May-June 1988

Journal of the Defense Systems Management College

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SPECIAL ISSUE

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Journal of the Defense

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To Our Readers....

Program Manager has a "new look." This May-June 1988 issue is larger and more technically oriented—something we plan for each calendar year. The remaining bimonthly issues of this journal of the Defense Systems Management College will not exceed our 52-page limit. We are interested in your comments and welcome letters to the editors, pro and con.

This *Program Manager* comprises, among other things, management theories with opinions from experts; a look at past acquisition improvements; agenda items for improving the acquisition process; acquisition streamlining; facilitating contractor productivity while increasing management control by the government; baselining for all times; and something of which we are proud, the expanded role of the Defense Systems Management College in training Program Managers for U.S. defense systems.

With this issue, we are happy to welcome Major General Lynn H. Stevens, USA, as the tenth Commandant of the Defense Systems Management College. He succeeds Brigadier General Charles P. Cabell, Jr., USAF, whose ongoing support will always be deeply appreciated.

The Staff
PROGRAM MANAGER

DOD'S MOVE TO A MORE PROFESSIONAL ACQUISITION WORK FORCE

Brigadier General Edward Hirsch, USA (ret.)

Critics claim the Department of Defense (DOD) is incapable of self-generated innovation and that interservice cooperation is sacrificed in favor of preserving Service prerogatives. The DOD quietly and effectively proved these criticisms to be less than accurate. As a result of actions predating legislative initiatives and blue ribbon panel reports to enhance professionalism of the acquisition work force, the Services jointly developed a management approach to attain the desired level of professionalism.

On 4 February 1988, the Honorable Robert B. Costello, Under Secretary of Defense (Acquisition), directed that:

> ...the mission of DSMC is expanded to include the entirety of acquisition management as now reflected in DoDD 5000.1.

Scope and magnitude of the new mission (Guidelines p. 7) represent the greatest challenge to DSMC since its inception in 1971 by then Deputy Secretary of Defense David Packard. Until now, DSMC, as the Defense Department's premier joint acquisition management college, has generally focused efforts on education, research and publications relating to program management and systems acquisition.

The DSMC must now broaden its horizons to maintain excellence in education and training in *all* essential elements of defense acquisition management. The DOD acquisition system includes all equipment, facilities, and services planned, designed, developed, acquired, maintained and disposed of within the Department. The system extends to establishing policies and practices governing acquisitions, determining and prioritizing resource requirements, directing and controlling the process, contracting, and reporting to the Congress. More explicity, the Congress has asserted that acquisition includes all contracting, logistics, program management, systems engineering, production and manufacturing personnel.

When Dr. Costello signed the letter dramatically changing the DSMC Charter, it culminated a focused and intensive 2-year joint effort by the Services and defense agencies to provide more cohesive and effective management for their ongoing efforts to enhance the professionalism of our acquisition work force. the Honorable William H. Taft IV, Deputy Secretary of Defense, personally provided impetus in August 1985 by tasking the Services to conduct a comprehensive review of actions needed to promote improvements in the management structure supporting our acquisition work force.

ACE Job Functions	OPM Official Titles/Series
1. Program Manager	1. a. Engineer/800 b. Program Manager/340
2. Deputy Program Manager	2. a. Engineer/800 b. Program Manager/340
3. Business/Financial Manager	3. a. Program Analyst/345 b. Budget Analyst/560
4. Contracting Officer	4. Contract Specialist/1102
5. Contract Negotiator	5. Contract Negotiator/1102
6. Contract Specialist	6. Contract Specialist/1102
7. Contract Administrator	7. a. Contract Administrator/1102 b. Contract Termination Specialist/1102
8. Procurement Analyst	8. Procurement Analyst
9. Price Analyst	9. Contract Price/Cost Analyst/1102
10. Quality Assurance Specialist	10. Quality Assurance Specialist/1910
11. Procurement Clerk	11. Procurement Clerk/1106
12. Procurement Assistant	12. Procurement Assistant/1106
13. Purchasing Series	13. Purchasing Agent/1105
14. Industrial Specialist	14. Industrial Specialist/1105
15. Property Administrator	15. a. Industrial Property Management Specialist/1103 b. Industrial Property Clearance Specialist/1103

The DSMC Center for Acquisition Management Policy was selected to direct this joint effort under the able sponsorship of Mrs. Eleanor Spector, Deputy Assistant Secretary of Defense for Procurement. The first phase of the tasking, a 3-month effort, was completed when the inter-Service/Agency group published a report in December 1985. That Acquisition Enhancement (ACE) Program Report:

—Developed broader experience prerequisites and increased education and training requirements for civilian and military personnel in 15 job functions (Figure 1).

—Drafted new DOD directives to promulgate increased requirements.

—Recommended establishment of a DOD University of Acquisition Management (DUAM) to provide the management infrastructure required to cooperate activities of the individual centers of learning within DOD.

—Recommended an in-depth follow-on study of the DOD acquisition training base.

Significantly, the increased experience prerequisites and more stringent education and training requirements were recommended by the Services, refined by the Study Group, and approved by Service Secretaries. All were aware they could be perceived to be "shooting themselves in the foot" by increasing requirements, knowing they were not meeting existing ones (more about that later). However, the need for enhanced professionalism and efficiency—not defensive, public relations risk avoidance—prevailed.

