Appendix B

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B-000 Specialist Assistance **

B-001 Introduction **

a. Audits vary in purpose and scope, some require an opinion on compliance with specific laws, contractual provisions, and other requirements; others require evaluations of efficiency and economy of operations; and still others require some or all of these elements. Sometimes expertise in a field other than accounting or auditing such as legal, actuarial, engineering, or production/quality control is necessary to obtain sufficient appropriate audit evidence to render an opinion. If expertise in a field other than accounting and auditing is necessary, the audit team should determine whether to use the work of a specialist.

b. A specialist is an individual or organization, possessing expertise in a field other than accounting or auditing, whose work in that field an audit team uses to assist the team in obtaining sufficient appropriate audit evidence. A specialist employed by DCAA is an internal specialist. Internal specialists include attorney-advisers in the legal office (DL), and industrial engineers and operations research specialists in the Operations Technical Support Branch (OTST). A specialist employed by another DOD agency or another department of the federal government is an external specialist. For example, DCAA audit teams often use the work of external specialists employed by DCMA such as engineers, government property administrators and insurance and pension specialists.

c. The GAGAS field work standards for performance audits require the audit team to evaluate whether to use the work of a specialist to address some of the audit objectives and require an assessment of the specialists' professional qualifications and independence. GAGAS also requires documentation of the nature and scope of the work the specialist is to perform and the specialist's procedures and findings so they can be evaluated and related to other planned audit procedures objectives.

d. In addition, when performing a compliance attestation engagement, the nature of the specific compliance requirement may require specialized skill or knowledge in a particular field other than accounting and auditing. In these circumstances, AT Section 601.43 requires auditors to follow the relevant performance and reporting guidance in AU-C Section 620, Using the Work of an Auditor's Specialist.

e. This appendix provides a framework to assist audit teams in adhering to government auditing standards for attestation engagements and performance audits related to using the work of a specialist.

B-100 Using the Work of a Specialist **

B-101 Audit Team Responsibilities **

a. The audit team has sole responsibility for the conclusions (i.e., audit opinion) expressed in the report. The auditing standards for performance audits and attestation engagements require the audit team obtain sufficient, appropriate evidence to provide a reasonable basis for the conclusions expressed in the report. Using the work of a specialist to obtain sufficient appropriate audit evidence does not reduce the team's responsibility for the audit opinion.

b. While the acquisition command or the contract administration office may involve specialists in analyzing the contractor's systems or cost submissions for its own purposes, audit teams cannot presume this analysis will anticipate and provide all the specialist assistance the audit team needs. When acknowledging the request for audit, audit teams should explain that professional standards require they make their own determination on the need for specialist assistance in performing the audit and additionally, the team should explain that it might request specialist assistance from the procurement community based upon that determination.

c. Professional standards require audit teams using the work of a specialist evaluate the competence, capabilities and objectivity (performance audits refer to independence) of the specialist for the auditors purposes. Policy evaluated the competence, capability and objectivity of DCAA internal specialists (B-103), and external specialists employed by DoD (B-104 and B-105). Audit teams seeking external specialist assistance from Non-DoD agencies, should contact PAS through the regional office for assistance in performing this evaluation.

d. Professional standards require the audit team coordinate and reach agreement with the specialist on the nature, scope and objectives of the specialists work, the roles and responsibilities of the specialist and the audit team, and the manner in which the specialist will provide the results of the evaluation. Refer to B-106 and B-107 for guidance on requesting assistance from internal and external specialists.

e. Additionally, professional standards require audit teams evaluate the adequacy of the specialist work for the audit team's purposes and document the evaluation in the working papers. Refer to B-108 for guidance on performing this evaluation.

**B-102 Determining the Need for Specialist Assistance **

a. Generally as part of planning the engagement, the audit team should consider whether there is a need for specialist assistance to obtain sufficient appropriate audit evidence and document that determination. Use Work Paper B-03, section 1, to document the determination.

b. Audit team's predominately seek a specialist’s assistance when examining contractor estimates used to propose the types and quantities of material or labor hours for manufactured items or services. However, audit teams may benefit from using specialists to examine other areas that affect the subject matter of the audit. For example, audit teams may wish to consider seeking assistance to determine the feasibility of production processes, the condition of inventory, equipment, and real property, the reasonableness of actuarial estimates related to pension and insurance costs or in interpreting laws, regulations and contract terms pertinent to the subject matter of the audit.

c. When performing risk assessment procedures and obtaining an understanding of the entity's internal controls and its environment, the audit team should obtain an understanding of how the contractor identifies transactions, events, and conditions that require the contractor to use an expert in a field other than accounting. In some cases, this information may be part of the contractor's estimating system policies and procedures, and in other cases the auditor may obtain the understanding through inquiry of contractor management during the walk-through of the contractor's assertion.

d. The risk of material misstatement may increase when the contractor needed expertise in a field other than accounting to prepare the assertion or establish and monitor a business system. The audit team may wish to consider the following factors in determining whether to request the assistance of a specialist when the contractor used a specialist.

(1) The nature, scope and objective of the contractor's specialist work in relation to the subject matter of the audit. For example, the audit team may wish to consider the materiality of the specialist work in relation to the individual cost elements and the total assertion and the complexity of the work, including the assumptions and methodology used.

(2) Whether the contractor's specialist is a contractor employee subject to management control and policies and procedures (e.g. estimating system) or is a party engaged by the contractor to provide the service (e.g. an actuarial firm providing the contractor services on pension calculations).

(3) The results of a DCAA audit of the system controlling the specialist's work (e.g. estimating system).

(4) The audit teams ability to evaluate the contractor's specialist work without the assistance of an internal or external specialist.

e. Audit teams can usually evaluate the support for an accounting estimate that uses historical accounting or financial information without assistance from a specialist. When determining the need for specialist assistance with accounting estimates, audit teams should consider the degree of estimating uncertainty associated with the estimates. Additionally understanding the degree of estimating uncertainty may assist audit teams with assessing the risk of material misstatement. Factors that may influence the degree of estimating uncertainty include:

(1) the extent to which the estimate is based on historical information,

(2) the length of the forecast period and the relevance of data drawn from the current or prior period to forecast the estimate,

(3) whether the comparison of prior estimates and actual costs discloses significant differences,

(4) the use and/or existence of recognized measurement techniques (e.g. pre-determined motion time systems) in generating the estimate,

(5) the extent to which the estimate depends on subjective and or complex judgments, and

(6) the sensitivity of the estimate to changes in assumptions.

f. If the audit team reassesses the need for specialist assistance during the course of the audit, it should document any changes to the initial assessment.

**B-103 Evaluation of Competence, Capability and Objectivity - Internal Specialist **

a. When performing attestation engagements, an audit team is entitled to rely on audit organizations quality control system if the internal specialist is subject to the requirements of that system.

b. DCAA internal specialists must meet the conditions of appointment for their position description and comply with any continuing education requirements required by that position. For example, civilian attorneys assigned to DCAA by Defense Legal Services must meet the minimum requirements for appointment and the continuing educations requirements of DOD Instruction 1442.02. Additionally the OTST specialists must meet the education requirements required by the position descriptions. This provides reasonable assurance that internal specialists consulting on an audit are competent and capable of performing work within the specialty area.

c. DCAA requires internal specialists consulting on audits to complete the GAGAS independence training annually and adhere to the Agency's quality control system for GAGAS independence. The internal specialist re-evaluates his or her independence and signs the audit specific independence determination workpaper when assigned to consult on an audit assignment. This provides reasonable assurance that internal specialists consulting on an audit assignment are objective and independent.

**B-104 Evaluation of Competence, Capability and Objectivity - DCMA and DoD Military Command Specialists **

a. Professional auditing standards indicate that evaluating competence and capability include considering whether the specialists work is subject to technical performance standards, or requirements imposed by law or regulation).

b. The Defense Acquisition Workforce Improvement Act (DAWIA) as promulgated under 10 U.S.C 1701 - 1764 required the Secretary of Defense to establish policies and procedures and designate by regulation positions within the DoD that are acquisition positions. This included establishing education and/or experience criteria for selecting individuals for those positions and ensuring there are appropriate career paths that are identified in terms of the education, training, experience, and assignments necessary for career progression to the most senior acquisition positions.

c. In accordance with DOD Instruction 5000.66 the Defense Acquisition University (DAU) has defined the various certification series that are comprised of different job series and published the certification requirements; and core competencies for Levels I (basic), II (intermediate) or III (advanced) associated with each job series. For example, the DAU published core competences for Level I, II, and III for the engineering category, contain information on the representative activities of the category, educational and experience requirements and core training competencies. Additionally DODI 5000.66

requires each DoD component implement the requirements of DAWIA, and certify its acquisition workforce members.

d. The DCMA Engineering and Analysis Directorate issues instructions establishing guidance for technical pricing support activities provided by DCMA engineering and technical staff including support provided to DCAA. These policies and procedures require engineering and technical staff have the educational and experience qualifications, and acquisition and functional training necessary to attain DAWIA certifications for their primary career field reasonably ensuring the competence of the DCMA specialists. In addition, the capability of a DCMA specialist is reasonably ensured by DCMA instructions that require the engineering team lead identify the necessary function support for completing the request, oversee the specialist's work and take responsibility for the quality of the work. DCMA instructions also require the maintenance of detailed work papers that support the technical analysis in the DCMA official files.

e. In addition, to DCMA, audit teams occasionally seek assistance from the technical directorates associated with the Army, Navy and Air Force military procurement commands. DCAA headquarters contacted the technical directorates to obtain information regarding policies and procedures pertaining to the specialists work, and Defense Acquisition Workforce Improvement Act (DAWIA) certification requirements.

f. As part of the DoD Acquisition Workforce the Army, Navy and Air Force procurement commands adhere to DAWIA certifications requirements for acquisition workforce members. The Army, Navy and Air Force established Director, Acquisition Career Management (DACM) offices, and the Air Force established the Acquisition Professional Development Program (APDP) to implement monitor and report on compliance with DAWIA certification requirements to Acquisition, Technology and Logistics (AT&L). Adherence to the DAWIA certification requirements helps ensure the competence of the specialists in the AT&L functional areas such as engineering.

g. Additionally the Army, Navy and Air Force directorates have issued various instructions, operating guides, manuals, pamphlets and or established internal training that provides guidance on performing and documenting technical evaluations and processes for the review and oversight of technical evaluation reports prior to issuance. This guidance and management oversight help ensure the capability of a specialist.

h. Professional auditing standards indicate matters relevant to evaluating objectivity of the auditor’s specialist include whether the work is subject to ethical standards, or requirements imposed by law or regulation.

i. Organizational components of the DoD, such as DCMA and the military procurement directorates must adhere to the government ethics regulations and the DOD supplemental ethics regulations. The DOD supplement to the ethics regulations, 5 CFR 3601.105, requires a DoD employee provide written notice of disqualification to his or her supervisor upon determining he or she cannot participate in a matter. Additionally, in accordance with the Undersecretary of Defense (USD) AT&L

memorandum, dated January 15, 2014 beginning in calendar year 2014 all acquisition workforce personnel are required to annually complete ethics training.

j. Adherence to the government ethics regulation and DoD supplemental regulation reasonably ensure that a DCMA and DOD military command specialists financial interests and business and personal relationships do not create conflicts of interest that would impair the specialists' objectivity. In addition, management's oversight of the specialist's work and DCAA's evaluation of the specialists work prior to incorporating it into the audit provide additional safeguards to objectivity.

