A FRAMEWORK FOR INTEGRATING DESIGN AUTOMATION WITH COMPUTER AIDED PARAMETRIC ESTIMATING (CAPE)

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Abstract

This paper will identify a shortcoming in the Design-To-Cost (DTC) capability of the military/aerospace industry and propose an Integrated Product Development Environment (IPDE) solution based upon:

1. The electronic integration of Computer Aided Parametric Estimating (CAPE) tools with Computer Aided Engineering (CAE) tools
2. The organizational integration of Cost Analysts and Engineers via Integrated Product Development Teams (IPDT's).

This solution is referred to as Integrated Design-To-Cost (IDTC). An IDTC toolset consisting of two mature, commercially available products (PRICE Systems PRICE Enterprise CAPE tool and Ascent Logic's RDD-100 systems engineering tool) will be used as an example of IDTC. DARPA's Rapid Prototyping of Application Specific Signal Processors (RASSP) program provided the seed funding, enabling the creation of IDTC under the guidance of Lockheed Martin's Advanced Technology Laboratories (Camden, NJ).

RASSP

Activities funded by the DARPA/Tri-Service Rapid RASSP program are having a profound impact on the treatment of cost as a design parameter by enabling the Engineering and Cost Analysis disciplines to work more closely together throughout the design process. The goals of the RASSP program are to reduce the cost and schedule of complex digital systems by a factor of four (4X) and to obtain corresponding increases in quality and reliability. In pursuit of these goals the RASSP Program has funded advances in design methodology, infrastructure, and processor architecture that will result in a state of the art design process, improved Electronic Design Automation (EDA) tool functionality and interoperability, and a scaleable processor architecture that supports increased usage of COTS, model year upgrades, and hardware and software design reuse.

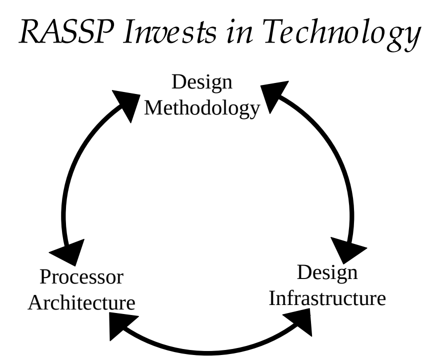

Figure 1.

RASSP investments will enable Design-To-Cost

PRICE Systems, a Computer Aided Parametric Estimating (CAPE) tool vendor, has teamed with Ascent Logic, a Systems Engineering tool vendor, and Lockheed Martin's Advanced Technology Labs RASSP team to create IDTC. The IDTC initiative is concentrated in the areas of infrastructure and methodology. CAPE tools are a proven method to estimate cost and schedule quickly and accurately. We believe that an IPDE that allows Concurrent Engineering teams to leverage the speed and accuracy of parametric cost models will increase the utility and efficiency of DTC activities and therefore contribute significantly toward 4X improvement. Toward this end, the Team created an IDTC capability that (1) bridges the electronic gap between existing Electronic Design Automation (EDA) products and CAPE tools and (2) bridges the organizational gap that exists between the Engineering and Cost Estimating disciplines.

Design-To-Cost

Design-To-Cost is the use of cost as a design parameter. Once viewed with optimism, evidence abounds that the design-to-cost initiative has failed to achieve its goals. In their paper "Computer Aided Parametric Estimating for New Business Ventures", B.E. Fad and R.M. Summers site a $10 million R&D program at one of the three largest U.S. auto makers that failed when a successfully developed fuel-efficient engine proved too costly to produce. A similarly fated Armed Forces Command and Control program missed its DTUPC goal by a factor of two. The second program is particularly significant because it had a DTUPC report as a monthly contract deliverable. What happened? The report that was supposed to constrain design to what could be afforded was ignored when arriving at technical decisions[1].

Certainly, there are individuals and organizations with success stories. But they are exceptions. The reality is that although DTC has been actively pursued by governmental and commercial interests, the expected benefits have remained largely unrealized. Many reasons can and have been given for this but most can be classified as symptoms that result from a systemic misunderstanding of the role that cost plays in DTC. Upon examination of business processes, it is clear that most organizations treat cost as a result of design - not as a design parameter[2]. It is not the case that cost goes untreated. In fact, cost targets are generally available in the early concept stage and are always addressed prior to sell off. But cost is not treated continuously during the design process and, as a result, the continuity between technical and cost objectives is lost.

Engineering Process

The engineering process is an iterative one marked by continuous expansion and refinement of a design. Each iteration results in a more granular view of the system. As the system view becomes progressively clearer, focus passes from one engineering discipline to another. The disciplines and EDA tools of today interface like sprinters in a relay race: one picks up where the last left off. This contributes to the "over the wall" mentality that has plagued so many failed projects. The design is figuratively thrown over the organizational wall from one department to the next, resulting in miscommunication, design errors and finger pointing. The RASSP methodology will mitigate this by incorporating concurrent engineering practices through Independent Product Development Teams (IPDT's) that transition the design smoothly. Advances in infrastructure (most notably scaleable VHDL) will increase the ability of EDA tools and their users to communicate collaboratively.