> *In short, the requirement for this enhancement was perceived by the Services, put in place at their request and supported by the Office of the Secretary of Defense (OSD), truly a team effort.*

The OSD immediately initiated staffing action necessary to promulgate the DOD directives and, in December 1986, published them. The DoDD 5000.23, "Systems Acquisition Management Careers," established increased experience, education and training requirements for Program Managers, Deputy Program Managers and certain General Officers. For example, *all* Program Managers assigned after 1 October 1987 *must* have successfully completed the Program Management Course at DSMC or a comparable course approved by the Under Secretary of Defense for Acquisition. This same requirement applies to General Officers assigned to procurement commands or as Program Managers.

The DoDD 5000.48, "Experience, Education and Training Requirements for Personnel Assigned to Acquisition," not only increases experience, education and training requirements for designated civilian personnel, but applies equally to military members performing certain acquisition job functions.

These important actions were, of course, designed to prepare our acquisition participants to perform more effectively. However, increased demands for training impose un-

precedented burdens upon offerors of this OSD-mandated training.

The OSD was determined to quantify the impact of these actions, improve training course content, eliminate unnecessary duplication among courses, develop procedures to fund reliably the training and control quotas, and develop an infrastructure to provide day-to-day coordination and cohesiveness to the DOD-wide education and training effort. In May 1986, OSD requested that DSMC conduct the follow-on ACE II Study which again was supported by all Services and the Defense Logistics Agency (DLA). This 7-month effort culminated in the report to OSD in December 1986 that resulted in the change to the DSMC mission.

The study found that individual Services and Agencies had applied significant resources, including senior management attention, to support ongoing OSD efforts to enhance the professionalism and efficiency of the DOD acquisition work force. However, these individual efforts, conducted within the existing management structure, proved inadequate to provide OSD-mandated training to all people requiring it.

A General Accounting Office audit in 1984 showed no more than 40 percent of required training being provided to personnel needing it. In August 1985, Mr. Taft directed Services and Agencies to support training for a minimum of 85 percent of their mandatory acquisition training requirements each year. The ACE II Study confirmed the training status by analyzing data generated by the Services.

> In short, the requirement for this enhancement was perceived by the Services, put in place at their request and supported by the Office of the Secretary of Defense (OSD), truly a team effort.

Simply stated, the study asserted it was not enough to direct attaining the training objective without providing a more effective management mechanism. Further, the study found OSD was relying, and properly, upon the time-honored philosophy of centralized policy direction and decentralized execution; but, the problem was, and is, too broad to be resolved by Service/Agency independent actions no matter how well conceived and executed. More coordination among the services was required.

The ACE II Study Group found approximately 56,000 civilian and military men and women in the acquisition work force dedicated to contracting, quality assurance and program management activities (Figure 2). It determined that the training backlog of the work force measured against the stringent training requirements contained in the aforementioned directives was awesome. It would require approximately 2,000,000 student "person-days" to overcome the backlog. The study group determined this was within the capability of our education and training base if—and only if—all available resources were applied in a coordinated fashion.

[illegible] COMPOSITION OF THE WORK FORCE TOTALS BY [illegible] AGENCY AND JOB SERIES (MILITARY AND CIVILIAN)

Job Function/Series	ARMY	NAVY	MARINES	AIR FORCE	DLA	OTHER DOD AGENCIES	TOTAL
Contracting	6,551	4,671	221	9,712	4,967	77	26,199
Procurement Clerk	2,077	1,791	68	1,512	2,190	16	7,654
Purchasing Series	1,101	1,630	108	425	69	6	3,339
*Program Manager (Major)	20	38	3	35	0	5	101
Program Manager (Non-major)	73	113	3	250	0	13	452
Deputy Program Manager	93	158	7	285	0	0	543
Business/Financial Manager	0	78	0	0	0	65	143
Quality Assurance Specialist	2,757	2,777	21	1,495	6,742	4	13,796
Property Administrator	162	161	2	232	374	1	932
Industrial Specialist	593	676	8	218	1,125	5	2,625
	13,427	12,093	441	14,164	15,467	192	55,784

*Major programs as defined in DOD Dir 5000.1

The study group recommended that several actions be initiated immediately to reduce this backlog.

Action 1.

Grant waivers where appropriate. Several courses with significant backlogs have performance testing, and waivers could be granted based upon these tests. Waivers also may be granted for appropriate experience and other education and training.

Action 2.

Redistribute training loads among equivalent courses within the DOD training base.

Action 3.

Identify existing courses outside the DOD training base that may be equivalent. Courses or combinations of courses that could be used in place of a training base course would increase capacity and also reduce backlog figures.

Action 4.

Increase current capacity without using additional resources. Mirror adjustments to class sizes could increase capacity by perhaps 10 percent.

Action 5.

Rely on existing correspondence modes to satisfy required capacity.

Action 6.

Develop additional correspondence modes where prudent. This mode is ideal for courses whose objectives are primarily knowledge level.

Action 7.

Offer additional classes per year. Increasing the number of class offerings each year will increase capacity without incurring development costs.

Action 8.

Develop exportable training courses. This includes video tapes, video discs, satellite communications, and computer-based medias.

Action 9.

Use additional contract courses to augment training base. This provides an immediate short-term means to address training capacity deficiencies.

