CHAPTER ONE

"Looking Back: Reflections on Cost Estimating"

We are delighted that you have chosen to learn about a vibrant career field that few people know about in any significant depth: the field of cost estimating. However, before we discuss the background, terminologies, statutory requirements, data sources, and the myriad quantitative methods involved and introduced within this textbook to help you become a better informed or better cost estimator, I would like to first discuss with you the idea of cost estimation as a profession. There are two facts that are most important in this field that are in seeming contradiction of each other: first, that cost estimating is "ubiquitous," always existing either formally or informally in every organization; and second, that it is often "invisible," or at least many times overlooked. My goal in this chapter is to provide some personal observations from my 30+ years of experience to shed light on the many significant purposes and roles played by cost estimation. These experiences also provide the opportunity for me to thank the many leaders, mentors, coworkers, and others who have provided me skills and insights throughout my career and whose contributions are reflected in this book. Lastly, I will comment on important changes that have been occurring in the profession within the last 30 years and some forecasts of future changes.

In the past, nobody went to school to become a cost estimator. To illustrate this point, I studied mathematics and economics in school, while my co-author, Greg Mislick, also studied mathematics and flew helicopters for the U.S. Marine Corps in his previous career. By different routes, we became practitioners of operations research and specialists in addressing the issue of "What will it cost?" In recent years, however, there have been graduate-level certificate and master's degree programs introduced to hone the skills of, and establish professional standards for, cost estimators. This textbook is our attempt to pass those skills and lessons learned on to you and to increase the knowledge and experience of those working in this field.

Every organization – from a typical household to the greatest nation – relies upon the disciplines and processes of this profession. The one question that typically comes up in a conversation about most topics is "What does it (or what will it) cost?" It is a question that you and I will ask numerous times in both our professional and personal lives. The most frequent response that we get to this question (especially from those who do not really want to give us an answer) is "I can't tell you exactly," as if this were a useful or satisfactory response. The answer is just a dodge. We were not expecting an *exact dollars*

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and cents answer. Rather, we were looking for an *approximate* answer to help us plan for the expense while we sort through the various options that we may be considering.

The characteristics of a useful answer to the "What does it cost" question that we look for in the circumstances of our daily lives are remarkably similar to those answers in commercial and government applications of cost estimating, although complexity and scale may camouflage this similarity. The essential characteristics of any good cost estimate are completeness, reasonableness, credibility, and analytic defensibility. Note that this list does not include the need to make sure the answer has plenty of *precision*. While the budgets we develop and the cost-benefit analyses that we construct require specific numbers in them, our professional work as cost estimators does not rely on getting answers "correct to the penny." A cost estimator should not agonize over the lack of a narrow range of possible costs for the cost estimate. If the ranges are overly large, the user of the estimate, such as your sponsor, consumer, boss, or other person who asked for the cost estimate, may tell you that they need a tighter range of costs, and you will then need to seek additional data or another methodological approach to support the refinement of your estimate. However, it may also be that a wide-ranging estimate that meets the criteria of completeness, reasonableness, credibility, and analytical defensibility is all that is required in the case of rapidly changing conditions and immature technologies. In fact, in the absence of data, it may be *all* that is possible.

This textbook is designed specifically to provide context to those cost estimating objectives of completeness, reasonableness, credibility, and analytical defensibility. Moreover, it will teach those mathematical techniques and procedures that are relevant to develop cost estimates and it will provide you with significant guidance through that development process.

I would like to share with you now six examples/stories that illustrate some of the lessons that I have learned while holding various positions in the corporate and government worlds. This includes positions while at a headquarters and during duty in the field, while inside the United States and abroad, and mostly (but not exclusively) while serving in defense-related positions. These examples are diverse, indicating the broad applicability of the tools of cost estimating. I hope that you will find them helpful while tackling programs and assumptions of your own in your present (or possibly future) career in cost estimating.