Cost Estimating Process

The cost estimating process of today parallels the contemporary engineering process. The estimate is expanded and refined as the design matures. These estimates are done to support cost reporting requirements that generally exist at defined points in a program. But, since cost is viewed as a result of design instead of as a design parameter, estimating is done to support the contract deliverable - not the design process. In fact, the type of estimating (parametric, analogy, or grass-roots) done to support the requirement for cost often varies according the discipline currently holding the design ball. This inevitably results in conflict because estimates performed with differing methodologies rarely agree. Certainly the comparison of differently based estimates has value in itself - it contributes to management's system of checks and balances. That is not the purpose of a cost estimate done to support the design process.

The Continuous IDTC Cost Estimating Process

The IDTC cost estimating process is a continuous, CAPE-based operation. The purpose of an IDTC cost estimate is to restrain technical freedom of license and thereby constrain emerging designs to an appropriate cost objective. The continuous cost estimating process is intended to support the cross functional IPDT and therefore requires the use of a common thread or language. For the Engineering disciplines, RASSP uses VHDL as a unifying design language.[3] CAPE will play a similar role in the cost analysis domain. Parametric estimates will be used at each stage of the design process, providing a unifying cost language. This unifying language will maintain the continuity of the cost estimate throughout the design process, mitigate interdepartmental disputes, and speed the DTC process. And, since a unified language has been incorporated, it becomes economically feasible to electronically integrate the cost tools with the EDA tools. The result is a continuous sequence of synchronized engineering designs and cost estimates that support each other and enable IDTC throughout each phase of the design process.

PRICE Systems: Integrated CAPE Tool Suite

The PRICE Systems tool suite consists of four integrated cost estimating models. PRICE H: hardware development and production. PRICE HL: hardware life cycle. PRICE M: modules & microcircuits. PRICE S: software development & life cycle. These models utilize systems of equations that implement Cost Estimating Relationships (CERs). CERs relate non-cost parameters like size and manufacturing process to cost and schedule. The PRICE tools have been in continuous use by cost estimators and engineers in government and industry for over twenty two years.

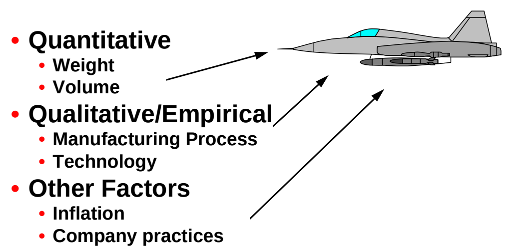

Figure 2.
Parametric models relate non-cost parameters to cost & schedule with CERs.

Ascent Logic: RDD-100

RDD-100 is an ERA (Entity, Relationship, Attribute) database with a substantial graphical data entry capability. RDD-100 supports requirements analysis, functional analysis, and physical decomposition. Using RDD, a Systems Engineer can decompose requirements down to single, testable units, specify and test the associated functionality, and allocate functions onto hardware and software components.

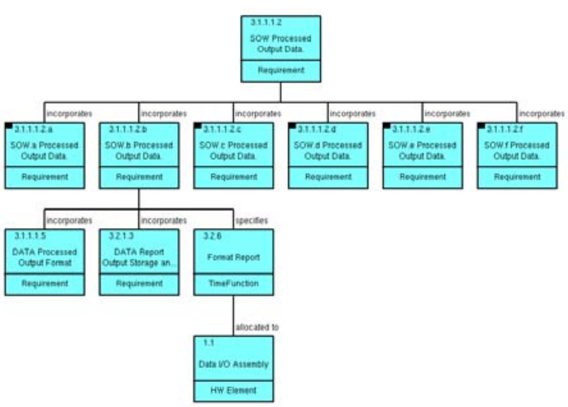

Figure 3.
RDD-100 models requirements, functions, and components in an integrated view.

This results is three hierarchical system views that are interrelated: requirements, functions, and components. The component view is actually an equipment breakdown structure. PRICE and Ascent, working with the ATL RASSP team created a set of database extensions to the component view that supports the System Engineer's cost needs through the life of a program.

RASSP-funded Integration

Through RASSP, an electronic interface between the tools has been developed that allows a system engineer using RDD to obtain cost analyses from PRICE. In addition, the use of these tools has been pushed down through the design process to support codesign and detail design activities.