B-105 Evaluation of Competence, Capability and Objectivity - DCMA Insurance/Pension Specialists **

a. The DCMA Contractor Pension Review Center Insurance Pension Specialists perform Contractor Insurance Pension Reviews (CIPRS) and provide assistance to DCAA regarding audits of contractor pension plans, insurance programs, and other deferred compensation plans.

b DCMA Insurance and Pension Specialists must meet education and experience requirements for the actuarial sciences services job series (1510) established by the Office of Personnel Management (OPM). In addition, DCMA insurance and pension specialists must obtain continuing education training in the areas of government contracting, contract law, and/or cost accounting standards and specific training on pensions and insurance from external sources. DCMA Acquisition (DCMA-AQD) issues instructions establishing guidance for insurance and pension specialists regarding the functions and roles and responsibilities of the specialists and requiring supervisory review and approval of report prior to issuance to an ACO or external customer that reasonably ensure the competence of the specialists. Therefore, we consider the DCMA insurance and pension specialist competence and capability is reasonable by the policies and procedures requiring supervisory review and the educational and experience requirements for the position.

c. As DoD employees, DCMA insurance and pension specialists must adhere to the government ethics regulations and the DOD supplemental ethics regulations. The DOD supplement to the ethics regulations, 5 CFR 3601.105 requires a DoD employee provide written notice of disqualification to his or her supervisor upon determining he or she cannot participate in a matter. Adherence to the government ethics regulation and DoD supplemental regulation reasonably ensure that a DCMA insurance, pension specialist's financial interests, business, and personal relationships do not create conflicts of interest that would impair the specialist's objectivity.

B-106 Requesting Internal Specialist Assistance **

a. Audit teams may verbally contact OTST to discuss the need for technical assistance from the Industrial Engineers or Operations Research Specialist and follow the verbal request with appropriate written documentation for OTST specialist assistance to provide evidence of the agreement with the specialist.

b. Audit teams seeking advice on contract law (e.g. interpretations of case law, statutes, regulations or other contract issues) in relation to an audit may contact Defense Legal through the regional office (e.g. RST) in accordance with the guidance in 4-902 or directly via e-mail at DCAA-DL@dcaa.mil. The agreement should discuss the nature, scope and objectives of the specialists work, the roles and responsibilities of the specialist and the audit team, and the manner in which the specialist will provide the results of the evaluation. Refer to 15-503 for coordination with legal on contracts disputes cases.

c. The audit team should document the coordination and agreement with the internal specialist and the receipt of the work product, technical report or legal advice in accordance with the work paper sections in Figure 4-4-2. Legal guidance will be placed in work paper 35.

B-107 Requesting External Specialist Assistance **

a. Audit teams should send written requests for external specialists' assistance. Requests for insurance pension specialist assistance should be sent to the DCMA contracting officer and coordinated with the Contractor Insurance/Pension Review Center. Requests for specialist assistance (e.g. engineering, government property) should be sent to the cognizant acquisition command or the contract administration office. The administrative contracting officer or his or her designated point of contact generally coordinates requests sent to the contract administration office. The procurement commands generally forward the request to the directorate that performs the technical evaluations.

b. The written request for specialist assistance should discuss the scope of the assistance needed and request a meeting or conference call with the cognizant contracting officer, the command or contracting office's team lead and the designated specialist to reach agreement on the:

(1) Nature, scope, and objectives of the specialists work. It may be relevant to discuss the reasons the specialist assistance is needed (nature), the specific system areas, cost estimates and time-periods the team wishes evaluated (scope) and the teams objectives for using the specialists work.

(2) Respective roles and responsibilities of the audit team and the specialist. For example when the specialist work will involve using source data, it may be relevant to discuss who will be performing the tests of the data such as verifying its origins or reviewing the data for completeness and internal consistency.

(3) Nature, timing and extent of communication. This would include discussing and obtaining the specialist acknowledgment letter or memo confirming agreement on the work to be performed, the manner in which the specialist will provide the results of the evaluation (e.g. written report, work product), and the due date for the evaluation results. Additionally, the team should designate a team member the specialist may

contact with questions or for interim discussions, and request the specialist designate a point of contact for questions on the evaluation report.

(4) Specialist's permissions and/or objections on referencing and/or disclosure of the technical evaluation report in the audit report if the audit team considers it necessary to explain a modified audit opinion.

B-108 Evaluating the Specialists Work **

a. The audit team should evaluate the adequacy of the work of the specialist for the audit team’s purposes including the relevance and reasonableness of the findings and their consistency with other audit evidence. The audit teams familiarity with the specialist's field of expertise, and the nature, timing and extent of work the specialist performed affect the nature, timing and extent of the audit procedures applied to evaluate the adequacy of the work.

b. Audit procedures to evaluate the adequacy of specialist work may include:

(1) Reviewing the specialist’s report or work product. Determine if the specialist’s report or work product adequately addresses each of the areas for which the audit team requested specialist assistance. Determine if there are any unanswered questions or concerns, and if so, discuss them with the specialist.

(2) Performing corroborative procedures such as observing the work of the specialist; examining published data, such as statistical reports or benchmark reports from reputable, authoritative sources; confirming relevant matters with third parties (e.g., agency industrial engineers); performing detailed analytical procedures; and performing calculations.

(3) If the specialist tested the source data due to its complex or technical nature, the audit team should inquire regarding the tests performed to evaluate the data's relevance, completeness, and accuracy.

c. Audit procedures to evaluate the relevance and reasonableness of the specialists findings or conclusions include determining whether the findings are clearly expressed, and whether the basis for the findings are well documented. For example, procedures may include evaluating if the report:

(1) references to the audit team objectives as documented in the agreement with the specialist,

(2) contains information explaining the scope of work performed,

(3) is based on an appropriate period and takes into account any relevant subsequent events, and

(4) appropriately considers any errors or deviations the specialist encountered.

d. When the purpose of requesting specialist assistance is to evaluate the underlying assumptions and methods, including models, used by a contractor in developing an estimate, (e.g. actuarial model or assumptions) the evaluation of the specialist work will primarily focus on whether the specialist has adequately reviewed the contractor's assumptions, methods, and models used in developing cost estimates.

e. When the specialist work involves the use of significant assumptions and methods, the appropriateness and reasonableness of those assumptions and methods used, and their application, are the responsibility of the auditor's specialist. Factors relevant to the auditor's evaluation of those assumptions and methods include whether the assumptions and methods are:

(1) Generally accepted within the field of the auditor's specialist (e.g. actuarial assumptions and methods).

(2) Consistent with those of the contractor, or if not, the reason for and effects of, the differences between the contractors and the specialists methods.

f. Auditors should document the evaluation of the specialists work in the audit work papers.

B-109 Resolving Inadequacies in the Specialists Work **

a. If the audit team determines that the specialist's work is not adequate for its purposes, the audit team should perform one or both of the following procedures in an attempt to obtain an adequate technical evaluation:

(1) discuss with the specialist the nature and extent of additional work that can be performed by the specialist and reach agreement on the performance of the additional work, and/or

(2) assess whether performing additional audit procedures is appropriate under the circumstances.

b. If the above procedures do not resolve the inadequacies, the audit team should consider if there is a reservation about the engagement because of the inability to obtain sufficient appropriate audit evidence. In such cases, the team would have to consider the impact the reservation has on the audit opinion.

B-110 Referencing the Specialists Work in the Audit Report **

a. The audit team should not refer to the work of a specialist in an attestation examination audit report with an unmodified opinion.

b. It may be appropriate to refer to the specialist report when the audit report contains a modified audit opinion, and reference to the specialists report is necessary to understand the modification. In such circumstances, the audit team should obtain the permission of the specialist before making such a reference in the audit report or disclosing the specialist report to the report recipients.

c. If the audit report references the work of the specialist, the report should indicate that referencing the external specialist report does not reduce the audit team's responsibility for the audit opinion. In addition, the audit report restrictions paragraph should describe any permissions and/or objections the specialist has to release of specialist report information contained in the audit report.

d. When audit teams request, but do not receive, the specialist report, the team should consider if the non-receipt creates a reservation about the engagement because the team was unable to obtain sufficient appropriate audit evidence.

B-200 Section 2 - Reserved **

B-300 Section 3 - Reserved **

B-400 Section 4 - Cost Estimating Methods **

B-401 Introduction **

a. Cost estimating encompasses planning, coordinating, compiling, and pricing of proposed material, labor, and other items. Depending upon the contractor's size and type of work, this function may be performed by a single department or several departments acting together.

b. The objective of this section is to provide a cost estimating overview of the labor and material areas, with the understanding that the estimating methods discussed may be used on other cost elements. A basic understanding of these areas is essential when attempting to evaluate a proposal. While the following guidance does not address a specific contractor estimating system nor a particular estimating method, the described principles and techniques will be applicable to most estimating environments.

B-402 Overview of Cost Estimating **

a. Cost estimating requires the application of skillful analysis and experienced judgment in projecting labor and material contract requirements. Timing constraints and the availability of historical data have an impact on the estimating process. Selections of appropriate estimating techniques require extensive analysis by contractors. Appropriateness of selected estimating techniques should be reviewed periodically. The same technique used when the program is at the engineering-concept stage, or when no bill of materials exists, is usually not appropriate for ongoing production. Because cost estimating integrates technical as well as financial information, the process requires input from many diverse organizational elements.

b. Although contractor estimating systems differ in approach and philosophy, their basic objectives are the same. Cost estimates are a series of informed projections and assumptions based on available information existing at the time of proposal preparation.

c. Cost estimating is comprised of logical steps. The level of detail required in these steps is often affected by the anticipated contract requirements expressed in the RFP. Typical steps in cost estimating follow:

(1) Ensuring that all relevant background documents such as historical costs, drawings, and specifications are available to assist in understanding job requirements.

(2) Determining which estimating techniques will be used, the level of detail required, and the amount of time available to generate and document a completed estimate.

(3) Determining if quotes and other information will be required from outside sources.

(4) Deciding if any elements require further clarification, redesign, or have potential manufacturing difficulties.

(5) Determining if the capability and capacity to manufacture required components exist in-house.

(6) Determining if further information is required to develop and complete estimates.

(7) Coordinating the activities of departments participating in the estimating exercise.

(8) Obtaining quotes, history, and other bases for material and subcontract items.

(9) Assembling direct costs by cost element, and computing indirect expenses using appropriate factors and rates.

(10) Consolidating proposal elements and documenting preparation rationale.

B-403 Estimating Process at a Typical Contractor **

a. At large contractors, the estimating (or pricing) department usually has overall responsibility for coordinating and assembling estimates to be incorporated into proposals authorized by top management. Preparation of detailed estimates is accomplished by the departments which will actually perform or supervise the work if the contract is received.

b. The cost estimating project is usually initiated in response to an RFP. The RFP provides a statement of work, outlines Government requirements, and invites contractors to prepare a proposal. It is also a source of information in establishing a baseline for labor and material requirements. Contractor proposals should include tasks and materials consistent with the RFP. When top management authorizes a response to an RFP, the estimating department reviews the RFP and top-management guidance and issues a "cost estimate request" to other departments within the company that will be involved in putting the proposal together. The estimating department generally has primary responsibility for coordinating the overall effort and authorizing the finalized proposal.

c. Contractors may also submit unsolicited proposals for requirements not yet reflected in any outstanding RFPs. When such proposals are pursued by a Government acquisition organization, the PCO will normally request a more detailed cost proposal before requesting an audit. The estimating process should be the same as when there is an RFP.

d. When production is contemplated on items not previously produced, the estimating department (or the related project management department) solicits a preliminary conceptual design from the engineering department. The preliminary design should be detailed to the point that individual parts can be identified and numbered. After the preliminary design has been completed and reviewed, a work breakdown structure (WBS) is prepared. The WBS is a matrix that organizes and describes proposed tasks and identifies the performing departments. This is best done before the details of the "cost estimate request" are finalized. (If conceptual design and detailed estimating must proceed concurrently, the contractor will have much greater difficulty producing a sound cost estimate.)

e. The planning process entails the preparation of delivery schedules, staffing projections, span-time requirements, and funding estimates. Planning is a cooperative effort that involves the estimating, engineering administration, and production planning and control departments.

f. "Grass-roots estimates" are basic estimates of labor, material, and other direct costs developed by the departments that will actually perform the work. In some cases, departments are asked to generate price estimates. When this occurs, special care must be exercised to ensure that sound purchasing considerations such as competition and quantity discounts are applied to the estimates.

g. The engineering department usually develops staff-hour estimates for all potential make items. These estimates are normally prepared at a very low level, such as by individual part. The manufacturing department uses this information with historical data to project labor requirements. These projections may be broken down by functional area and/or cost center (e.g., system analysis, design, fabrication, assembly, test, inspection, packaging, and shipping). A variety of techniques including manloading, statistical relationships, past experience, and judgment are used to produce staff-hour estimates. Additional information such as program schedules and configuration/performance characteristics from preliminary and final engineering design drawings may be worked into the estimates. In all cases, the method used to produce direct-labor estimates should be discernible, and supporting documentation should be available for verification.