Example 1.1 Cost Estimation in Support of a Major Ship Program As the Navy proceeded to build the inaugural (lead) ship in a new class of ships, large cost growth began to challenge the project. I was asked to figure out why this was occurring. After much analysis, I found that there were several reasons for the growth. One reason, in particular, that is useful to discuss for the education of new cost estimators, was that one of the cost driving assumptions made during the original cost estimate was simply, and significantly, incorrect. The original cost estimate had assumed that when the Navy's lead ship was being built in the shipyard, there would be another *commercial* ship under construction at the same time, and these two ship programs would share the shipyard's overhead costs. This would relieve the Navy's ship from carrying the full burden of the shipyard's overhead costs by spreading these costs over the two ships. The cost estimators who produced the original cost estimate had relied upon credible information and had exercised appropriate due diligence. They had confirmed that the shipyard had the work for the second ship on its order books, and they received confirmation from the Defense Contract Audit Agency (DCAA) of this order, as well as DCAA's satisfaction that this commercial ship would be built in accordance with the contract. It was thus reasonable to assume that the shipyard's overhead rates would be split between the two ships. However, when the Navy ship was being built, the commercial firm canceled its ship building order, for its own business reasons. Consequently, it turned out that there was no second ship in the yard with which to share overhead rates, and these overhead costs had to be covered entirely by the US Navy!

Naturally – and through no fault of the US Navy – there were indeed significant (and legitimate) cost increases. They did not occur due to inexperience or due to naïve program management by either the government or the shipyard. Thus, the first lesson learned in this example is that *assumptions always drive cost*. The second lesson learned is that *assumptions can be fragile*. While a key assumption in your program may be accurate at one moment in time, it may not be accurate at a later time. This was indeed the case here. The third lesson learned in this example is that the one constant you can always rely on is change. *Change will always occur*! Even a cost estimate completed with due diligence and reasonableness can be wrong. After all, in this example, all the evidence pointed to the fact that there would be a second ship in the yard. In conclusion, be aware that plans and circumstances do change during the life of your program, and they most likely will. Ultimately, these changes will affect your estimated and actual costs.

Example 1.2 Cost Estimation in Support of a Major Missile Program A frequent root cause of underestimation in a cost estimate (and therefore a strong invitation to a cost overrun) is the omission of the cost of a significant component of the necessary work. In cost estimating, we refer to such a component of the necessary work as a work breakdown structure element (WBSE). Whether the omission occurs purposely or accidentally makes no difference, for as the project is executed, labor costs and material costs associated with the missing WBSE will still accrue, the bills will be presented for payment, and a cost overrun will then occur.

A cost estimate on a missile that was an expensive new major defense weapon system provides an example. Let's call our missile program that we are costing Program A. Experience with such weapon systems that were part of Program A had taught me that a sensor would be part of this weapon system; in fact, I expected that the development of this sensor would be one of the *major* cost elements in the research and development (R&D) phase of the lifecycle cost estimate. The program office confirmed that a new sensor was indeed part of the design of this weapon and that the new sensor was integral to the weapon's successful performance. However, the program manager's R&D cost estimate *did not include the sensor*!

When I asked the PM why there were no sensor costs included, he stated that a separate program (which we will call Program B) was developing the sensor and that his Program A would do a "technology lift" from Program B, thereby avoiding any sensor development R&D cost to his program. While I understood this argument, I also knew that there was no guarantee that Program B would be able to complete its development of the sensor and make it available within the timelines of our program, and I was skeptical that there would be no sensor-related R&D charges in our program. The key problem, however, was that if the sensor development in Program B was delayed, it would then delay Program A, extending our schedule until the sensor technology was in fact completed. Any extension would then cause additional costs. Consequently, I argued for the identification of contingency funds in the program to cover this possibility. Fortunately, the program manager agreed, which proved to be fortuitous when Program B (that was developing the sensor) was ultimately canceled. Thus, we had to restructure Program A to incorporate the sensor development project within our own budget.