These actions were not enough. The study group determined additional and concurrent efforts were required to: 1) enhance the learning value of mandatory courses by making them more competency-based; 2) restructure them to reduce variety and number; and 3) establish fewer mandatory courses per experience level for each job function series and require attendance at those courses early in each individual's eligibility period. The study group felt this dual and concurrent approach would, *if properly coordinated*, overcome our training backlog within approximately 3 years without application of significant amounts of unprogrammed funds. The operative words are "if properly coordinated."

The keystone recommendation of the study was to identify a central entity to provide full-time day-to-day direction to the entire effort; not because it offers a panacea to the education and training problem confronting DOD, but because it offers the best managerial approach the study group could develop to cope with the problem *over the long term*. The study group was convinced that short-term *ad hoc* personality driven "solutions" had not worked well enough; nor was the *status quo* acceptable.

Coordinating and, to a degree, directing implementation actions are part of the expanded mission of DSMC. The Commandant will exercise authority across the spectrum of the DOD education and training base only in curriculum areas relevant to mandatory acquisition training and education and will be responsive to the Under Secretary of Defense for Acquisition. Any action to delete or develop such courses will be taken only after appropriate consultation with appropriate functional experts like the Defense Contracting and Acquisition Career Management Board (DCACMB).

Responsibility for teaching mandatory courses will remain with existing learning centers (Figure 3) which will develop, revise, or delete the courses. Funding for student travel and per diem for mandatory courses will be provided by DSMC starting in fiscal year 1990. In this regard,the DSMC will be an honest broker to provide the student seats required to meet Service requirements. Costs will be based on annual mandatory requirements submitted by the Services and DOD agencies. The DSMC will provide Services and DOD agencies a block of quotas annually to administer, based on their requirements for mandatory courses. Predominately Service unique, nonmandatory courses will continue to be taught and funded by Service schools.

Since March 1987, the Services and Defense Agencies have been anticipating this mission change and have worked closely with DSMC. Their actions were in response to a March 16, 1987, letter from Dr. Costello, in

SPONSORING SCHOOL	COURSE IDENTIFIER	COURSE TITLE
AFIT	PPM 057 (JT)	Contract Administration (Executive)*
	PPM 151 (JT)	Industrial Property Administration
	PPM 153 (JT)	Production Management I
	PPM 300 (JT)	Advanced Property Administration**
	PPM 302 (JT)	Government Contract Law
	PPM 304 (JT)	Advanced Contract Administration**
	PPM 305 (JT)	Production Management II**
	QMT 170 (JT)	Principles of Contract Pricing**
	QMT 345 (JT)	Quantitative Techniques for Cost & Price Analysis
	QMT 540 (JT)	Advanced Contract Pricing**
ALMC	8D-4320 (JT)	Management of Defense Acquisition Contracts (Basic)**
	8D-F12 (JT)	Management of Defense Acquisition Contracts (Advanced)**
	ALMC-B5 (JT)	Management of Defense Acquisition Contracts (Executive)*
	ALMC-B3 (JT)	Defense Small Purchase (Basic)
	ALMC-B4 (JT)	Defense Small Purchase (Advanced)*
	ALMC-TY (JT)	Defense Contract Property Disposition
	ALMC-QC (JT)	Quality Assurance Management I**
	ALMC-QD (JT)	Quality Assurance Management II**
NAVY	ER	Defense Acquisition and Contracting Executive Seminar
AMETC	TBD	Defense Quality Assurance*
DSMC	DSMC-4	Program Management Course
	DSMC-31	Major Systems Acquisition for Contracting Personnel*

*Course to be developed.
**Existing course to be reviewed, as appropriate, to reflect course consolidations.

which, he asked the DSMC Commandant "to serve as my action agent, with support from the Services and DOD agencies, to accomplish the following tasks as quickly as possible.

—Establish a Curriculum Advisory Council as recommended by the ACE II Report.

—Task learning centers to develop competency based curricula and courses as recommended by the ACE II Report and in consultation with the responsible functional groups (e.g., Defense Contract/Acquisition Career Management Board).

—Initiate actions to increase student output of selected courses.

Initiate actions to streamline mandatory training waiver procedures

—Initiate actions to formalize per diem and travel funding as recommended by the ACE II Report.

—Develop and promulgate course equivalency procedures and standards."

These actions are well under way. Near-term activities will continue to focus upon compietion of the Costello tasking; this requirement is immediate, compelling and formidable. The longer-term challenge of extrapolating the successful ACE Program model to include the remainder of the acquisition work force will require the active participation, dedication and cooperation of the Services, Agencies and appropriate DOD learning centers. Certainly, DSMC has a role to play in this important endeavor. Equally certain, however, is the fact that it cannot "go it alone."

GUIDELINES

DEFENSE SYSTEMS MANAGEMENT COLLEGE

EXPANDED MISSION

It is DoD policy to prepare and assign fully qualified individuals to positions in support of defense acquisition. Existing documents establish and implement training, education, and experience requirements for some acquisition personnel. To facilitate fulfillment of this training and education requirement, and provide for improved education opportunities for the entire acquisition workforce, the mission of the Defense Systems Management College (DSMC) is expanded to include the entirety of acquisition management.