h. A make-or-buy committee, normally chaired by the program manager, reviews required materials and associated labor, and determines which items should be produced internally. In some instances, decisions will be deferred until a contract award is made and further design effort completed.

i. The estimating department requests the purchasing department to provide estimates for all potential buy items. The purchasing department is provided with the best available specification data from the engineering and quality assurance departments. Delivery requirements are provided by the manufacturing planning department. Material unit prices (including purchased parts, raw material, buy-to-drawing items, and subcontract items) are obtained by the purchasing department from vendor quotations, current purchase orders, catalogs, and in some cases statistical methods. Material costs are usually developed by applying these prices to unit quantities in a bill or list of material provided by the engineering or manufacturing department. The purchasing and estimating departments are usually responsible for determining appropriate material escalation factors. Escalation is either quoted by major vendors or projected using specific price indices.

j. Each estimate is reviewed and approved at the functional level. These estimates are then submitted to the estimating department which assembles the total proposal estimate. Estimating personnel integrate, adjust, and analyze estimates for accuracy and completeness. The cost estimate is summarized further by functional organization, major tasks, and other breakdowns required by the RFP. When all direct-cost elements have been received and properly classified, applicable direct-labor rates and indirect-expense rates and factors (e.g., labor overhead, material burden, and G&A expense) are applied to complete the basic cost estimate. These rates and factors may be developed by the estimating or accounting departments. Fee calculations are usually applied in accordance with RFP guidance and company pricing policy. The completed cost package is then reviewed for accuracy and reasonableness by program management.

k. Subsequent to initial pricing and the determination of profit factors, the proposal is reviewed by a management committee usually consisting of representatives from marketing, accounting, plant management, estimating, and the program office. The committee scrutinizes the reasonableness of estimates, overall acceptability, and compatibility with the company's business strategy. This process culminates in the formal release of the pricing proposal and supporting rationale.

B-404 Government Regulations **

Several Government regulations provide guidance relevant to cost estimating:

a. Standard forms are no longer available for the submission of certified cost or pricing data or data other than certified cost or pricing data. The contracting officer may require submission of certified cost or pricing data in the format indicated in Table 15-2 of FAR 15-408, specify an alternative format, or permit submission in the contractor's format. Table 15-2 provides a vehicle for the contractor to submit to the Government a proposal of estimated and/or incurred costs by contract line item with supporting information, adequately cross referenced, and suitable for detailed analysis. It requires a breakdown of cost by line item so that pricing data is easily understood and tracked. Data other than certified cost or pricing data may be submitted in the offerors own format unless the contracting officer decides that use of a specific format is essential and the format has been described in the solicitation.

b. FAR 15.403-4 requires contractors to issue a certificate of current cost or pricing data attesting that the information furnished was accurate, current, and complete as of the date of final agreement on price.

c. FAR 3.501 deals with investment pricing and addresses contractor attempts at "marginal buying" or "buying in". The regulation instructs contracting officers to ensure that contract shortfalls are not recovered in subsequent pricing actions when it is believed the contractor is using artificially low prices to "buy in".

d. Earned Value Management System (EVMS) Guidelines, as described in DoDI 5000.02, define contractor management system requirements on significant flexibly-priced contracts for selected items identified as major defense systems.

B-405 Types of Cost Estimating **[**](#)

a. The basic elements of cost are direct material, direct engineering and manufacturing labor, other direct costs, indirect expenses, and cost of facilities capital. The cost estimating technique selected will be dictated by the availability of historical evidence and Government requirements, and rarely is one estimating technique used to the exclusion of all others. For example, contractors typically use synthetic estimating in conjunction with parametric and comparative techniques.

b. Cost estimating methods may be categorized into six main groups: subjective, parametric, comparative, synthetic, global, and research and development. Further comments related to each of these follow.

(1) Subjective. This estimating method develops costs using experience, judgment, memory, informal notes, and other readily available data. Typically, these kinds of estimates are used in proposals when drawings have not yet been developed or the contractor is faced with limited proposal preparation time.

(2) Parametric. This method creates labor and material estimates by statistically analyzing and manipulating historical data to reflect current quantity requirements (see 9-1000). For example, previous raw material requirements on a price-per-pound basis could be used to project current proposal amounts. Parametrics uses one or more cost estimating relationships (CERs) to estimate costs associated with the development, manufacture, or modification of an end item. Special cost comparisons are required to validate parametric estimating systems.

Variables used in CERs must be logically related and statistically valid. The rationale for selecting the variables should be well documented. Parametrics are often used to cross-check estimates developed using other estimating techniques.

(3) Comparative. This method develops proposed costs using like items produced in the past as a surrogate. Allowances are made for product dissimilarities and changes in complexity, scale, design, and materials. The comparative method can be used in conjunction with parametric estimating and can be used to develop adjusted unit costs while parametrics are applied to project the newly proposed quantities. Improvement curve applications are an example of comparative estimating.

(4) Synthetic. This method divides proposals into their smallest component tasks. Estimates are developed for component tasks which make up the whole. Synthetic estimates are normally supported by detailed bills of material.

(5) Global. This is a quick and subjective technique used to determine the advisability of continuing with a project.

(6) Research and Development (R&D). There are two basic approaches available for this difficult type of estimating. The first is a simple form of targeting R&D objectives in the context of a fixed budget. As in the preparation of routine budgets, the breakdown should be compatible with the cost-accounting system and procedures established to monitor and control expenditures. A second method of estimating R&D is a trial-and-error procedure involving an interchange of ideas and information including all available records of past R&D effort and experience. Because there are so many unknown factors involved in R&D effort, the potential for error in this type of estimating is especially great.

**B-406 Validation of the Cost Estimating Method **

a. Normally, contractors settle on a cost estimating procedure and use it repetitively. Validation of estimating procedures entails a comparison of cost estimates to actual costs for completed projects. If the actual costs accurately reflect the work content and historically approximate the estimates, then the estimating procedure should be considered reliable. Parametric-technique documentation should show that work being estimated is comparable to the prior work from which the costs are developed. Data is verifiable if it is generated from an adequate estimating system as described in 5-1204.1. Attention to validation of a contractor's estimating procedure is critical, and will save audit effort in the long run.

b. Deviations between estimated and actual cost are usually a consequence of human error or changed circumstances. Some common causes of deviations in estimates follow:

(1) Careless accumulation of supporting data.

(2) Incorrect design information.

(3) Unexpected delays causing premiums to be paid for overtime or material.

(4) Unexpected processing problems requiring deviation from the manufacturing plan.

(5) Failure to identify unrealistic bids from subcontractors.

(6) Failure to rework preliminary estimates to produce an accurate finished estimate.

(7) Reliance upon estimators who are not familiar with job processes.

(8) Making a "guesstimate" and then "padding" it to protect against unanticipated costs.

(9) Failure to consider price breaks on quantity purchases.

(10) Inappropriate use of learning curves or other techniques.

c. Controlling Estimate Deviations

(1) Project Simplification. A successful approach has been to divide a project into component parts of roughly equal size and generate estimates for the component parts. The summation of the component estimates typically produces fewer errors than the high-level approach.

(2) Random Errors. Some cost estimating errors occur at random and their causes may be difficult to identify. A determination of the magnitude of these errors needs to be made so that allowances in cost estimates can be provided for. Statistical analysis may be used (by the contractor and the auditor) in making this determination.

(3) Biased Errors. Other cost estimating errors can be identified to causes. Trends can usually be developed for these type of errors. Examples of biased errors and their causes follow:

(a) Fluctuation in labor and material costs caused by economic conditions.

(b) Variation in the cost of a machine, tool, or piece of equipment attributable to its size or capacity.

(c) Decrease in the cost of performing an operation as the number of units produced increases.

d. Contractor estimators should periodically monitor the accuracy of their estimates. Cost-to-noncost cost estimating relationships (CER) should be monitored in the same manner as cost-to-cost CERs. For change-order pricing or for repetitive use, CER monitoring is critical. Significant deviation from actuals should alert the estimators to the influence of random and biased errors.

e. Contractors may use estimating methods that will cut proposal preparation costs. Cost benefit analysis must be performed to assure that the costs of implementing and monitoring new methods do not outweigh the benefits of reduced estimating costs. If analysis suggests that they do, then the matter should be pursued for potential cost-avoidance recommendations as discussed in 9-308.

f. Cost or Pricing Truth in Negotiations, 10 U.S.C. 2306a, requires the contractor provide the Government with all facts available at the time it certifies the cost or pricing data as current, complete, and accurate (see 14-100). All estimating techniques employed must meet the same basic disclosure requirements under the act as discrete estimates. If a contractor uses a cost-to-noncost CER in developing an estimate, the data for the CER should be current, accurate, and complete (see 9-1000). The certification is not to the judgments employed in preparing the estimates, but to the factual data underlying the contractor's judgment.

B-407 Labor Cost Estimating Methods **

B-407.1 Overview **

a. Labor is a major element of direct cost and overhead allocation. Total labor cost is described by the equation:

Total Labor Cost = Rates X Labor Hours

Evaluation of the accuracy of labor-hour quantities requires a thorough understanding of a contractor's estimating methods. Commonly used labor estimating methods will be described in following sections.

b. Different terminology is frequently used to classify labor. The accounting and non-accounting classifications are as follows:

(1) Accounting. Auditors use the terms "direct" and "indirect" to describe the manner in which labor costs are charged to end-items or products. Direct labor such as factory workers and design engineers is closely linked and identifiable to end items. Indirect labor such as general engineers and supervisors is accounted for in overhead pools and distributed to a base. In this guidance, attention is focused on verification of direct labor requirements.

See 9-300, 9-500, and Chapter 8 for guidance dealing with the potential that contractors may under or over recover costs as a result of inconsistency in the classification and treatment of labor costs, and deviation from applicable Cost Accounting Standards.

(2) Non-Accounting. Engineers and manufacturing personnel use the terms "touch labor" and "non-touch labor" to distinguish between individuals who have direct hands-on involvement in manufacturing and testing processes and those who do not. Examples of touch labor personnel are production workers, test technicians, numeric control operators, and electronic assemblers. Non-touch-labor employees include some

engineers, production control personnel, administrators, and logistic personnel. Usually touch labor is direct; however, not all direct labor is touch labor.

c. There is little uniformity among contractors in the way they categorize labor when estimating costs. However, direct labor can generally be grouped into the following three major categories.

(1) Manufacturing Labor. This is touch labor on a product or a service which advances the product toward completion. Most weapon systems contain metal components. Organizations engaged in metal manufacturing normally employ numerical control (NC) machinists, sheet metal fabricators, and welders.

Another common component of weapon systems is electronics. Electronic manufacturing typically encompasses printed circuit board (PCB) manufacturing, PCB assembly, cable and harness assembly, and final box or cabinet assembly.

Some contractors use processes which necessitate specialized labor. For example, non-metallic manufacturing deals with plastics, injection molding, composite technology, and transfer molding. Other specialties include foundry, forging, and chemical processing.

Many of the above operations produce components that feed a final assembly. Frequently, final assembly areas will be dedicated to just one product such as a missile or aircraft. If the effort is large, labor may be categorized by major aircraft structure or worker trades.

In the shipbuilding industry, manufacturing labor is generally organized by trade such as electricians, pipefitters, welders, machinists, riggers, loftsmen, painters, grinders, burners, and carpenters. Other trades may be present depending on the particular shipyard.

(2) Support Labor. Support workers are responsible for the smooth operation and coordination of production activities. Production planning and control, quality inspection, material transportation, and warehousing personnel are examples. Other support labor activities ensure that manufacturing labor personnel have all the proper capabilities to manufacture products efficiently. Examples are toolmakers and equipment maintenance personnel.