The major lesson learned here is that technology that is not developed or "mature" always presents the very real possibility that it just may not work, or may be delayed in its development, and a dependent program will then also be delayed, with corresponding increases in costs. For instance, when a program is delayed, personnel costs will increase since the workers still need to be paid, but now over a much longer period of time. There is also a more general lesson, which is that it is important to identify all technological and other risks to any program and consider their cost impacts, and to then develop contingency cost estimates under the assumption that these risks may unfortunately come to pass.

Example 1.3 Cost Estimation in Support of a Major Ship Program For years, the US Navy knew that it needed to modernize its combat logistics fleet (CLF). However, during those years, the shipbuilding appropriations were being used nearly in their entirety to develop and procure surface combatant ships instead. To work around this funding problem, a clever idea suggested that a commercial shipyard build the next generation of CLF ships, with the intention that upon completion of each ship, the Navy would then enter into a "long-term lease" for the ships. This would thus allow the CLF to be funded from the operations and maintenance account (the O&M, N appropriation) of the Navy, rather than funding it from the shipbuilding appropriations, as was the norm. I was asked to analyze whether this arrangement made financial sense, while others were examining the financial and legal implications of this potential arrangement. My analysis was to be a "cash flow" and/or "net present value" cost benefit analysis, comparing the cost of the conventional method of procuring this ship from shipbuilding appropriations with the proposed "build-to-lease" option using operations and maintenance dollars. I also needed to include the many "what-if" analyses to test the sensitivity of the bottom line cost to variations in the assumptions and values of variables being used in the analysis.

After significant study, we found that under a wide variety of reasonable circumstances, the proposed idea of "build-to-lease" made financial sense. If you were to consider only the financial metrics of the analysis, a reasonable person would be led to propose the course of action which leveraged savings from the "build-to-lease" option. This cost beneficial proposal, however, was not brought to the attention of the Secretary of the Navy despite its cost and benefits, since it was deemed to be "poor public policy and practice" for a variety of reasons. In other words, no matter how financially attractive or analytically defensible this proposal was, it was matters of public policy that trumped the analysis and drove the decision to not "build-to-lease." The lesson learned here is that cost issues are always a *major* concern, but they are almost never the *only* concern. Cost estimating is a function that informs and supports decision-making. An analyst should not assume that decision-makers will inevitably follow the recommendations of his or her analysis, regardless of how complete, reasonable, credible, analytically defensible, and even elegant that it may be.

Example 1.4 Cost Estimation in Support of a Major Automated Information System (MAIS) Often, it is important to do *rough order of magnitude* (ROM) cost estimates to help senior defense personnel sort through the cost implications of alternative courses of action for complicated projects. Knowing whether a program is going to cost *roughly* \$75 Million or *roughly* \$200 Million helps decision-makers distinguish between those options that are potentially viable and those that are not. A memorable example of this was the idea to develop an automated defense-wide system to support civilian and military personnel and pay functions across all of the military services and all "components" (that is, the Active forces, the Reserve Forces and the National Guard). This was intended to be the largest enterprise resource planning program of its kind ever implemented. We were tasked to "develop an estimate of what this new MAIS would cost and to compare that cost with the cost of maintaining approximately 90 legacy personnel and pay systems which this program would replace." We were tasked long before any specific requirements (other than the broad description given in the previous sentence) had been fully thought out or discussed. At this time, there was certainly no estimate of the size of this program, and size is often a critical variable for developing a credible cost estimate. We recognized that this personnel and pay system would be a very large software and hardware effort, and to reasonably capture the cost of the software program, we needed an estimate of its size, measured either in source lines of code or in function points. The program manager certainly had no estimate of either. We were trying to "bound" the problem by saying (in effect) that this effort was going to be "bigger than a breadbox and smaller than a barn," or, as we decided, "bigger than any Microsoft product, but smaller than the largest missile-defense project." Obviously, the estimates we developed had a wide range of outcomes. Was this range of estimates useful to the decision-makers, or did they need exact answers in order to make their decisions? The important lesson learned here was that at the front end of a project, when many unknowns still exist, rough order of magnitude estimates with a wide range of possible cost outcomes may still be sufficient for senior decision-makers to move the decision process forward.