To accomplish this mission, the DSMC will be the action agent for the USD(A) with the support of the Services to:

a. Provide certification of DoD and non-DoD education and training centers for course equivalency.

b. Provide full-time oversight for DoD acquisition training and education in coordination with the appropriate functional board.

c. Avoid unnecessary duplication in curricula.

d. Develop and promote current and effective methods of acquisition-related training and education.

e. Ensure the conduct of high quality mandatory training and education courses of study by DoD and non-DoD sources that shall prepare selected military officers and civilian personnel for assignments in acquisition career fields.

f. Manage the annual quota allocation process related to the courses described in DoD Directives 5000.23, 5000.48, 5010.16, and DoD Manuals 1430.10-M-1 and 1430.10-M-2 and as directed by the USD(A) to encourage the most cost effective use of DoD and non-DoD training resources while maintaining an adequate level of acquisition training expertise and facilities within DoD to accomplish the mission.

g. Budget for resources associated with the quota allocation process, including all mandatory training and education.

h. Develop appropriate experience, education, and training standards that may be used in place of mandatory acquisition courses.

i. Develop appropriate alternative training and education programs to include non-DoD and contract activities.

j. Promote and conduct research and provide information related to acquisition management training and education.

k. Recommend to the USD(A) additions or deletions to the mandatory courses in DoD Directives 5000.23 and 5000.48 after coordination with appropriate functional boards.

l. Provide oversight, review, and guidance in course development activities to maintain course quality.

Functional Boards, such as the Defense Contracting and Acquisition Career Management Board (DCACMB), the Quality Assurance Council (QA Council) and the Defense Management Education and Training Board (DMETB), shall provide advice to the DSMC regarding the requirements of education and training of functional personnel under the cognizance of the respective boards.

The *Commandant, DSMC* shall be responsible for executing the mission in accordance with the policy guidance provided by and approved by the USD(A). The Commandant shall review the operation and accomplishments and report findings to the USD(A) annually.

The *Secretaries of the Military Departments* and *Directors of the Concerned Defense Agencies (or Their Designees)*, shall:

a. Ensure that the DoD Component schools and training centers develop effective working relationships between the DSMC and the schools.

b. Submit to the DSMC the annual *requirements and 5-year projections* for each mandatory course to meet the mandatory education and training requirements.

c. Maintain entry, no-show, graduate, and other course data and provide same to the DSMC upon request.

d. Advise the DSMC of manpower authorizations used to staff the Service Learning Centers for the DoD mandatory courses.

e. Submit semiannual cost data for student and faculty travel and per diem, operations and maintenance (O&M) support costs, and curriculum development, maintenance and revision costs.

The *Secretary of the Army, or designee*, shall:

a. Provide support services and maintain facilities and equipment essential to the functioning of the DSMC at Fort Belvoir and ensure that administrative and resource support is timely, adequate, and supportive of the DSMC's mission.

b. Include the DSMC's annual budget in the Department of the Army's overall budget and financial plan and Program Objectives Memorandum (POM) submission. The USD(A) will be consulted prior to incorporation within Army-level documents of any proposed downward adjustments in the DSMC's budget, POM submission, manpower, or facilities.

The *Assistant Secretary of Defense (Force Management and Personnel)* shall:

a. Through the *Training and Performance Data Center* develop and maintain an education and training information data base to support acquisition requirements, including those for course files, master course schedule, and job aids.

b. Through the *Defense Manpower Data Center* develop and maintain a functional and training related data base to track the training status of acquisition personnel.

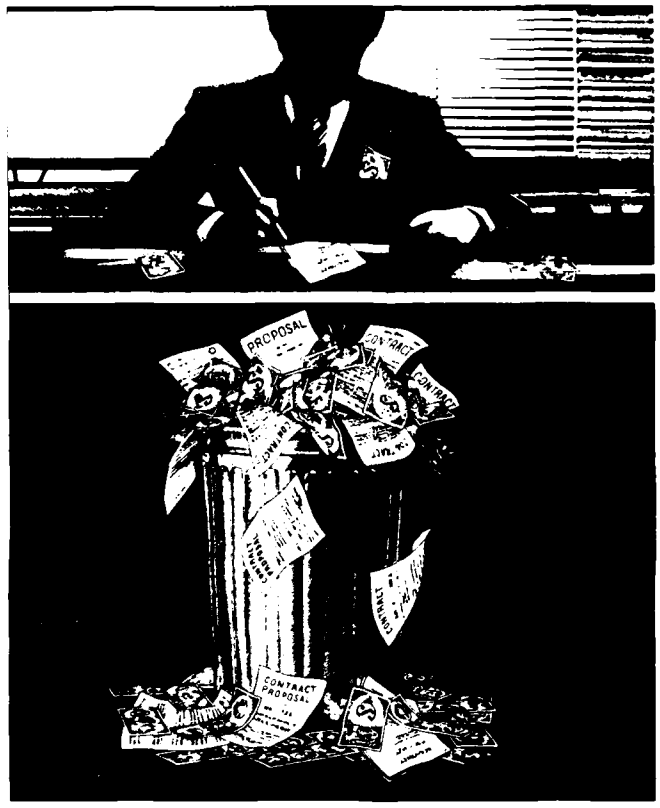
Programming, Budgeting, and Financing

1. The DSMC shall separately identify and budget for its resources to include funds for student and faculty travel and per diem, Operation and Maintenance (O&M) student support costs, and curriculum development and revision costs for the mandatory courses. The DSMC's program and budget plan will be submitted to the Army, its executive agent.