A distinction is usually made between recurring (sustaining) and non-recurring onetime support labor. Recurring effort is a function of the number of units produced. Recurring labor assists manufacturing personnel by incorporating design changes, productivity improvements, and process control monitoring. Non-recurring labor does not depend upon quantity of units produced. Examples include tool design, instruction writing, and factory rearrangement. These activities are onetime occurrences. The separation of non-recurring and recurring labor is important and must be performed to obtain accurate estimates.

(3) Engineering Labor. Engineers are primarily involved with product research, design, and production support. Engineering labor comprises a significant portion of labor costs for high-technology weapon systems. The major disciplines of engineering are industrial, mechanical, electrical, chemical, and civil. Some subspecialties are hydraulic, tooling, manufacturing, test, quality, reliability, and facilities. Engineers working in these specialties usually have degrees in one of the major disciplines. Technical cost estimates are frequently prepared by engineers.

d. Cost estimating is not an exact science. Quality cost estimates are possible, however, if pertinent historical information is available and expert judgment and experience are applied. Information used in preparing cost estimates includes:

- actuals for the same item or activity,
- actuals for a similar item or activity,
- labor standards with adjusted historical efficiency factors,
- standard cost with forecast adjustment factors, and
- tentative, judgmental, rough estimated hours, or hours based on a similar item/activity.

One of the initial steps in evaluating a contractor's estimating procedure is to ensure that accurate and reliable information was used to make estimates. Examples of information that may produce unreliable estimates are:

- Factoring support labor based on judgment rather than using earlier production contract history.
- Using Lot 1 experience in lieu of improvement curve projections from Lot 1 experience for estimates of subsequent production lots.
- Using a cost estimating method based on experience at one facility although the item proposed will be manufactured at a different facility.
- Employing an estimating method based on a supposed "industry-wide-accepted-and-used" method rather than in-house experience.

B-407.2 Labor Estimating Methods <u></u>**

a. Available labor estimating methods have application across a wide range of business functions and product designs. Seven general estimating approaches are normally used. Selection of the most appropriate estimating technique and use of high-quality estimating data are necessary to produce reasonable and accurate labor estimates. These seven methods, listed in relative increasing degree of accuracy, are:

(1) judgment and conference,

(2) comparison,

(3) unit method,

(4) factor method,

(5) probability approaches,

(6) cost-and-time estimating relationships, and

(7) standard time method.

b. Judgment and Conference. Good judgment is essential when using any of the seven labor estimating methods. In the absence of historical data, estimators may have to rely solely on judgment. When the judgment method is used, labor cost estimators are selected for their experience, common sense, and knowledge. An estimator must be objective in attempting to measure all future factors that affect actual cost.

Various techniques are used to enhance judgment. Sometimes judgmental estimating is done collectively. The conference method is a group consensus-method of establishing a collective estimate. This method usually involves representatives from various organizations conferring with the estimators to jointly estimate cost. Major drawbacks to the conference technique are the lack of analysis and a verifiable trail of facts from the estimate back to the governing assumptions. In spite of these drawbacks, the conference technique is widely used.

The major problem with both the judgmental and conference techniques is the influence of personal bias. Forecasts can be influenced by a person's assigned role, position, and special interests. Depending upon the degree and direction of personal bias, estimates may be high or low.

Judgment must be applied in deciding which estimating relationships will be used. Secondly, judgment is important in determining the impact of technology and the type of adjustments that must be made. Judgment is also required to decide whether the results obtained from estimating relationships are reasonable in comparison to the past cost of similar items.

c. Comparison Method. This method compares items being estimated to items of similar configuration (and known cost) to produce labor estimates. The comparison method is similar to the judgment method, except that it attaches a formal logic. The comparison method is represented by the following algebraic equation:

Estimated Cost (New Design) = Historical

Cost (Similar Design) + Adjustments

An estimator confronted with the task of projecting labor costs for a new product design should investigate similar product designs for which historical cost data exists.

To be of use, similar designs must closely approximate the technical characteristics of the new design. Allowances are made for product dissimilarities in complexity, scale, materials, function, and other parameters. A comparison estimator makes judgmental additions and subtractions to costs of a similar design to obtain new cost estimates. To produce accurate cost estimates, the estimator must understand the factors and relationships that have an impact on product costs. For example, when using the comparison method to estimate the cost of a new electronic assembly board design, it is important to understand that number and type of electronic components are the critical factors, not overall board size.

d. Unit Method. This method of labor estimating relies on an accumulation of past experience which is divided by a cost driver to produce a cost per unit. Other terms used to describe this method include order-of-magnitude, lump sum, module estimating, and flat rates. One typical example of unit estimating is “labor cost of fabricated components per pound of casting”. Another example is "support labor hour per manufacturing labor hour”.

e. Factor Method. A logical extension of the unit method of estimating is to improve accuracy by using more than one factor. Use of separate factors for different cost items should improve results. For example, building construction can be estimated by using a unit factor such as dollars per square feet. However, an improved method might be to use separate unit factors for heating, lighting, electrical, and other elements. The individual costs are summed to obtain total labor costs.

Comparison, unit, and factor methods typically use only selected historical data. The auditor should make sure that historical data is representative and complete. The contractor should be able to provide rationale for including or excluding historical data.

f. Probability Approaches. This estimating method makes provision for uncertainty in the estimating process. Other approaches typically produce discrete estimates. For example, a contractor may estimate that 365 staff-days are required to complete a test-stand. Using a probability technique, the same estimate would be expressed as follows:

> *The contractor is 75 percent certain that it requires 365 staff-days to complete the test-stand.*

Probability approaches attempt to compensate for random occurrences and dependency between events. A good example of dependency is wall construction. A normal sequence of events in wall construction is studding, plumbing, electrical, sheet rock, and painting. Each stage is dependent upon a prior stage being completed. Probability approaches make recognition of the fact that specific labor costs can be affected by other activities which must first occur.

Computer simulation, Monte Carlo techniques, and PERT are examples of probability approaches. Input estimates for these approaches are derived from the other estimating methods. Auditors must carefully review the base for the input estimates. Final estimates result from the probability approach's treatment of the input estimates. The mathematical and statistical characteristics of probability approaches can be complex and, consequently, subject to high risk of error.

g. Cost-and-Time Estimating Relationships. Statistical estimating methods can produce mathematically fitted functions called cost estimating relationships (CERs) and time estimating relationships (TERs). CERs and TERs are developed by mathematically relating cost or time estimates to a cost driving feature of the product or manufacturing environment. Examples of cost drivers include number of transformer wire leads, quantity of components mounted on a printed circuit board assembly, number of wires making up a cable assembly, end item weight, or cumulative production quantity of any product.

The estimating relationship is an equation with two kinds of variables. The equation provides the ability to predict a dependent variable on the basis of knowledge of one or more independent variables. The relationship between the variables must be a logical one. Whether the relationship is cost-to-cost or cost-to-noncost, the contractor should be expected to demonstrate that it is logical. A variable whose value is to be predicted is called the dependent variable. The cost or time driver is the independent variable. The estimator using experience and judgment identifies potential cost drivers and mathematical relationships. If they exist, mathematical relationships between the two kinds of variables can take on many forms including linear and exponential.

To develop CERs and TERs, historical data on both dependent (labor) and independent (cost drivers) variables must exist. Regression analysis is then performed to determine if a mathematical relationship exists between the variables. Mathematical relationships are evaluated by including and excluding various cost drivers until "best fit" relationships are identified. DCAA has issued extensive instructions in the use of regression analysis. Refer to the Graphic & Regression Analysis Guidebook for more information.

Common CERs and TERs are described by improvement curves, linear relationships, and power law and sizing models.

(1) Improvement Curve. Improvement curve theory is based on the principle that the time required (labor) to produce successive quantities of a product decreases with (a) additional experience and (b) introduction of improved methods and tools. The theory supporting improvement curve modeling is well established. Workers accrue manipulative skills and familiarity with the details of the job. Improved plant layout and tooling impact productivity. Process planning refines the work into orderly and producible stages. Raw materials, parts, and subassemblies are purchased in more suitable designs, sizes, and shapes. Shop organization and control practices are revised to address production problems. The improvement curve theory holds that improvement will be a constant percentage over doubled quantities.

Mathematically, the improvement curve (unit theory) is expressed as:

Appendix B

$$y = ax^b$$

Where:
x = the unit (or lot) mid-point
y = the direct cost (or hours) for unit x or the average direct cost (or hours) for the lot whose mid-point is x.
a = a coefficient depicting the direct cost (or hours) for the first unit
b = the improvement coefficient

An improvement curve normally displays a negative slope which reflects a decrease in required time for successive product quantities. Since the reduction is primarily due to increased knowledge and skill, the curve is also referred to as the learning curve, experience curve, or progress curve. DCAA has issued extensive guidance on the use of improvement curves. Refer to the instructions to EZ-Quant for more information.

(2) Linear Relationships. The relationship between labor and the cost driver (dependent and independent variables) is frequently linear. A linear relationship can be described graphically by a straight line. The representation of a single independent linear equation is:

Labor Cost (or Time) = Coefficient X Cost Driver + Constant

Where:
Coefficient = the ratio of the change in Y associated with a given change in X (referred to as the slope of the line)
Constant = the value of Y when X is zero (the Y intercept)
Cost or Time = the dependent variable (the variable to be predicted)
Cost Driver = the independent variable

As the quantity of the cost-driving variable changes, cost or time also changes proportionally.

Linear CERs and TERs are not just limited to a single independent variable. When developing the equation, the cost estimator may choose an infinite variety of variables until the best correlation is found.

(3) Power Law and Sizing Model (Cost Capacity Relationship). This theory models the relationship between similar products of different sizes, weights, and volumes, and takes into account "economy of scale". The following equation provides the mathematical relationship for comparison on this basis:

$$Cb = Ca(Qb/Qa)^{X}$$

Where:	
Ca =	actual cost for reference size Qa
Cb =	estimated cost for new design size Qb
Qa =	size of reference design a
Qb =	size of new design b
x =	correlating exponent $O < X < 1$

For example, a contractor has determined from historical records that machine-component manufacturing-labor costs increase by half as the machine-component weight doubles. The correlating exponent (x) in the above equation is determined as follows:

Rearrange the equation to:

$$Cb/Ca = (Qb/Qa)^{x}$$

Based on data given, the following is obtained from the equation:

$$Cb/Ca = 1.5 \text{ and}$$

$$Qb/Qa = 2$$

Substituting these values into the rearranged equation in (2) above, the equation is:

$$1.5 = 2^{x}$$

Using logarithms, the exponent (x) is found as follows:

$X = \log 1.5 / \log 2$

$X = 0.585$

The contractor's records indicate that a 1,000-pound component was completed in 1,000 hours. The new component to be estimated weighs 1,250 pounds. Substituting into the equation gives the following results:

$Cb = 1{,}000 \text{ hrs } (1{,}250 \text{ lbs}/1{,}000 \text{ lbs})^{.585}$

$Cb = 1{,}139 \text{ hrs}$

Note that a 25 percent increase in weight results in only a 14 percent increase in manufacturing hours.

h. Standard Time Method. The standard time method is the most precise technique for estimating manufacturing labor. The basis for the manufacturing labor estimate is a “labor standard”. Contractors do not bid standards but bid labor cost based on standards which are adjusted to reflect production inefficiencies. Adjustments take the form of a productivity factor. The following algebraic equation represents this concept:

Estimate of

Actual Labor = Standard / Expected

Productivity Factor

(1) Standard. As discussed above, a standard is a measure used for making judgments or as a basis for comparison. A labor standard is a unit of time required to accomplish a work task. Industrial engineering work measurement techniques (see B-407.3) are used to develop engineered labor standards (ELSs).

Engineered labor standards provide an unbiased assessment of a "fair day's work”. The term "engineered standards" is frequently misapplied. True engineered standards are not based on history, judgment, guesses, comparison, or opinions.

Cost estimators will determine a product's total ELS content by summing all the ELS for assemblies, subassemblies, manufactured components, and other efforts required to build a product. The ELS content summation process is roughly analogous to adding up material costs in an exploded assembly/subassembly BOM. Total ELS content will not remain stable for a product over an extended period of time. ELS apply to specific methods, machinery, tools, and automation available at the time when the standards were established. If contractor management does not estimate any reduction in ELS, it is implied that no attempt will be made to improve operations.