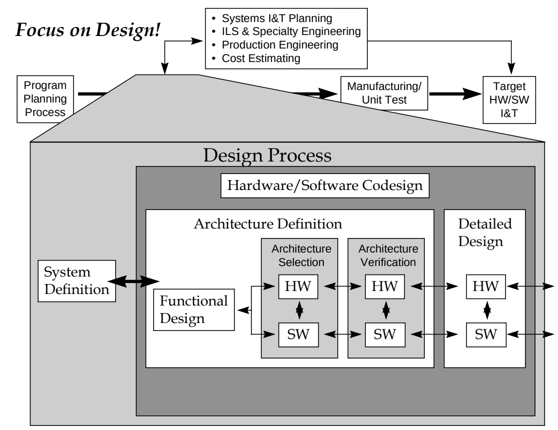

Figure 4.
RASSP Design Process.

Use of Parametrics

Today, industry utilizes parametrics primarily in support of early concept activities. Companies typically use parametrics to perform bid/no-bid analyses, to cross-check bottom-up estimates, and to evaluate subcontract bids in support of build vs. buy decisions. However, in the quest for competitive advantage, many companies are extending the reach of parametrics and, where appropriate, are now utilizing it as their basis-of-estimate. This activity gained momentum with the formation of the government/industry Parametric Estimating Initiative (PEI). Support for the PEI extends to Vice President Al Gore's Reinvention Laboratories and was clearly expressed in a 28 August, 1995 memo from Eleanor R. Spector, Director, Defense Procurement that stated "I fully support the use of properly calibrated and validated parametric cost estimating techniques on proposals submitted to DoD."

Design-To-Cost In Practice

The interaction of parametric estimators and engineers today is supported by purely organizational means. It consists of an iterative series of interviews during which the engineer conveys the physical description of the design and the estimator feeds it back via an estimating breakdown structure that should match. Because Engineers and Estimators have different educational backgrounds and vocabularies this process is error prone. The manner in which the design is translated into estimating parameters varies from estimator to estimator. Rules of thumb, expert knowledge and historical calibrations are used. The rules and their application are rarely codified into written procedures. The process is manual and qualitative. As a result, the same Engineer/Estimator pair could conceivably create different estimates for the same design. The process requires that both the Engineer and the Estimator be available at the same time, and, since they come from different functional areas, management is probably involved as well.

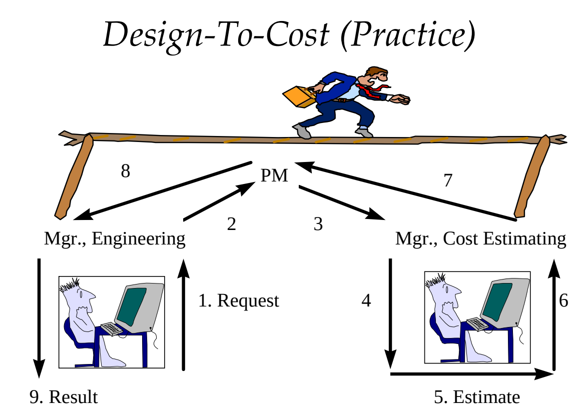

Figure 5

Design-To-Cost today is an organizational process featuring state of the art components like management intervention, key punch errors, and undocumented, qualitative judgment.

In practice, the organizational process is often actually worse than described. In a parametric estimate at least the cost estimating relationships are documented and consistently applied via a computer model and a single estimator can often do the job, leading to consistency in the application of qualitative judgment. But bottom up estimating is often used instead. That means that the cost estimating relationships will not be applied by a computer model, that multiple people will be determining which relationships to apply, and that qualitative judgments will be similarly dispersed. And that's just for labor hours. For material dollars, a bill of material is composed from vendor quotes. Though on the surface this appears reasonable, in actuality it is not. Studies have shown that less than 20% commonality sometimes exists between the BOM and the delivered equipment. Finally, labor rates and loadings are applied to the hours and the estimate is summed. The bottom up estimate is labor and time intensive, restricting the number of design alternatives that can be explored. In fact, the Reinvention Laboratories have estimated that over $1 billion could be saved annually through the use of parametrics.

But wait, it gets better. You see it is actually at this point that traditional DTC really falls on its face. After the estimate is used for a bid it is rarely used again. In fact, it is unlikely that a complete estimate will be attempted unless the contract requires and funds it. The estimate will most likely be used to allocate cost throughout the equipment breakdown structure where it becomes a goal to subsystem managers like size, performance, or schedule. If a subsystem appears likely to miss a target then work and budget must be redistributed. Because of the time expense incurred, the estimating work to support a reallocation is generally confined to the areas impacted. And the judgment of which areas are effected is often just that: a judgment. In the end, the estimates that are done are generally done in support of a contract deliverable - they justify decisions that have already been made because the design evolves faster than the estimates can be made.