2. If additional instructional resources and supporting facilities are required over and above that allocated for the mandatory courses, requirements shall be forwarded to the DSMC with a detailed justification plan for them. The DSMC shall make adjustments where possible in the DoD acquisition training base to eliminate the need for the additional resources. If adjustments cannot be made and additional funding is required, the request shall be forwarded to the USD(A) for applicable action and direction.

Brigadier General Hirsch is the Chairman, Center for Acquisition Management Policy, the Defense Systems Management College.

Dr. Alan W. Beck, CPCM



If we generally write good contracts, which clearly and fairly state the responsibilities of the seller in performing for the buyer, why do we have changes? Changes are needed whenever the original contract agreement is no longer adequate to document what needs to be done. Controlling contract changes is a management challenge both for contractors performing the contract and for government managers who want the contractor to do what should (in whose opinion?) be done. While relatively simple or technologically stable goods or services are procured in contracts which may have no changes, contracts for complex items developed in an arena of technological uncertainty may require thousands of changes.

The process for making formal written changes to the contractual agreement is one of getting and documenting the revised contract agreement. The basic contract may have terms which anticipate and establish ground rules for certain categories of change, such as the Government Furnished Property (GFP) clause, the Changes clause, or some specially tailored clause language in the Special Contract Requirements section of the contract.[1] If your contract lacks special language covering a particular change situation, the basic process is to seek agreement of what is to be done by the contractor, and to establish the appropriate price and delivery schedule.

To look at how we control contract changes, let's first look at the formal terms and process of making contract changes. Then, with the vocabulary and process knowledge as a foundation, we can look at how to deal with the various factors causing change. With process understanding and insight into causes, we can then discuss actions to improve change management.

Definitized Or Undefinitized

There are two major choices of how to put a change on a contract. The preferred way is to get full and final negotiated agreement on work, cost and schedule with both parties signing the change. When both parties sign the change it is called a supplemental agreement. The less preferred, but sometimes appropriate way if you can't wait for a fully priced definitized agreement, is to have an "undefinitized" change.

Undefinitized changes are less preferred because the price remains to be negotiated. While it is often undesirable to have someone (like your home builder) working with a "blank check," sometimes it makes sense to have work started before firm prices are established; i.e., when I tell the gas station "my car is running rough, please fix it." To protect against the unlimited potential "blank check" cost, contracting officers normally obtain a "not-to-exceed" price agreement to put a cap on the yet-to-be-negotiated price for the change (such as telling the gas station, "Fix it if it's not more than $200)."

I. Undefinitized Change Order

Change Orders are the most commonly thought of type of undefinitized contract change. Because complex work is often likely to require change, the Federal Acquisition Regulation (FAR) has standard Changes clauses for government contracts.[2] The Changes clause allows contracting officers to unilaterally direct changes in the specification, shipping or packing. This means that the government may direct a change in *what* it wants (technical requirements, not quantity), *where* it wants it delivered, and *how* the item should be packed. Since the change may well impact the costs and schedule of the contract, the clause allows for the contractor to request an equitable adjustment in the contract cost and or schedule.

1. *Technical requirements, funding and management approval.* How does the change order process work? Basically, the contracting officer needs technical detail of what is to be changed in the requirements, funding to cover anticipated costs, and authority to issue the change order. The greatest of these hurdles may well be getting authority to issue the change order. Contractual authority under the FAR changes clause is not the difficulty; the issue is more often a management concern for limiting undefinitized work. Many organizations have additional review procedures requiring special justification and approval before their contracting officers are allowed to issue undefinitized changes. Even the Congress has gotten into management of undefinitized contractual actions through legislation limiting overall percentages on new awards. This trend will not make it easier for contracting officers to issue undefinitized actions when appropriate.

2. *Not-to-exceed price agreement.* The contracting officer will want the contractor to agree to a not-to-exceed price to limit the government's potential cost exposure for the change. When there are uncertainities in the pricing, a rational contractor will increase the not-to-exceed price slightly over "best guess" estimates. When the contractor is rushed to provide a price, without time to talk to subcontractors or to do detailed cost estimating, the word may be "if you want it bad, you get it bad." Where unusual circumstances might dictate contractual direction without waiting to agree on a not-to-exceed price, it is theoretically possible to do without one, but this is rare and not good practice.

3. *Issue the change order.* Given management approval, money, requirements, and an agreed not-to-exceed price, the easy part is to make the contract change. It may be as a simple as a one-page contract change form with a fund citation and remarks block entry which simply says "Engineering Change Proposal 336 is incorporated, pursuant to the changes clause, at not-to-exceed $800,000." The contracting officer may need to get internal legal or other review, and may want to include by reference the contractor's letter offer of the not-to-exceed price, or may ask the contractor to also sign the undefinitized change to formally record agreement to the not-to-exceed price. Once the contracting officer gets the document approved and signed, it is mailed, or handed, to the contractor with copies sent to the finance office to record the obligation, to the payment office, and to others on the contract distribution list.

4. *Definitize the undefinitized change.* The undefinitized change order is, in a sense, a temporary change. It requires subsequent agreement on the exact changes to the contract pricing. This agreement to definitize the change is done contractually in a Supplemental Agreement—the same way most changes are done if urgency doesn't justify starting the contractor first with a change order.

II. Definitized Supplemental Agreement

The preferred way to change contract requirements is with a definitized supplemental agreement, which both parties sign, documenting full agreement on what is changed and the price adjustments, if any, resulting from the change. This is the way the majority of changes are incorporated into contracts. Undefinitized change orders are rare, but sometimes justified because the process of issuing a supplemental agreement can take months. Let's look at the key steps to see what is done and why it sometimes takes 6 months or more to complete the action.