Example 1.5 Cost Estimation in Support of a Major Policy Decision A major overseas US Army command was having difficulty with retention and maintaining its force structure within the enlisted ranks. One significant part of the problem was identified as low re-enlistment rates among the junior enlisted members. Based on US Army regulations at the time, the command's policy allowed a service member's family to accompany him or her overseas. The Army would pay for the overseas move and also support the family overseas with a housing allowance and base exchange privileges, but only if the service member had attained at least a minimum rank. The junior enlisted personnel who were not re-enlisting at sufficient rates were precisely those who were below the rank necessary to have their families accompany them and to receive those elements of family support. Consequently, their families usually remained in the US while the service member completed the overseas tour. In that way, retention suffered due to hardships caused by this separation. We proposed a policy that would extend this family support to these junior enlisted members. Our analysis addressed whether the estimated costs of implementing this policy outweighed the benefits of the estimated lower recruiting and training costs due to higher retention rates. The rough order of magnitude estimates that we provided were sufficient to convince the Army to implement this policy and the results of this policy change did indeed increase enlisted retention for the U.S Army. *For the cost analysts, it is highly satisfying to see crunched numbers turn into effective policy.*

Example 1.6 Cost Estimation in Support of a MAIS Program This example involves analyzing the issue of when to insource or outsource goods and services. While this particular case is taken from the US Navy, it has broad applicability in all services and businesses. The Navy was considering outsourcing its ashore (i.e., its "non-ship") information technology (IT) infrastructure and operations, including all of the computer hardware, software, training, and help desks. Even before the Request for Proposal (RFP) was developed or published, the Navy required a cost benefit analysis to address the important issue of the Return on Investment (ROI) of such an enterprise. ROI is simply a fraction. The numerator is the savings estimated from the proposed outsourced system when compared to the existing (or status quo) system, while the denominator is the estimated cost of the investment required to transition and maintain the proposed outsourced system. The challenge in this analysis was that we had little data to estimate either the numerator or denominator! The Navy did not have the costs for either the infrastructure or operations of the existing system, nor did the Navy have any insight into which vendors might bid for a comprehensive outsourced set of goods and services and therefore, what it would cost to capitalize and operate the proposed outsourced option. Given those significant restrictions, we still made reasonable assumptions to characterize these unknowns, and, from these assumptions, we developed our cost estimates. Subsequently, we conducted extensive sensitivity analyses in order to understand the relationship between ROI and the different values of important independent variables. We identified a critical variable in these computations, which was the fraction of best commercial practices which the Navy would be likely to achieve if it transitioned from the existing insourced option to the proposed outsourced option. For example, if the Navy was able to harvest only a small fraction of the benefits of the commercial best practices (say something in the 0 to 20% region), then the hoped-for savings would not be achieved, and the ROI would be negative or unattractive. On the other hand, if the Navy was able to harvest a larger fraction of the benefits of the commercial best practices (say something in the 80 to 95% region), then the hoped-for savings would be achieved, and the ROI would be positive and attractive. Therefore, we could present a two-dimensional graph to senior decision-makers. The horizontal-axis of the graph was the "percentage of best practices achieved," and the vertical-axis of the graph was the "ROI of investing in the new system." This graph compresses a great deal of the assumptions, methodology, and analysis of the cost and benefits into a single visualization tool. Of course, there is a corresponding loss of analytical nuance and texture in this simplification. Nevertheless, it was precisely the simplicity and transparency of this tool that permitted very senior decision-makers to make a reasoned decision, grounded in credible and defensible analysis. The lesson learned here was it is not necessary – in fact it is almost *never* necessary – to say to the decision-maker that "This is the correct answer, and here is the analysis that supports that assertion." Rather, the objective of the cost estimator should be to think of him or herself as a "guide" to the decision-maker, piloting him or her through the decision space that underlines the problem at hand. In that way, the analysis is left in the hands of the analyst, and the decision is left in the hands of the decision maker, both as it should be.