Integrated Design To Cost

The IDTC Methodology also begins in System Definition but it builds upon the Engineer/Estimator relationship outlined above. With IDTC the estimating process is carried on electronically. Once a candidate design has been made, the Systems Engineer exports the physical description of the design from RDD-100. This description is read by PRICE and translated into cost estimating parameters. The cost estimating parameters are then merged with information from the Cost Analyst to produce a complete data set which is sent to the parametric estimating engine. The engine produces a cost and schedule estimate for the system and exports that data back to the Engineer. The Engineer then reads that data into RDD-100 where is aligns with the existing structure. The IDTC process can be initiated by the Estimator or the Analyst.

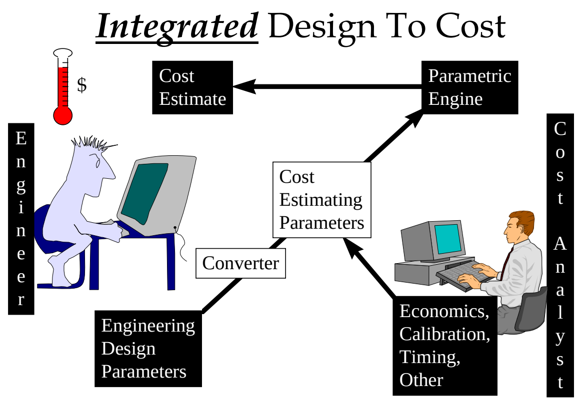

Figure 6.
IDTC integrates the Engineer and Estimator electronically, codifying estimating rules into computer applied estimating relationships and eliminating keypunch errors.

The IDTC estimating process is an improvement to the organizational process in every way. It is faster, enabling more alternatives to be explored. It is more accurate and repeatable because the rules that are applied are controlled by the estimator, codified into a PRICE Rule Language script, and executed by a computer. Because the rules are codified the Engineer doesn't need to meet with the Estimator every time an estimate is desired. That doesn't mean they aren't both involved, they are just out of each other's critical path. Because it is parametrically based, it does not use a bill of materials. With IDTC an estimate can be turned around in minutes instead of days or weeks.

But where IDTC really pays off is after the initial estimate. The initial estimate is back populated to RDD in a "budgeted cost" field associated with each component. As the design matures and alternatives are explored, the cost estimate is back populated into a "predicted cost" field within each component. Through the use of RDD consistency checks, the Systems Engineer can then validate each cost estimate against the component cost budgets automatically. And, if a subsystem reallocation is required, the integrated requirements, functions, and component hierarchies can be automatically traced to determine everything that is impacted - that doesn't eliminate judgment, it adds to your ability to make good judgments. The reallocation estimate can be accomplished in minutes - not days, meaning that decisions can be based on cost (hey, wasn't that the original idea?). And the estimate will be for the entire system.

Collaborative Estimating With PRICE Enterprise

So far, we have only discussed the collaborative use of Systems Engineering and CAPE tools without actually identifying how they interface. The PRICE strategy for interfacing with RDD was to build a mechanism that supports the transfer of parametric inputs into PRICE from any design tool and the transfer of cost and schedule information out of PRICE. The mechanism we use for this is called PRL (PRICE Rule Language). PRL is used to encapsulate the estimating rules that translate design parameters into PRICE inputs. PRL is an interpreted C-like language that easily translates various file formats and can map multiple design parameters into PRICE inputs. It is tied into the PRICE API, allowing it to embed the translated parameters into the model, run it and iterate if needed, and export (again in multiple formats). PRL eliminates the problems that usually occur when two tools are integrated with a program because it is not tied to a PRICE file format and is extensible enough to read the interchange formats of the tools it interfaces with. Because it is not compiled, PRL scripts remain viable as each point tool follows its upgrade path. In addition, PRL merges cost analyst information from two sources: a default file and an override file. PRICE used PRL to create the RDD link and is currently in the process of creating a Mentor Graphics BoardStation link. Other tools interfaces are currently being considered as well. PRICE and Ascent Logic have signed a strategic alliance agreement and are jointly marketing the package described in this paper.

Summary

Our ability to produce smaller, faster architectures in the form of chips, printed circuit boards, and electronic racks has grown faster than our ability to design, manufacture, and support them. If our design methodology solutions, as measured by cost and schedule, fail to keep pace with technology, the systems of tomorrow are liable to collapse under their own technological weight. Advances in methodology, infrastructure, and architecture are prerequisite to the goal of reducing the cost and schedule of designing complex systems. Integrated Design To Cost will play a key role in the evolving methodology that will support this solution by increasing the Engineer's access to cost, decreasing the effort required to perform trade-off analyses, and providing fast, accurate, repeatable estimates. However, in order to reap the maximum benefit from parametrics, the role of the cost analyst in the IPDT must be as clearly defined as the interfaces between the cost tools and the design tools.

Bibliography

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