Engineered standard time does not relate to any particular unit of production. An unhindered average skilled worker can achieve an ELS almost from the first try.

Most cases of inefficiency in the factory are attributed to management deficiencies. Work measurement techniques do not recognize the concept of achieving standard at a specific cumulative production point (e.g., 1000th unit). The standard attainment method, discussed in B-407.3b, adjusts an efficiency factor to a production unit. The efficiency factor is applied to a standard to obtain estimated labor cost.

(2) Routings. Routing sheets provide a detailed breakdown of operations required to process raw material and/or produce parts and the time required to perform each of these operations. Each product part number manufactured internally by a contractor will have a routing sheet. If the contractor uses a work measurement system, each step will have a description and standard time. Contractor management can use this information to plan, schedule, and control the shop.

Proposed labor costs based on standards can be verified against information contained on routing sheets. Use of a statistical sample will expedite the verification process. Verification frequently reveals numerous problems, including addition errors, erroneous adjustment factors, and missing labor standards. Without verification, contractors may substitute poorly derived estimates in lieu of estimates based on valid labor standards.

(3) Audit. Duplication and inclusion of unnecessary standards are difficult to detect. Make/buy parts should be carefully scrutinized to verify that double counting has not occurred. Alternate routings which include extra operations may be listed on routing sheets. Their existence provides flexibility to handle unusual circumstances such as machine breakdown, critical machine overload, or product quantity variations which affect machine selection. Inclusion of labor standards for alternate routings can produce duplication and inflation of labor estimates.

B-407.3 Work Measurement Techniques **

Work measurement is a generic term used to refer to the setting of a time standard by a recognized industrial engineering technique, such as time study, standard data, work sampling, or predetermined motion time systems.

a. Standard Time Method Work Measurement Techniques. Work measurement techniques determine the time required to do a task. To account for differences in factory conditions and employees, a universal labor standard was defined as follows: the time for an average skilled worker to complete a task under average conditions, working at an average pace, and using a prescribed method. Average is not defined in a mathematical sense but has the meaning of typical or expected. There is a misconception that a standard reflects what a "perfect" worker can achieve under "ideal" conditions. By definition, ELSs relate to an "average" worker and "average" conditions.

Techniques for establishing labor standards are stopwatch time study, predetermined motion-time data, work sampling, and standard data.

(1) Stopwatch Time Study. The use of a stopwatch time study to establish ELSs requires:

(a) observing the task and subdividing it into motion elements,

(b) timing and statistically establishing an arithmetic average for the elements,

(c) normalizing, rating, or leveling the elemental times, and

(d) applying an allowance for PF&D (personal, fatigue, and minor delays).

Normalizing, rating, or leveling are used to adjust the observed time to a comparative standard. Operators will perform a task at a pace above normal if they have superior skills or are intentionally rushing. Conversely, operators will perform at a pace below normal if they are not totally familiar with the job or are purposely slow. To compensate for the difference in pace, the Industrial Engineer must rate the performance of his subject by established criteria.

(2) Predetermined Motion-Time Study. There are a number of predetermined motion-time systems available including Methods Time Measurement (MTM), Work Factor Systems (WOFAC), and Basic Motion-Time (BMT) Study which break manual tasks into basic motions. Predetermined time systems were established to avoid the difficulties of timing and normalizing. Observing the task and subdividing into elements are required to classify all motions into elemental components. Unit times have been tabulated for elemental components according to factors such as distance, degree of muscle control required, precision, and strength. The ELSs are completed by application of a PF&D factor to the elemental component unit time.

(3) Work Sampling. Work sampling is used to establish standards for:

(a) large work crews or

(b) long-duration job cycles with irregular patterns.

Continuous observation of the worker is not required with work sampling. A statistically significant quantity of worker observations is made so that proportions of time devoted to various activities can be determined at given confidence levels. This technique produces the least accurate ELSs.

(4) Standard Data Systems (also referred to as Standard Time Data System or STD). These systems provide labor standards prior to the actual performance of work. (Other methods of establishing standards require direct observation.) Because of this characteristic, standard data systems are important in the cost-estimating process.

There are two kinds of STDs:

(1) synthetic, and

(2) analytical.

Synthetic STDs use a catalog of individual operation ELSs which are added to create a total labor standard for a manufactured part. An analytical STD uses a mathematical formula to establish the total labor standard for a manufactured part. Both require using ELSs previously developed via time study, predetermined motion time systems, and work sampling.

Synthetic STD combine separate ELS. Many tasks are repeated frequently, and are identical regardless of the product being manufactured. The time standards for these tasks, once established by a work measurement specialist, can be cataloged and referred to each time they are required. Examples are loading/unloading of a machine, driving a rivet, or removing a part from a fixture.

Establishing a synthetic data system ELS requires an industrial engineer to determine all the required manufacturing steps. In addition to establishing labor standards, this procedure is necessary to determine process routing. The engineer refers to the STD catalog for the appropriate manufacturing step's standard time. The ELS for a manufactured part is a summary of all the standards for the separate manufacturing steps.

Analytical standard data systems are similar to CERs (B-407.2g). The difference is that labor standards are substituted for historical actual hours during the development process. Sets of previously established labor standards for a product and related possible cost driving characteristics (parameters) are gathered. Regression analysis is then performed to determine the mathematical relationship between the developed labor standard and the cost drivers. Numerous relationships (determined by including and excluding various cost drivers) may be tested until a best fit is established.

STDs are derived from ELSs previously developed by direct observation of manufacturing operations. A significant problem is that contractors frequently lose or misplace this data. STD systems require periodic maintenance and auditing to ensure accuracy. Retention of original data is extremely important to both the maintenance and audit functions.

Unmaintained, STD system accuracy will deteriorate because of changes in the work environment. An effective STD requires that adjustments be made for changes in machinery, tooling automation, and procedures. Since ELSs are specific to machines and tools, it is extremely important that all changes be reflected in the standards. Periodic audits are required to ensure that system accuracy and reliability are maintained.

STDs not based on engineered standards are suspect. Guesstimates, standards derived from technical literature, will likely produce unreliable results.

b. Standard Time Method Productivity Factor. The expected productivity factor is part of the Estimated Labor Time equation for the Standard Time Method. Standards assume a degree of efficiency for work accomplished by an average worker under average conditions. Products may be manufactured under conditions that make standards unachievable. Productivity factors adjust product standard times for varying work conditions and other influences.

Productivity factors are derived from contractor historical timekeeping data. Productivity factors are estimated by adjusting historical efficiency for various influences and special circumstances. Adjustment factors are developed using the unit method, and improvement curves. Expected productivity is described by the following equation:

Expected

Productivity Factor = Historical

Efficiency X

Adjustment

(1) Historical efficiency is normally developed for a specific period. The efficiency factor is the ratio of standard hours earned to actual hours spent on an increment of work. Earned hours is the time in standard hours credited to a worker (or group of workers) who completes a given task (or group of tasks). When earned hours equal actual hours, efficiency equals 100 percent. Efficiency is described by the following equation:

Efficiency Factor = Earned hours

(Standard/Actual hours)

(elapsed time)

Efficiency factors can be developed for any level in a contractor's organization. Auditors should verify that an appropriate efficiency is used for the organizational level most closely identified with the actual work. For example, using a plant-wide efficiency for estimating labor for an individual department or vice versa will distort the labor estimate.

(2) Adjustments to historical efficiency are required to project expected from historical costs. Normally, contractors lower productivity factors based on the belief that the estimated product is unique and differs from the products which generated the historical basis for its estimate. These adjustments require special audit attention.

The impact of different production quantities on productivity is generally estimated by:

(a) the standard attainment, and

(b) first unit estimating methods.

To develop an estimate using these methods, historical realization factors and their related cumulative production quantities are collected. An improvement curve is developed by means of regression analysis. The x-intercept is the standard attainment point (or the cumulative production quantity) when realization equals 1.0. The first unit estimate of realization is the y-intercept (or the point where the cumulative production quantity equals 1.0). Both approaches treat the curve slope similarly, but they differ in how they express efficiency in relation to the cumulative production unit.

(3) Standard Attainment Method. This method assumes that a cumulative production quantity exists where the standard will be achieved. Achieving standard means achieving an efficiency factor of 1.0. Contractors will speak of 100th, 250th, or 1,000th unit standard, which means they expect to eventually achieve efficient production after producing that quantity of a product. The productivity factor is developed from an estimate of the expected realization. The realization factor is developed by projecting backwards from the point where realization equals 1.0 (at the standard attainment point) to the lot mid-point of the product being estimated.

Auditors are cautioned to evaluate how the standard attainment technique is applied. Contractors may fail to substantiate method parameters such as slope and realizations with historical data. Frequently, contractors assert that there is a traditional standard attainment point, e.g. 1,000 units. There is usually no validity to this assertion since each company has a unique rate of improvement.

Another caveat has to do with the slope of the curve. In typical improvement curve applications, steep rates of improvement (100 percent being flat, 80 percent steep, and 60 percent very steep) are projected forward from actuals which reduces estimated cost. In the standard attainment estimating technique, because the estimator projects backward up the curve, steeper curves produce significantly greater estimated costs. Contractors may state they are being aggressive by projecting steeper curves than are historically supported. Such a statement is usually false.

(4) First Unit Estimating Method. This method is essentially the opposite of the standard attainment approach. As previously discussed, historical information is used to derive the typical realization factor for the initial production unit. The realization factor is developed by projecting forward from the first unit realization factor at the expected improvement curve slope to the product lot mid-point. Labor cost is estimated by multiplying the standard labor content by the lot mid-point realization factor.

B-408 Material Cost Estimating Methods **

B-408.1 Overview **

Two major components of contractor proposals are labor and material estimates. Material is the cost element that is usually the easiest to estimate and check. It can normally be seen and touched in the end product. The material component may vary anywhere from 30 to 70 percent of the total cost depending on the type of contract (e.g., production, development, or research).

a. Material costs are normally divided into three major categories: direct, indirect, and burden.

(1) Direct material consists primarily of raw material, purchased parts, subcontracted items, and interdivisional transfers. The term "direct" is applied to this material since it can be readily identified in the end product.

(2) Indirect materials are those items necessary to produce the product but do not become a physical part of the end item. Materials such as lubricants, welding rods, and shop supplies are good examples. Because their direct usage levels are difficult to determine, indirect materials are usually allocated through indirect expense pools.

(3) Material burden is a term used to describe the indirect activity associated with converting purchased material into an end product. Costs related to material procurement and handling are collected in material burden centers. At smaller contractors, material burden may be included in general overhead expense pools rather than in a separate material overhead account. At larger contractors, material burden centers may be organized along functional lines that will separate rates for procurement, handling, etc.

b. The major categories of direct material are:

(1) Raw Material. Bulk or unfinished materials that require processing or are involved in manufacturing processes. Examples include sheet stock, castings, forgings, bar stock, wire, printed circuit board materials, epoxies, resins, paints, and solvents.

(2) Purchased Parts. A component, or subassembly, purchased as an off-the-shelf item which becomes an integral part of the product.

(3) Subcontracted Material. Material manufactured to specifications, drawings, or standards outlined in a subcontract. Subcontracted material may be low or high cost. Subcontracted low-cost material typically results from a contractor's inability to produce the part due to capacity constraints, quality problems, special processes, unique assembly techniques, or other manufacturing limitations.

High-dollar subcontracted material items, by Government contract law, require special treatment. When purchases of specific items exceed certain dollar thresholds, contractors are required to perform price analyses or audits. In some circumstances, they may arrange for an assist audit by DCAA at a subcontractor location.

(4) Interdivisional or Interplant Transfers. Materials that are purchased from another business unit of the contractor.

(5) Vendor Charges/Tooling. Costs incurred by a supplier to set up or prepare for production. These charges usually consist of production line set up and the

fabrication of unique tools needed in manufacturing processes. Examples include drill fixtures, cable jigs, cable potting molds, and printed circuit artwork.

(6) Packing Material. Material required to package the product for safe delivery. Special packaging requirements are normally dictated by contractual provision and classified as direct material.