1. *The contractor prepares and submits a change proposal.* This action may be contractor initiated or requested by the contracting officer. There may be considerable preliminary work by either or both parties in planning what needs are changing, proposing technical changes (possibly formal Engineering Change Proposals) or even in preliminary cost estimating (such as needed to agree on a not-to-exceed price.) That activity could take weeks or months. The contractor's proposal preparation time depends on the complexity of the pricing; where there is extensive subcontracting, the pricing may be more accurate if the contractors have time to get detailed price quotes from their subs rather than back-of-the-envelope guesstimates. Even a simple change may take a month for the contractor to get all the prices estimated, summed and approved as a proposal.

2. *The government evaluates and audits the proposal.* To determine the right terms, technical effort and price for the change requires careful proposal review and cost analysis. This review typically takes two major actions—technical evaluation and audit. The technical evaluation reviews the proposed materials, labor and work requirements. The materials review may cover technical characteristics, scrap estimates, and quantities required. The labor review includes both levels of each skill required and the hours for each level. The work requirements review would include overall evaluation on any changes in the statement of work or technical specifications. The audit (for changes more than $100,000) involves Defense Contract Audit Agency (DCAA) review of three major areas: the contractor's labor costs for each proposed level of skill, the indirect "overhead" cost rates for labor, material, or dollars, and the costs for proposed materials. The DCAA audit typically takes 6-8 weeks, with additional time for inputs by the contract administration team. Sometimes, a few days can

be saved by good coordination with the in-plant contract administration team to ensure that DCAA gets the proposal promptly, and that the in-plant team gets timely opportunity for field pricing support input on the proposal.

3. *The government and contractor prepare for negotiations.* Negotiation preparation involves identification of any issues to be resolved and detailed cost analysis to estimate the appropriate pricing for the effort. The contracting officer or a specialist will "crunch" the numbers for each portion of the price. The recommended range of labor hours and skills from the technical evaluation will be multiplied by the hourly rates from the audit report for each category of labor. These costs, and any other direct costs, form the basis for computing indirect costs using the audit recommendations on overhead costs. Material costs are estimated, with material overhead projections based on audit report input. Other indirect costs such as General and Administrative or Fringe costs are estimated using the audit/field pricing support recommended rates. Profit is estimated using the guidelines of the FAR plus supplements. Fact finding discussions may be required to provide a basis for negotiation. Negotiation strategy for the entire package, including any changes to the pricing structure or contract incentives, may then be reviewed for pre-negotiation clearance according to local procedure. This pricing and negotiation preparation process may take a few days or a couple of weeks.

4. *Negotiations.* This is the art of obtaining agreement on what is to be done and on what terms. How long it takes depends on the complexity of the change and the participants' interaction.

5. *The contract language is drafted and reviewed.* Controversial new language will probably be worked out at the negotiation table, but after negotiation the exact wording and format of the planned change has to be drafted. Depending on dollar value and management interest, the proposed change package will then be subject to review by legal officials and a special contract review activity according to local procedure. Hopefully, none of these reviews will require reproposal and renegotiation.

6. *The contractor reviews and signs.* The proposed contract modification is mailed to the contractor for signature. The contractor may require internal reviews before signing the proposed change. This could take a few hours if the change was relatively simple, or weeks if the change was serially coordinated from organization to organization with no special priority.

7. *The contracting officer reviews and signs.* On receipt of the contractor-signed proposed modification, the contracting officer will make a final review and may have requirements for other internal reviews or clearance before signature. The Army and Navy have a procedure called Business Clearance to provide signature approval authority. The Air Force requires counter signature by higher-level authority if the dollar value is above certain thresholds. This step may take several days, particularly if someone in headquarters wants to ask more questions.

8. *Reproduction and mailing.* Reproduction of copies for the contract mailing list may take several more days. The supplemental agreement does not become effective on signature, but when it is distributed ("mailing date") to the contractor and to finance to record the obligation.

III. Other Formal Changes: PIO and ADMIN

In addition to the change order and the supplemental agreement, there are other areas in which the PCO can issue changes. Administrative (no cost) changes may be issued by the contracting officer unilaterally to make minor (non-controversial) changes such as changing the name of a government representative, or obligating additional funding for an incrementally funded contract. A Provisioned Item Order (PIO) is used to order spare parts through the provisioning process; these orders may be added unilaterally to a production contract to permit timely (concurrent) manufacture of the initial spare parts while the production parts are being made. The PIOs are an administratively convenient way to order spares. They may cite estimated prices (undefinitized) with the ACO negotiating final prices. Prompt ordering using undefinitized PIOs to allow concurrent production with end-items may provide schedule and cost benefits which outweigh the usual government preference to wait for negotiation of definitized prices before ordering.

IV. Managing Change

The manager's challenge is how to limit or eliminate non-essential changes while seeing that necessary changes are made in a timely manner, within the constraints of law and policy. Frequently, changes are needed when (or before) they are suggested, so the users or requiring activities may want the change made as soon as possible. This increases pressure on the manager for rapid approval technically, for finding existing money rather than waiting for justification in a budget submission, and for wanting the contractor to start work quickly rather than wait for a definitized change. Managers are paid for making things happen; however, the system inserts pragmatic checks to be sure we don't make mistakes. The preference for getting a definitized fair price before work starts is often frustrating to contractors and government managers who want changes to be made quickly.

