysis, and Cost As Independent Variable with 30 years of Economic experience. Quentin received his Bachelor of Science in Engineering Technology Electronics from California State University at Long Beach California in 1970 and his Masters of Science in Financial Economics from West Coast University Los Angeles in 1976. Quentin has been on the Board of Directors for the International Society Parametric Analyst and has also previously served as ISPA's Treasurer. Quentin has over 26 years with the company. Quentin has presented a number of papers at prior years Systems Engineering Symposia and at ISPA, SCEA, INCOSE, and NDIA conferences/symposia.

George L. Stratton is an Engineer Fellow and the assistant Department Manager in Raytheon Missile Systems' Systems Engineering Laboratory's Cost Engineering Department. He currently leads/supports many challenging assignments. He holds degrees (AS, Dixie College & BS, Utah State) in Physics, an MBA (Pepperdine), and has completed partial work toward a Ph.D. (Claremont Graduate School) in management science. He is trained on Parametric models and was selected for and completed the Hughes line managers training course. He is the past vice president of the Southern California Chapter of ISPA (International Society of Parametric Analysts) and is now serving on ISPA's international Board of Directors. George has over 23 years with the company. He helped author "The Testability Notebook" published by RADC in 1982 and has presented a number of papers at internal Raytheon Systems Engineering Symposia and at ISPA, SCEA, INCOSE, NDIA, AIAA, and ICEC conferences/symposia.

Ed Casey is a Principal Engineer in Raytheon Missile Systems' Systems Engineering Laboratory's Cost Engineering Department. He has been with Raytheon for over 11 years having worked in both the Northeast and the Southwest. Duties include Design to Cost, Cost as an Independent Variable, Affordability and parametric modeling. Ed earned his Bachelor of Science at the US Naval Academy and his Masters of Science at Salve Regina University in Newport, RI. He is currently the Membership Chair for the Southern Arizona Chapter of INCOSE. Ed is a retired Naval Officer having served on carriers, cruisers, and minesweepers and served with the SeaBees. He had a tour at the Pentagon and at the Naval War College.

Diana Patane is a Senior Systems Engineer in RMS' Systems Engineering Laboratory's Cost Engineering Department. She has been with Raytheon for four and a half years and has worked in the aerospace industry for TRW, Honeywell, and Hewlitt Packard, for 13 years. She currently serves as the Design to Cost Metrics Coordinator. Diana earned a Bachelor of Science Degree at Weber State University, Ogden, UT, and an MBA (Management (1994) and Technology Management (2003) from the University of Phoenix, Ogden/Salt Lake City, UT and Tucson, AZ campuses). She is a Certified Business Manager through the Association of Professionals in Business Management. A lifetime member of the International Society of Parametric Analysts (ISPA), she serves as their Membership Chairman.