(7) Minor Material. Low-value items such as nuts, bolts, fasteners, and wire that are not cost effective to estimate in discrete quantities. Also known as line stock items, they are usually proposed as a percentage of direct material, or as a rate per manufacturing hour. They may, however, appear in detailed bills of material as individual line items.

(8) Freight. Estimated contractor delivery costs that are proposed either as a direct item or as a percentage of direct material.

(9) Other Direct Costs. These items are not readily identifiable as part of the product and are not subject to labor or material indirect expense loadings. Examples include computer timesharing, technical publications, photographs, and blueprints.

c. Recurring and Nonrecurring Costs. Major material cost categories may also be described as recurring and nonrecurring costs:

(1) Recurring Costs. Those costs which are variable and are dependent upon the quantity produced. Examples of recurring costs are direct materials used in production, contractor set-up charges, and charges associated with tooling that must be accomplished with each production run. While not repeated on each unit manufactured, set-up charges are repetitive for each release and, as such, must be amortized into unit cost. Most vendors will amortize set-up charges before quoting unit prices; others itemize them separately.

(2) Nonrecurring Costs. Those costs which represent the fixed effort expended to produce an item regardless of quantity. Nonrecurring costs consist primarily of vendor tooling and engineering/testing charges.

(a) Vendor Tooling. Vendor or subcontractor costs to make tools needed to produce materials or fabricate parts. Vendor tooling can be categorized as either proprietary or accountable tooling. Proprietary tooling is the property of the vendor. Examples are forging dies, extrusion dies, patterns, and molds. Accountable tooling will eventually become the property of the purchaser or Government. Tooling possession is obtained after the vendor no longer requires its use. Tooling costs are normally applicable to subcontracted parts, but may be encountered with purchased parts.

(b) Engineering/Testing Costs. These costs are associated with vendor design effort, development activities, qualification testing, or first article qualification. Testing charges frequently include the cost of components used in tests that either destroy or impair article function.

Except for the eventual replacement of tooling because of wear, nonrecurring costs are onetime in nature and may suffice for several follow-on pricing actions. To avoid duplication, these costs should be shown separately and not included in the unit cost.

B-408.2 Estimating Methods **

The methods employed to estimate material quantities and costs are largely dependent upon material type and information available at the time of proposal preparation. Material requirement data may range from detailed part lists to rough estimates based upon the available history on like items. Regardless of the method employed, estimates will be difficult to make and will be subject to significant error when a major portion of the materials represents unique items that have not been previously produced.

Direct material constitutes the major portion of material cost and requires expert technical knowledge to estimate. IT data bases are used in developing models which may be used in parametric cost estimating systems and for development of comparative - similar to - bills of material when discrete bills of material are not available. Indirect material and material burden are largely accounting issues.

The general procedures associated with estimating direct materials are as follows:

(1) Estimate quantity requirements.

(2) Determine raw material requirements; convert measurements as necessary; and estimate actual yields.

(3) Estimate current prices.

(4) Adjust estimated prices for cost trends and quantities and project total cost.

(5) Document procedures and methods utilized in the estimating process.

B-408.3 Bills of Materials (BOM) **

Perhaps the most frequently used method of direct material estimating is the priced BOM. Most auditors are familiar with this mechanism and often use the BOM as a basis for sampling material costs. The auditor should evaluate both the unit prices reflected in a priced BOM and the material requirements aspect. At some contractor locations, there may be more than one type of BOM. The original bill of material, known as an engineering BOM, will list all of the parts required to produce the end products. In some cases, engineering may be unable to estimate certain actual-quantity requirements such as the length of a wire. To address detailed material requirements, manufacturing may develop a manufacturing BOM which is used as a manufacturing aid.

The BOM is a comprehensive list of all parts required to produce an end item. At large contractors, BOMs are loaded into computer data bases which provide the capability to request information in many formats. Additional information such as description, when used, as well as item number and dollar value may also be contained in the data base. A BOM can be requested for an end product or any subassembly. The two most common BOM sorts are as follows:

a. Part Number Ascending Order. This BOM is "exploded" and sorted by ascending part number showing total quantity required for each part of an end item. A detailed report may give further information including where the part is used. Figure B-4-1 illustrates a part number ascending order BOM.

b. Assembly/Subassembly. This BOM is hierarchical and lists major assemblies followed by all levels of subassemblies. Figure B-4-2 illustrates the assembly/subassembly BOM. Figure B-4-3 is another representation of the assembly/subassembly BOM. This representation is often referred to as an "indented" BOM.

Each format has advantages and disadvantages. Hierarchical BOMs permit tracing material assemblies to drawings, and accounting for the use of each part. Hierarchical BOMs do not communicate total part requirements; therefore, sampling is difficult because other formats may not be available. Part number ascending order BOMs disclose total requirements and pricing, but do not describe product organization and composition; therefore, auditors will normally have difficulty in determining actual part requirements.

Regardless of the format employed, the BOM is an essential tool in validating material requirements and serves as an intermediate vehicle in tracing requirements to original drawings. The drawings disclose part listings and show how the parts are integrated to form completed stages or finished products. Frequently, an estimating department will price a BOM to be used as supporting data. With the exception of tooling and other minor additives, a priced BOM should be comprehensive. Costs not shown in the bill of material can be verified through vendor tooling quotes or historical analyses.

B-408.4 Routing Sheets **

A routing sheet is usually a process description showing discrete manufacturing operations and associated times. Some routing sheets will also disclose material quantity, tools, fixtures, and labor standards. They may be referred to as operations sheets.

Routing sheets are a main source of labor information and are also discussed in the labor section (B-407.2h). Routings may be used as a substitute for BOMs for cost-estimating purposes. Care should be exercised when routing sheets are used in conjunction with BOMs to ensure that costs are not duplicated.

Figure B-4-4 presents an example of the routing for the part number 8876902. In this example, there is only one line item, RS3000197, which is listed under product structure.

B-408.5 Engineering Drawings **

Material requirements are normally determined from engineering drawings. To properly evaluate proposed material quantities, it is important that the auditor understand engineering drawings.

An engineering drawing graphically shows the configuration of a part or assembly. It can be a sketch drawn by a draftsman or generated by a Computer-Aided Design (CAD) system. The trend at most contractors is toward CAD. With CAD, operators can develop complete drawings using a light pen. A good feature of CAD is that drawings can be recalled from computer memory and changed with minimal effort. Regardless of method, drawings are essential in all phases of design and manufacturing.

Typically, engineering drawings are classified as either level 1, 2, or 3. These levels represent a natural progression from conceptual design to production. Level 1 drawings address conceptual and development designs; level 2 drawings are concerned with production prototypes and limited production quantities; and level 3 drawings are production oriented. A drawing level or various combinations of levels may be established by a contractor, or specified in a contract.

The drawing level and quantities required to satisfactorily depict product function and material requirements are determined by design complexity, product sophistication, and engineering judgment. Drawings illustrate and provide essential information needed to design and manufacture a product including:

(1) physical characteristics,

(2) dimensional and tolerance data,

(3) critical assembly sequences,

(4) performance ratings,

(5) material identification details,

(6) inspection tests,

(7) evaluation criteria,

(8) calibration information, and

(9) quality control data.

All product components should be supported by engineering drawings. All drawings should be tied to the end item drawing with major subassemblies and components identified. Drawings should be available to the lowest level unit part.

Normally, engineering drawings use the hierarchy or level concept. Each assembly or subassembly will have drawings identifying all components and additional levels of subassemblies that constitute the upper-tier product. For complex projects, as many as 10 levels of drawings may be used, beginning at the component or manufactured part level and culminating in an assembly or subassembly. Manufactured components may have material reference drawings which further define forging, casting, and similar requirements. In short, all parts required to manufacture an end-item will be shown in drawings along with their relationship to the next higher-level drawing.

Each drawing should contain certain basic information which can be used by the auditor to assess material requirements. Figure B-4-5 is an example of an engineering drawing.

B-408.6 Material Allowances **

Material allowances, also known as material adjustment factors, are the difference between the product material requirement and the actual material consumed during manufacturing. The material-allowance factor represents allowances for scrap, attrition, rework, and other factors that influence material cost and cannot be precisely estimated because of incomplete BOMs and future design changes in subcontractor delivery requirements.

Contractors have used various approaches to estimate material allowances. Some of these approaches are acceptable, while others are questionable. Material allowances can be applied to an individual part and be included in the BOM quantity. In other cases, it may be applied as a lump sum to the total material requirement. The basis of these adjustment factors should be closely scrutinized to ensure they are reasonably valid and that there are no duplications. Historical evidence should be available to support the factors. However, the existence of history should not be considered as automatic evidence of validity because the previous losses may have occurred under different circumstances. Factors frequently used in pricing actions should be periodically reviewed under separate assignments. Section 9-407 further addresses material-allowance factors.

a. Scrap is defective material that cannot be used in its present condition. Scrap may result from operator error, unacceptable vendor material, handling damage, or out-of-control processes (such as poor heat treatment). Scrap allowances should normally be based on historical data. Reduction in scrap should be expected as learning occurs.

b. Process loss is the difference between the amount of material required at the beginning of a process and the final amount used for the finished part. In comparison, scrap loss is defective material while process loss is the material lost during the manufacturing process. Process loss may be estimated using an overall factor or separate factors for major sub-elements such as trim loss, chip loss, and excess casting material. BOM quantities for items manufactured from raw material such as sheet metal, bar stock, and composite frequently are adjusted to include process loss factors. Also note that raw-material items like sheet metal and bar stock are generally only available in certain industrial standard sizes and lengths. As a result, estimating factors are frequently applied to the finished material requirement to convert from industry standards to proposed sizes and lengths in order to determine the amount of material to be purchased.

(1) Process Trim Loss. This occurs when a rough cut is made from the standard-size purchased material. Because the dimensions of the rough cut are not perfectly compatible with that of the standard size, the leftover material is commonly known as process trim loss or residual loss. In some instances, it can amount to a large portion of the material required for the end product.

(2) Process Machining Loss. This is the difference between the rough-cut size and final size. The rough cut part may be bored, milled, ground, threaded, or processed in some other way to create a final part.

Process machining and trim losses are often figured together and added to the required raw material quantity. Scrap loss is added as a separate factor.

c. Inventory Adjustments. Physical inventory normally varies from the inventory of record. This is a result of theft, carelessness, or miscounting. Although the variance can be either positive or negative, it is usually negative and known as inventory shrinkage.

d. Inventory Obsolescence. Parts become obsolete in storage because of changes in their physical characteristics. Normally, it is not economically feasible to restore these parts to the required condition. Some parts have a specified shelf life and cannot be used even though they may look visually acceptable. Other parts go through physical deterioration because of excessive heat, humidity, and mishandling. Parts with excessive rust may be more expensive to clean and restore than to replace. Certain cables, electronic components, and chemicals have shelf lives and are governed by military standards. These parts are disposed of because of expected deterioration.

e. Engineering Obsolescence. Material and parts may be become obsolete because of design changes. These design changes are a consequence of parts testing, failure in field use, and unanticipated user requirements. Engineering changes will result in material not being used on the product. This factor estimates the cost of material that can no longer be used.

f. Engineering Design Growth. Designers often fail to fully comprehend the technical requirements of a proposed product. As a complex program matures and develops, material content will often increase. The costs estimated by this factor should diminish as the program matures.

g. Attrition. This is the allowance established to compensate for loss, breakage, floor shortages, and other damage such as solder burns. The allowance is often used to finance the original overbuying or rebuying of material.

h. Other Allowances. Contractors use other allowance factors besides the attrition factor, and each factor needs to be carefully evaluated on its own merit. Material allowance factors may be offset by salvage income resulting from the sale of scrap or obsolete items. Salvage credits can be substantial, particularly for items categorized as obsolete according to DoD standards. The cost of material can be summarized as:

Total

Cost = Material Cost/Item +

(Material Allowances - Salvage)

B-408.7 Estimating Raw Material **

The process of estimating raw material can be complex. To explain the process, a sheet metal part is illustrated in Figure B-4-6.