Undefinitized work authorization may make good sense when the costs of delay in implementing change are weighed against the benefits of earlier change. Managers have to decide when it makes good business sense to order changes without firm negotiated prices. As senior managers, and now the Congress, have perceived problems with undefinitized work authorization, they have limited working level management's flexibility to work with procurement personnel to determine how to contract for change. Management by quotas tends to take over, with managers and procurement offices scored by how they minimize "undesirable" (undefinitized) actions. As these controls change from watching trends, to management by ultimatum, such as "There will be no more undefinitized changes in my organization," harmful effects can result from well-meaning attempts to cope by contractors and government managers.

Let's look at what can happen as senior officials limit the flexibility of contracting officers to issue formal change orders to initiate desired changes promptly. One insidious result, because we often don't know the true impact, is the cost of schedule delay. Where a production effort is underway, delay in change implementation can mean costly out-of-station work or even field rework or retrofit. Delay in completion of items may mean a delay in fielding needed operational capability. A second action, which could result in negative impact, misunderstanding and claims, is when a contractor senses the need and proceeds with the change "at his own risk" without government (PCO) authorization. This means that the contractor is no longer performing in accordance with the written contract. If the change is never approved and added to the contract, the contractor might be unable to deliver and, thus, not be paid for the work. A third negative action could be government liability if the government knows that the contractor is performing the changed work, and government personnel encourage or don't expressly discourage the action. This could result in a board or court ruling that the contractor was doing work for the government and, thus, should be paid. It is simply not fair (unethical) to expect or encourage contractors to work without proper authorization. Those who ask for work without proper funding and authority risk personal liability for violating federal law and regulation. A fourth adverse impact of delay in contract change approval is in suboptimal more costly "work-arounds" if a contractor stops work in the area to be changed (perhaps as a result of a government stop work order).

V. Constructive Changes

Sometimes, actions or inactions by government personnel in authority, or simply circumstances, cause a contractor to perform work differently than required by the written contract. This is called a constructive change. A contractor, believing existence of a constructive change, may file a claim for equitable adjustment in the contract. To prevent constructive change claims, many acquisition managers and contracting officers have implemented educational programs, included disclaimers for correspondence and meetings, and put special requirements into contracts to require timely notification of any circumstances where the contractor feels that a change has been directed. While many people think that a constructive change occurs when a contractor is directed to do something beyond contract requirements, there are other situations causing constructive changes which may not be as preventable or as "bad." Extra or different unexpected work might be caused by unforseen problems in vague, insufficient, or defective specifications. A lack of timely government action might cause the contractor to have delay cost, called constructive deceleration. More work requirements than contemplated, such as additional work requests or excessive government reviews, could result in a claim of constructive acceleration for schedule relief and more money.

VI. Improving Change Management

Solutions to improve the management of the change process encompass contracting techniques and management effort to improve the people-side of the business. Contracting techniques include writing contracts with provisions to help manage change as well as taking timely and professional action to change contacts when needed. Contractual language that helps manage changes includes incentives like the optional "swing" clause which incorporates contractor initiated Engineering Change Proposals below a certain threshold at no change in contract cost. This clause saves administrative time in evaluating prices while motivating the contractor only to propose essential changes. Specially tailored language in the Special Contract Requirements section may help limit changes. A Notification of Changes clause may help limit constructive changes and, at least, will help promote timely action. Managing change with timely actions requires appropriate consideration of the pros and cons of undefinitized change orders, followed by careful planning and management of the change-definitization process. When there is a heavy volume of changes, the contracting officer may group several changes in process into one contract modification to avoid duplicative paperwork and review cycles. Sometimes, technical managers do this by holding several non-urgent changes for "block" change or even a new model designation for configuration management and logistic support reasons. Once the change gets into the contract definitization process described above, effective management planning and follow-up can make a big difference. More than 80 percent of the change definitization time may be taken up by activities outside the office of the contracting officer. The effective contracting professional uses overall management skill in coordinating and influencing work done by a variety of activities. When many changes are pending, follow-up actions to shepherd actions through the evaluation, audit, pricing, negotiation, writing, review and approval process are coordination challenges for management. In my opinion, good change management requires top-quality professionals who understand the rules and the process and who are dedicated to getting the job done in a professional and timely manner. They need authority to make decisions and act in the government's best interest without layers of management review and second-guessing to lengthen the process. With enough high quality and dependable people working with requirements people and managers, contracts and changes can accurately reflect and promote agreement. The agreement's documenting and promotion is, after all, the basic reason for contracts, and the key to effective acquisition.

Endnotes

1. For more on Special Contract Requirements, see Beck, A. W., "Reading the Fine Print: Special Contract Requirements," *Contract Management*, March 1987.
2. For more on the background, origin and purpose of the FAR, see Beck, A. W., "FAR is Near," *Program Manager*, September-October 1983.

Dr. Beck is Director of the Business Management Department at the Defense Systems Management College.