Hopefully, these six examples helped you to see the difficulties that can be encountered throughout your program, and the lessons learned from these examples. At this point, I want to transition from talking about specific examples that provide lessons learned in cost estimating to reviewing some of the changes that have been occurring in the cost estimating community over the past 30 years and changes that I feel are likely to occur in the future. It is useful to consider these changes within three dimensions: *people, processes, and the data*. The following are descriptions of these three dimensions, complete with some personal observations.

People: When discussing "People," the following questions need to be considered:

- Who are the people who enter the cost estimating profession?
- What are their academic and professional backgrounds?
- Where do they obtain their education and training in the intellectual, technical, methodological, and ethical requirements of the profession?

Thirty years ago, government cost estimators entered the profession primarily with bachelor's degrees in the engineering sciences, followed by degrees in mathematics, statistics, economics, and operations research. With the exception of a master's degree program at the Air Force Institute of Technology (which was by and large for young Air Force officers, Captains and below), there were no formalized, degree-granting courses of instruction in cost estimating at civilian colleges, universities, or military schools, either at the undergraduate or graduate level. New entrants into the field learned their skills largely in an apprenticeship mode; that is, they were assigned to work on a project under the supervision of someone who already had experience and knowledge, and the new entrants continued in that mode until they had learned enough to become the mentors to the next entrant. To combat this lack of formal education in the cost estimation field, the Office of the Secretary of Defense, Cost Analysis Improvement Group (OSD, CAIG) commenced an annual Department of Defense Cost Analysis Symposium, called DODCAS. DODCAS served as a forum for the exchange of information and skills within the Department of Defense's extended cost estimating community, and remarkably is still going strong, although there has been a recent hiatus due to the exigencies of sequestration and other recent budget stressors! This is not just for attendance by members of DoD organizations, but also for DoD contractors as well. (For more information, conduct an internet search for "DODCAS").

Fortunately, the landscape for education within the cost estimating community is changing. Beginning cost estimators are now better educated, as many new entrants already have masters degrees in the previously mentioned disciplines. Formal and informal internship programs have also been developed by organizations for their new entrants. We are entering the era of more advanced education now available specifically in the cost estimating field.

To amplify this last point on education, there are now three major repositories of cost estimating intellectual capital, with two of them leading to certification in cost estimating and the third to a master's degree in cost estimating and analysis. These three include the following:

- The first major certification source is the *International Cost Estimating and Analysis Association* (ICEAA; http://www.iceaaonline.org/), formerly known as the "Society of Cost Estimating and Analysis" (SCEA), which has developed sophisticated training and certification programs. While these programs are used by some people and organizations within the DoD, the primary customers are those contractors and consultants who provide goods and services to the government, as well as commercial firms whose work is not oriented to government needs. Commercial firms that wish to have uniform standards across their enterprise have adopted the ICEAA certification process as their standard. More is said on this topic in Chapter 3.
- The second major certification source is the *Defense Acquisition University*, which primarily supports personnel who work in various areas related specifically to the Defense Department's processes and the business of acquiring goods and services. This includes training and certification in cost estimating. Numerous training modules are available in a wide variety of subject areas.
- While the first two sources provide certifications, the Naval Postgraduate School (NPS) and the Air Force Institute of Technology (AFIT) developed a joint distance learning *Master's Degree program in Cost Estimating and Analysis*. The first cohort of thirty students commenced their studies in late March 2011, and that same cohort proudly graduated in March 2013. The second cohort with 26 students graduated in March 2014. Cohorts commence annually each spring for this two-year program. The program is open to all who meet its entrance requirements. The program is unique in granting a Master's degree specifically in cost estimating and analysis.