Figure B-4-1

Ascending Order - Bill of Material **

"Exploded" for D-5930 Pedestal Drive Assembly

Part	Part Description	Where used	Seq.	Quant.	Code	Policy
4093	Pinion	D-3090	2	1	P	2
5065	Bearing	D-5930	4	2	P	3
D-3056	Retaining Ring	D-3090	3	1	P	4
D-3075	2,” Bar Stock	D-3095	1	2	P	4
D-3095	Shaft	D-3090	1	1	A	1
D-3090	Shaft/Pinion Asm	D-5930	6	1	A	1
D-3740	2 X 8 Back Bracket	D-5725	1	1	P	2
D-3741	1 7/8” X 8 ft. Brkt.	D-5725	2	1	P	2

D-3742	1/8" Rubber Seal	D-5725	3	1	P	2
D-5725	Bracket Assembly	D-5930	5	1	A	1
D-5925	Pillow Blk. Base	D-5930	2	1	P	2
D-5926	Pillow Blk. Cap	D-5930	1	1	P	2
D-9002	3/8" Nut	D-5725	4	2	P	4
D-9003	3/8" Washer	D-5725	5	2	P	4
D-9004	3/8 X 4 1/2 bold	D-5725/5930	3/6	6	P	4

Figure B-4-2

Assembly/Subassembly - Bill of Material **

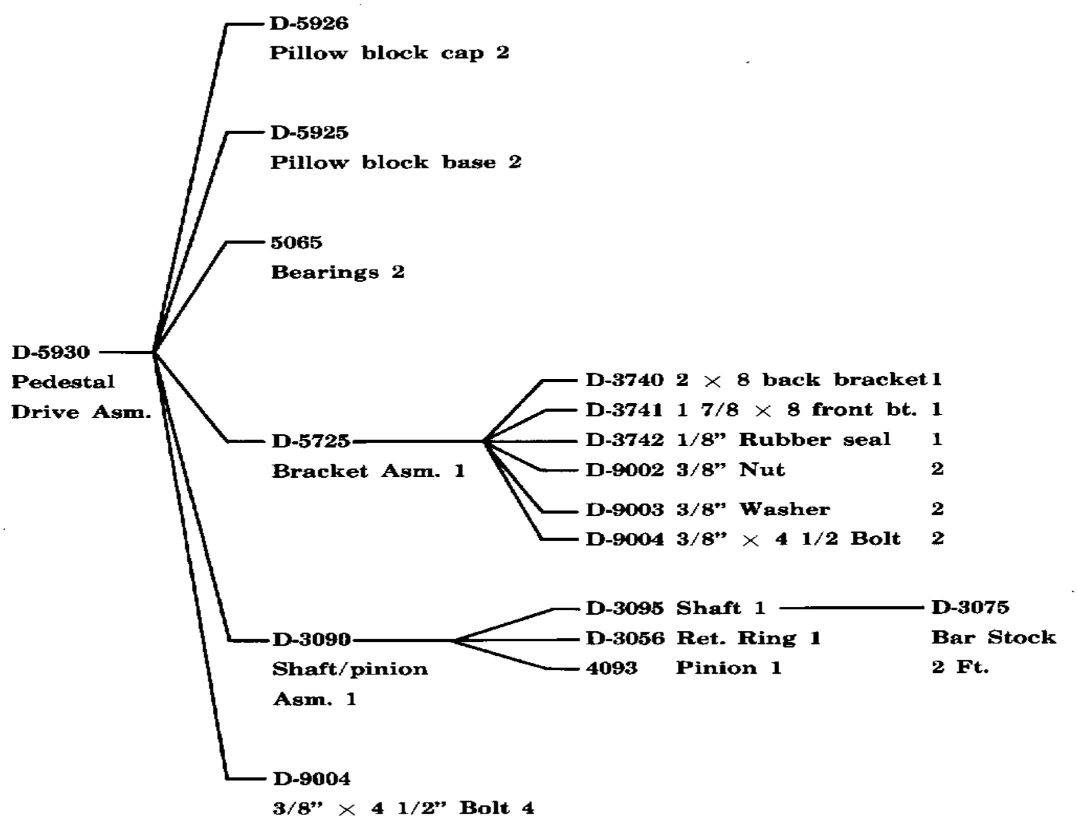


Figure B-4-3

**Assembly/Subassembly -"Indented" Bill of Material **

Level	Part	Description	Where Used	Seq.	Quant.	Comm. Code	Policy
0	D-5930	Pedestal Dr. Asm.			1	A	1
1	5065	Bearings	D-5930	4	2	P	3
1	D-3090	Shaft/Pinion Asm.	D-5930	6	1	A	1
2	4093	Pinion	D-3090	2	1	P	2
2	D-3056	Retaining Ring	D-3090	2	1	P	4
2	D-3095	Shaft	D-3090	1	1	M	2
3	D-3075	2 2/4" Bar Stock	D-3095	1	2 ft	P	4
1	D-5725	Bracket Asm.	D-5930	5	1	A	1
2	D-3740	2 X 8 Bk. Bracket	D-5725	1	1	P	2
2	D-3741	1 7/8 x 8 FT. Brkt.	D-5725	2	1	P	2
2	D-3742	1/8" Rubber Seal	D-5725	3	1	P	2
2	D-9002	3/8" Nut	D-5725	4	2	P	4
2	D-9003	3/8" Washer	D-5725	5	2	P	4
2	D-9004	3/8 X 4 1/2 Bolt	D-5725	6	2	P	4
1	D-5925	Pillow Bl. Base	D-5930	2	2	P	3
1	D-5926	Pillow Bl. Cap	D-5930	1	2	P	2
1	D-9004	3/8 X 4 1/2 Bolt	D-5930	3	4	P	4

Figure B-4-4

**Example of a Routing Sheet **

Appendix B

FIGURE D-4-4 EXAMPLE OF A ROUTING SHEET

PART NUMBER	RT CODE	ROUTING SHEET	PAGE NO 1 OF 1 PRINT DATE 9/25/86
8876 902 •	A1		

CHANGE NO	BY	ISSUE DATE	PART DESCRIPTION	PROGRAM DESCRIPTION	MIN–MAX
8876 902A	KP	09/24/86	ARMOUR PLATE	TARGET STATION	1 – 25

QUANTITY	R.MAT.CODE.	PRODUCT STRUCTURE	PRODUCT DESCRIPTION	DIMENSIONS
19.450	RSSA	R83000197	4340 SHEET STEEL	12 ¼ × 19 ½ × .197

OPER NO	BEQ NO	DEPT NO	WCN NO	PROCESS DESCRIPTION	T/F/G NUMBER	QT	T/F/G DESCRIPTION	FEED	SPEED	T	S.U. STD	T	PROD STD	M/MC RAT.	M
0010A1	010 020 030	471	4012	MARK AND SHEAR PER LAYOUT SHEET. 14 PIECES PER SHEET	8876902 8 01	1	LAYOUT SHEET			E	050	S	050	1.0	1
0020A1	010 020 030	472	4013	DRAW AND CUT TO SHAPE DEBURR EDGES & SHARP CORNERS	8876902 T 01	1	TEMPLATE			E	050	S	250	1.0	
0030A1	010 020	472	4020	USING JIG DRILL 7 HOLES AND DEBURR	8876902 J 01	1	DRILL JIG	2.00	250	S	250	S	200	1.0	1
0035A1	010	455	4001	INSPECT						N		N			
0040A1	010	473	2005	HEAT TREAT PER SPEC.	MIL-H-6875 M235	1	MIL. SPEC. SHEET			E	050	E	500	0.5	2
0045A1	010	455	2020	INSPECT FOR HARDNESS TO ROCKWELL C 54						N		N			
0050A1	010 020	475	3864	TEMPER FOR 2 HOURS BY HEATING TO 325 F + 20						E	050	E	2250	1.0	1
0060A1	010 020 030	475	3870	MANGANESE PHOSPHATE COAT PER MIL SPEC. TYPE M CLASS 2	MIL-P-16232 M280	1	MIL SPEC. SHEET			E	050	E	300	1.0	1
0070	010	475	3910	VAPOR DEGREASE						E	050	S	100	0.5	1
0080	010	475	3930	PRIME						E	050	S	100	1.0	1
0090	010	475	3931	PAINT GREEN PER SPEC.	MIL- M390	1	MIL SPEC. SHEET			E	050	S	230	1.0	1
0100	010	455	3940	INSPECT						N		N			

Explanatory notes to Figure B-4-4

(a) Part Number - Identifies the processes described on the routing sheet to a specific part or assembly. There may be alternate routings for a part number if different types of processing are potentially required. The cost estimator should fashion estimates based on prime routing, or the routing which is most likely to be used.

(b) RT Code - Code used to indicate whether the routing is primary (e.g. A1) or alternate (e.g. B1, C1).

(c) Change Number - This number normally refers to an engineering change notice (ECN) number. It relates directly to a change on a drawing.

(d) By - Initials of the person who made the last change to the routing sheet.

(e) Issue Date - The day the last change was made. This date may be different from the ECN date. Changes in methods, standard, tooling, etc. may be responsible for changes in the issue date.

(f) Part Description - A brief description, usually the name of the part.

(g) Program Description - Indicates the main program or the assembly where this part will be used.

(h) Min-Max - Describes an optimal quantity range for the processes described on the routing sheet. If the shop order quantity outside the indicated range, there may be a more efficient method of producing the part.

(i) Quantity - Represents an amount of material that will be required to fabricate one unit. Quantity may be expressed in pounds, cubic inches or other units of measure. Sometimes, the units will not make sense by themselves. Familiarity with raw material codes and product structures will be required to interpret the quantity.

(j) R. Mat. Code - Contains an abbreviation for the specific type of raw material used. In this example, the code is RSSA. "R" represents raw material, "SS" is for sheet steel, and "A" could mean a special kind of sheet steel, indicate a buyer code, or even a vendor.

(k) Product structure - Indicates the next level part number required to manufacture the part. In this example, there is only one part number, RS3000197, which is a particular type and gauge of raw sheet steel.

(l) Product Description - A name for the part number identified in product structure.

(m) Dimension - Indicates the size of raw material required at the start of the manufacturing process. Normally, this space is used for raw material only. In some cases, it can be used to give more information about the components.

(n) Operation Number - Identifies the work breakdown or operations required to produce the part. The numbers are ascending, and indicate the order in which the work must be performed. In this example, all operations are identified by a six character code. The first four characters specify the sequence, while the last two characters differentiate between primary and alternate operations. In the example, primary operations are identified by the code AI. Secondary operations could be identified by other codes such as B1 and C1. Primary and alternate processes may appear on the same routing sheet.

(o) Sequence Number - Used in updating routing sheets.

(p) Department Number - Identifies the principal department where work is to be performed.

(q) Work Center Number (WCN) - A number identifying the work station where the operation is to be performed. It can refer to a machine, bank of machines, or an assembly bench. Sometimes, department and machine numbers are combined to form a WCN.

(r) Process Description - Describes the process and gives instructions for operators and supervisors.

(s) T/F/G/ Number - This number identifies a tool (T), fixture (F) or gauge (G) required to perform an operation. A tool number could be a physical tool, numerical control tape number, or an instruction sheet.

(t) QT - Quantity of tools required to perform an operation.

(u) T/F/G Description - Description of tools, fixtures, and gauges.

(v) Feed - Indicates how fast the material should be advanced. Normally, feed is expressed in inches per minute, or inches per revolution.

(w) Speed - RPM (revolutions per minute) at which a machine must operate to produce the part.

(x) T, E, S, and N - T indicates type of labor standard used for set up and production; E shows standard was estimated; S indicates standard was studied or engineered; and N stands for nonstandard operation, or no labor standard (i.e., labor may be indirect or a factor).

(y) S.U. Std (Set-up Standard) - Staff-hours required to setup an operation for production. The alpha character in the preceding column indicates whether the standard was estimated or engineered.

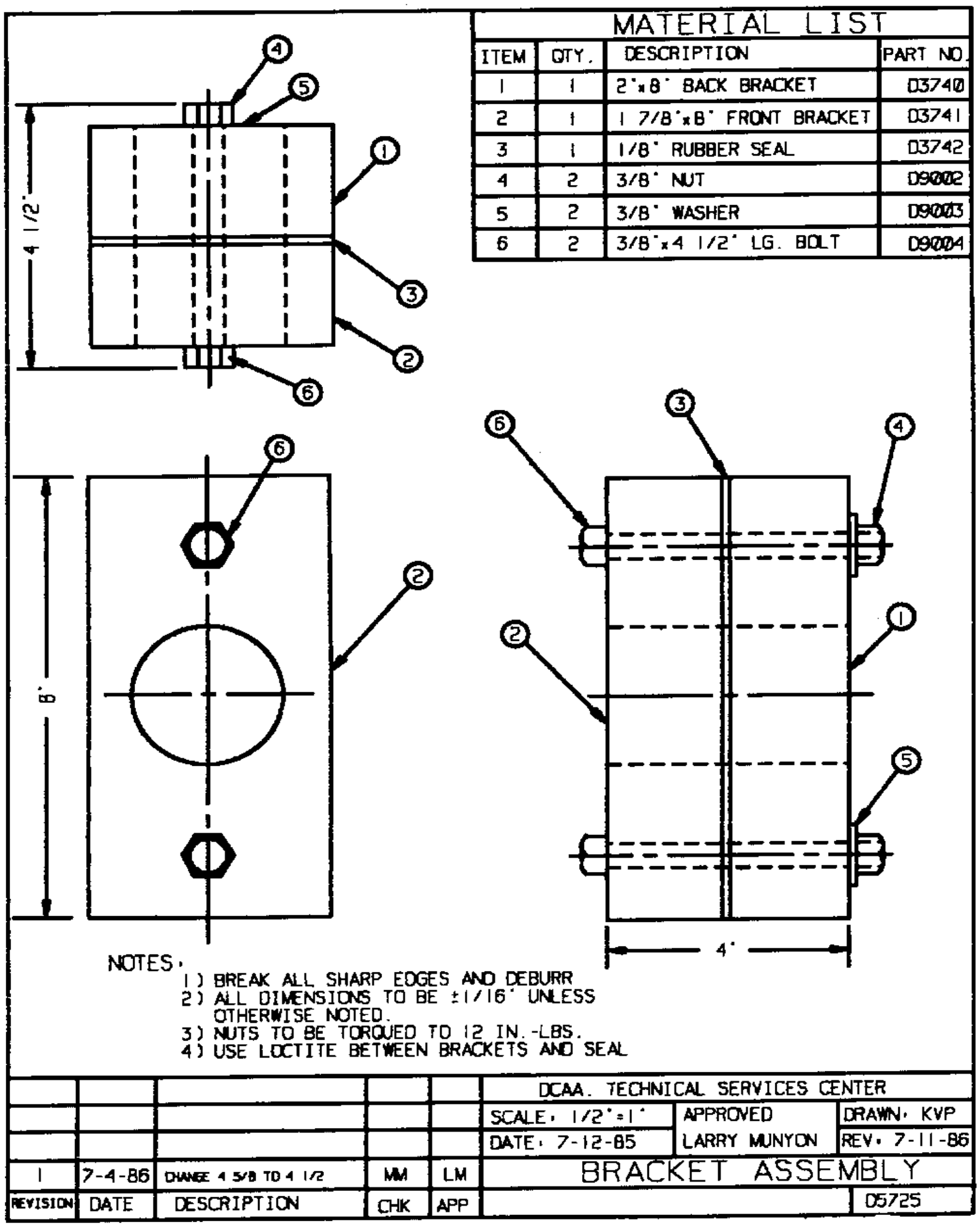
(z) Prod. Std. (Production Standard) - Staff-hours required to perform the operation. The preceding column indicates if the standard is estimated or engineered. Standards are normally in hours per piece. They can also represent time required to produce a lot (e.g. 100 pieces). In this example, the operation is performed on a per piece basis. Hours are rounded to three decimal places. Care should be taken to ensure that estimators do not further round the numbers which may produce overstated estimates.

(aa) M/MC Rat. (Man/Machine Ratio) - Indicates number of people required to perform a task. An operator/machine ratio of .500 means that an operator is required to operate two machines at the same time. A ratio of 2.00 means that the task requires two operators.

(ab) M - Indicates number of machines available, and is used primarily as a scheduling tool.

Figure B-4-5

Example of an Engineering Drawing **



Explanatory notes to Figure B-4-5:

(a) Drawing Number/Part Number - All drawings are numbered by part or assembly number. In some cases, a part drawing may have more than one page. A drawing may depict more than one variation of a basic part.

(b) Sheet Number/Continuation Sheet - Depending upon complexity, any number of sheets may be necessary to show the drawing for a particular item.

(c) Drawing Description - A brief description of the part.

(d) Dimensions - Indicates whether the metric or English system was used to prepare the drawing. A conversion table may be included on the drawing.

(e) Scale - Shows scale used for preparing the drawing. All drawings are drawn to scale to give correct relationships to other components on the drawing.

(f) Tolerances - Design engineers establish ranges for dimensions and other factors so that a manufactured part will function as intended. Tight tolerances result in more costly manufacturing processes.

(g) Size - All drawings are standardized into five sizes for economical storage and reproduction purposes. Sizes range from A to E, with E being the largest. Most contractors store drawings on microfilm attached to punched cards which show part number, description, and drawing size.

(h) Revisions - The revision log lists all changes from initial release and onward. It identifies Engineering Change Notice (ECN) numbers, description, dates, and personnel making the change. There may be ECNs in process which may affect the drawings. Such drawings changes will be incorporated by the drafting department after completion of the approval process. All parts must meet the latest change specifications unless a waiver is obtained from the customer.

(i) Material List - Also known as a bill of material. The parts list identifies all components required to produce the part shown on the drawing by item number. Item numbers cross referenced to a parts list can be shown on the drawing or on a separate sheet. The parts list further provides additional information such as drawing numbers, quantity, part description, required materials, and references to the next higher level of assembly.

Inexperienced users will have to carefully examine drawings to determine material requirements. Occasionally, parts lists may not be included on the drawings or associated documentation. Additionally, some parts may be duplicated on the next drawing level.

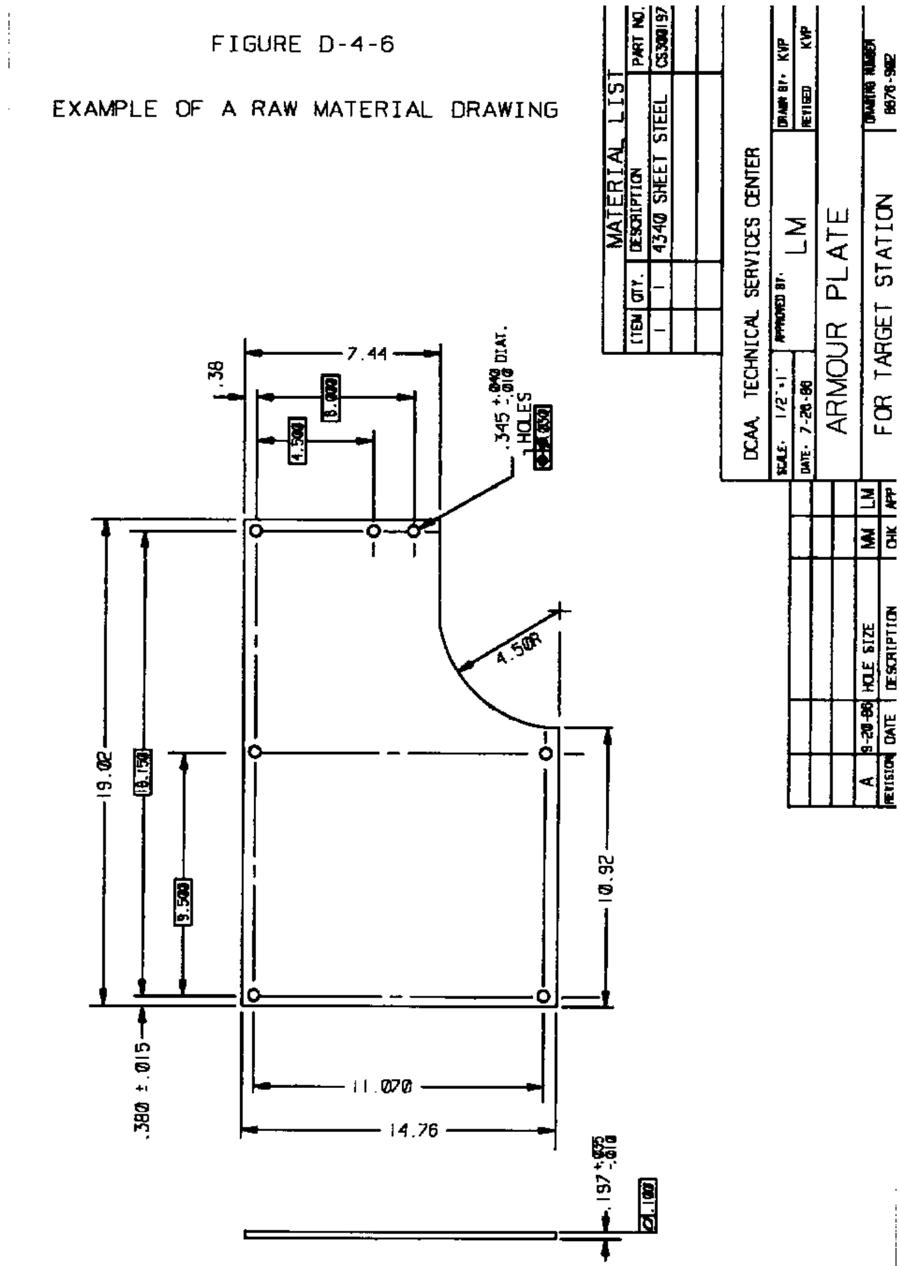
(j) Type of Material - Specifies materials to be used and/or alternatives. This reference is very important in verifying the "quality" of proposed parts. The majority of materials used by contractors will be military standard materials.

(k) Notes - Used by the design engineer to communicate special nonstandard requirements or precautions.

(l) Type of Finish - A symbol and/or number indicating the degree of smoothness (finish) required for different surfaces.

(m) Security Classification - Drawings may have security classifications.

Figure B-4-6
Example of a Raw Material Drawing **



Explanatory notes to Figure B-4-6:

(a) Process machining allowances are added to the designer's finished dimensions on the drawing. In this example, the largest part dimensions are 11.96" X 19.02" X .197" which equals 44.81 cubic inches. The manufacturing engineer knows that he will need to add at least 1/4" to two sides of the part. This allowance is based on the individual estimator's judgment and experience. Therefore, the amount of material specified is 12.25" X 19.5" X .197" = 47.06 cubic inches. The process machining allowance for this case amounts to 5.0 percent.

(b) Process Trim Allowances are calculated using a method similar to the one described below.

Example Assumptions:

Raw material is available only in 4' X 8' (48" X 96") sheets.

The dimensions of each piece are 12.25" X 19.5" (determined by adding 5 perc ent process machining allowance).

The contractor has calculated that 14 pieces can be obtained from each sheet.

Calculations:

Amount of material per piece = 64.84 cubic inches ((48" X 96" X .197") / 14)

Trim Allowance = 17.78 cubic inches (64.84 - 47.06)

Trim Allowance as a percentage = 37.8 percent (17.78 / 47.06)

Potential Savings:

If 17 pieces per sheet could be obtained with minimal add-on labor cost, the amount of material per piece could be reduced to 53.4 cubic inches.

This equates to a savings of 17.6 percent per piece when compared to the proposed amount ((64.84 - 53.4) / 64.84).

(c) Unit of Measure Conversion. Sometimes, raw material is expressed in different units of measure. For example, steel is normally purchased and sold by weight (pounds). In the manufacturing environment, it is measured in cubic inches. Conversion is fairly simple and can be accomplished by applying factors. To convert 64.84 cubic inches of steel to pounds, multiply by the factor .281 to obtain the amount (18.22 pounds). Some estimates may use rounded factors which may produce overstated amounts. For example, if .281 were rounded to .3, an overstatement of 6.8 percent would result.