- Further information is available on the NPS website at: http://www.nps.edu/Academics/DL/DLPrograms/Programs/degProgs_MCEA.html

It is hard to predict the future. However, in a limited, quantitative way, that is precisely what the profession of cost estimating does. I expect the future personnel mix will include many more people with formal training in cost estimating from the various sources now available, especially the distance learning *Master's Degree program in Cost Estimating and Analysis* described in the previous paragraph. The timing is apt as these well-trained personnel will be needed to replace a population of baby boomers who are turning toward retirement.

Having discussed the people involved in the cost estimating field, I next turn my attention to the *Processes* involved in cost estimating.

Processes: When discussing "Processes," the following questions need to be considered:

- What are the intellectual underpinnings of the profession that permit cost estimates to be made?
- What are the processes by which cost estimates are developed, validated, and inserted into the larger decisions that affect acquisition, budgeting, and analysis of options?

Thirty years ago, the main methodologies for developing cost estimates were cost factors, cost estimating relationships (aka CERs, which are equations that express cost as a function of technical or performance variables), and learning curves, all of which will be explained fully in this text. These methodologies were underpinned by "actuals," cost data from analogous, historical programs. Risk and uncertainty in a cost estimate were addressed by the standard procedure of sensitivity analysis, which observes how the baseline cost estimate behaves when important assumptions are varied through reasonable ranges. The results of sensitivity analyses permit the analyst to provide a more nuanced and robust cost estimate than one that merely provides a point estimate. For example, rather than stating that "The baseline cost estimate for Program X is $1.2B (in FY13$)," the cost estimator can instead state that "The baseline cost estimate for Program X is $1.2B (FY13$), and the range of cost outcomes is expected to be $1.0B to $1.3B as the quantity procured is increased/decreased within a range of ±10%."

Thirty years ago, we were also just beginning to automate all of the computational aspects of our estimates. Prior to this time, it was quite normal for estimates to be developed on big paper spreadsheets, with arithmetic done manually, or for more complicated computations such as learning curves, computed on an electro-mechanical calculator. The advent of the laptop-based program called VISICALC (an early antecedent of today's ubiquitous EXCEL-type spreadsheets), caused quite a stir in the cost estimating community! Its consequences far exceed the simple cost savings in the number of pencils and erasers that we no longer need to use. More importantly, we are now able to do many more sensitivity analyses within the timeframe allotted to do the study, thereby providing a richer set of supports to the decision-makers.

As a new program wound its way through the hierarchical decision process, the associated cost estimate traveled with it in a review cycle that checked for the completeness of the following areas:

- Work breakdown structure elements (WBSE)
- The credibility of the analogous program data
- The correctness in accounting for all assumptions

- Applying appropriate and accurate methodologies
- Checking for other possible errors

Cost estimates were briefed to several levels of decision makers, ultimately ending at very high management levels. This process was a good indication that cost estimates, especially for major projects, were taken seriously. Back then, the Army, Navy, and Air Force already had Service Cost Centers to perform these functions, and OSD CAIG (now OSD CAPE) reviewed the largest programs. (For a history of the CAIG, see Reference 1 at the end of this chapter). These reviews were held under the auspices of regulation, meaning that each service had developed its own regulations for proper handling of cost estimates. Statutory authorities came later, when laws were developed that mandated that the cost estimates be accomplished in accordance with certain standards.

In 2015, the review processes remain largely intact. Cost factors are still derived from analogous, historical programs, and CERs are still derived using statistical regression techniques and historical data. Moreover, sensitivity analyses are still done. But now, with our capability to do Monte Carlo simulation analyses with great rapidity on automated spreadsheets, we are instead easily able to generate probability distributions for our cost estimates, thereby providing richer statistical insight for decision makers.

Three important changes to the decision-making process occurred to aid decision makers. These include the following:

- The first change is that there are now statutory requirements (mandated by law and Congress) that govern important phases of the cost estimating process. One example is the requirement for all major programs (typically, programs whose cost estimates exceed certain monetary thresholds) to have two cost estimates completed on them. One estimate is completed by the responsible program office (called the Program Office Estimate, or POE), and the other one is an Independent Cost Estimate (known as an ICE) to check and ensure the completeness and reasonableness of the POE.
- The second change is that the ICE must be considered by the Secretary of Defense in making the Milestone decisions. Milestones are periodic reviews performed as a program progresses through its life cycle from conceptualization, to research and development, to procurement, to operations and maintenance, and finally, to disposal. The fate of a program – whether to be continued or restructured or cancelled – is decided at these milestone reviews and the ICE is one of the big contributors to that decision. This requirement only calls for consideration of the ICE; it does not require the adoption of any particular cost estimate.
- The third change is that both the POE and the ICE must include the cumulative probability distributions that are generated by Monte Carlo simulations, as previously discussed.

The passage of the Weapon Systems Acquisition Reform Act in 2009 (WSARA 2009) heightened the visibility of the cost estimator and the cost estimation process within the Department of Defense and this intense focus on costs and on the education of increased numbers of cost estimators, plus the processes by which costs are estimated, will continue. WSARA 2009 mandated the creation of the Director of Cost Assessment and Program Evaluation (OSD CAPE), thus elevating the purpose and visibility of the cost estimation field. The director position requires Senate confirmation, and the office has very broad execution and reporting responsibilities in both cost estimation and cost-benefit analysis.

Data: Last, I turn to the Data used in cost estimating. Data includes the various measurements that are taken of the project for which a cost estimate is being developed. These measurements are often numerical values, but they may also be categorical variables. Examples of these measurements include cost metrics, physical measurements such as size and performance descriptions, and programmatic descriptors, such as the quantities being bought, the duration of the R&D phase, and the number of vendors to whom procurement contracts will be awarded. As you will explore in depth later in this book, data derived from analogous historical programs (aka "actuals") are the indispensable core of every professionally developed cost estimate. Therefore, the identification, collection, normalization, organization, storage, and analysis of data underpin everything that we do as cost estimators.

Thirty years ago, the collection of historical data was an "ad hoc," paper-based effort. The Department of Defense asked vendors to provide cost reports, showing time-phased costs incurred on a program that are allocated to the various elements in the project's work breakdown structure. Contractors were generally under no pressure to make these reports available, and consequently, to a large extent, they often did not provide these reports. The reports that *were* provided were accumulated in a library, and they were tended to by a very small cadre of dedicated personnel. Cost estimators often kept their own files of particular reports, and they protected them as valuable sources of analogous actuals for future cost estimates. I often think that this stage of cost estimating data-keeping was comparable to the medieval period in human history, (before printed books became available), in which hand-produced manuscripts were rare, valuable, and had very limited distribution.

Today's data resources situation is extraordinarily different from what it was 30 years ago. Data is provided by vendors in the form of cost reports, which are collected, normalized, subjected to error-searching routines, and filed in accessible web-based databases with due regard to proprietary data protection and security requirements. These reports and databases are described in Chapter 4 on Data Sources. Storage and accessibility of historical data continues to create a greater depth to the available data and easy access for those with the approved needs.

In closing this chapter and these reflections, it is hoped that these introductory remarks will provide you with an appreciation of the scope, applicability, difficulties, and utility of cost estimating and perhaps inspire you to master the material in this text and fine tune the diverse skills we apply to the complex question of "What will it cost?" Chapter 2 will begin this journey: it will discuss what cost estimating is; what the characteristics of a good cost estimate are; why we do cost estimating and the importance of cost estimating in the Department of Defense (DoD) and in Congress; how and when cost estimates are created and used; and cost estimating terminology.

Reference

1. Don Shrull, ed. *The Cost Analysis Improvement Group: A History*. Logistics Management Institute (LMI), McLean, VA, 1998, ISBN 0-9661916-1-7, Library of Congress Catalog Card Number 98-65004.