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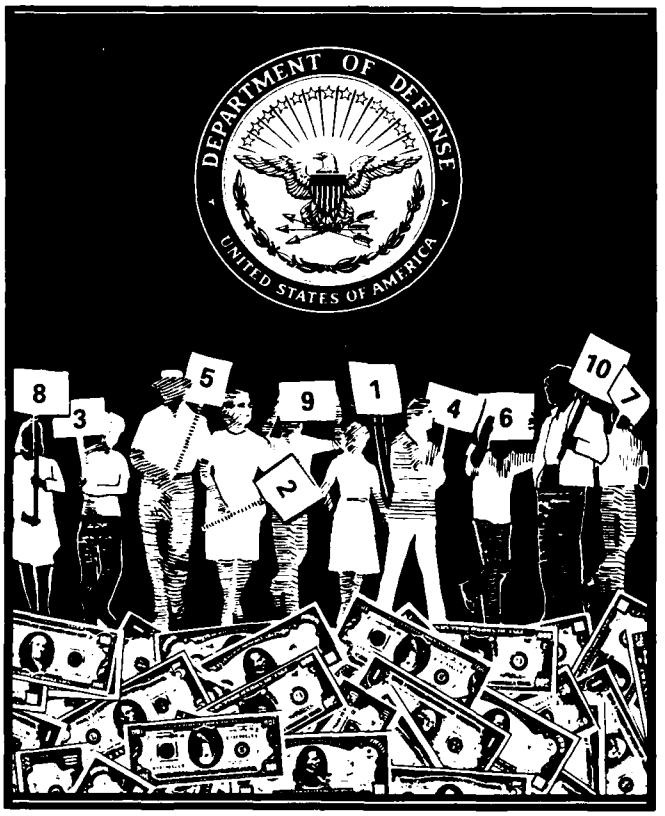
The Honorable Robert B. Costello
Under Secretary of Defense (Acquisition)



here are 10 major items on our defense acquisition agenda. There are different levels of detail on several. I want to address what we in the Department of Defense are doing to solve our problems, which everyone knows are there.

We have made significant progress in recent months. On the other hand, let's not be smug. There's a lot of work to be done, and part of what I want to leave with you is a loud exhortation and challenge to work with us to make things better.

The 10 agenda items are these:

1. Bolster the defense industrial base;
2. Improve the effectiveness of the acquisition work force;
3. Improve product quality and reduce the cost of poor quality through total quality management;
4. Forge a new relationship between government and industry;
5. Acquisition regulatory reform;
6. Reduce the lead time 50 percent for introduction of new technology;
7. Develop a strategy for international technology, acquisition and logistics programs;
8. Institute a cost estimating process called "could cost," or competition in a sole-source environment;
9. Definitely influence how we manage special access programs;
10. Additionally, always emphasize DOD's commitment to small and small-disadvantaged businesses.

Synoptically, these 10 goals and strategies, which encompass all program milestones during the acquisition life cycle, are intended to streamline both:

—The methods by which we conduct business, by bringing them more in line with commercial business practices, while recognizing certain nuances peculiar to defense acquisition; and
—The procedures used to increase quality and reliability and reduce weapon systems costs.

Our ultimate goal is to provide our fighting forces the best and most capable weapon systems possible, at the most efficient cost, on time, and fully supportable.

Let me again emphasize DOD's commitment to small and small-disadvantaged businesses.

Small businesses are a vital element in our national industrial base. We want them to participate in defense contracting and have their fair share of our market. We want them to prosper and grow. They are the lifeblood of our free enterprise system.

Last year, small business received more than $26 billion in DOD prime contract awards, representing some 19 percent of our total prime awards. However, small-disadvantaged business accounted for only $3.1 billion, or 2.3 percent. The Congress has tasked DOD to increase the percentage for small-disadvantaged business to 5 percent of all procurement, RDT&E, military construction and operations and maintenance dollars.

The challenge is worth it, and we can do it. To attain that goal, we must rely on our senior officials to adjust the temperature and build the right climate. We need your help in this area.

We are calling this and many of our initiatives "cultural changes," which take time, evolve gradually, and require selling and cooperation. It takes leadership to convince institutionalized people and processes that the changes will make everyone's job easier, and provide the best and least expensive weapons for the field.

In today's severe budgetary constraints, we must cooperate and look for better ways. Once found, we must press on with them regardless of tradition, business as usual, and the syndrome of "it's always been done this way."

Let's discuss bolstering the industrial base.

Our ability to respond to mobilization is critical. I measure this criticality in our *being prepared* to be mobilized. The framework is DOD's new industrial alert conditions system, called INDCONS, where industrial strength is called up in stages.

The DOD is encouraging industry to take a number of actions including modernizing plants and processes, streamlining management, pooling resources to do together what might seem impossible to do alone, and restoring the competitive fierceness that has not died, but appears at times to be in neutral.

We are looking at regulations to see what we can do without. If we don't need them for mobilization, do we really need them now to guide and constrain us? We don't think so.

To enhance readiness of the industrial base, we are looking at the shelf-life phenomenon. Is it more practical, for instance, to have cheaper batteries or less stringent packaging requirements? Should we implement a "just in time" delivery capability, if we know we will use the material within a few weeks?

We continue to examine contractor incentives—profit policies, contract types and their usage at various stages in the development and production processes; also, other fundamental economic incentives bringing us better quality, performance and lower cost.

We are looking at the issue of reverse technology transfer, at a trade policy that allows us to transfer offshore technology to the U.S. industrial base, for use by military as well as the public, especially when those offshore contractors are performing on one of our contracts.

We are looking at the war reserve stocks capacity policy and whether we are spending the right amount on inventory. Or, should we shift to spending more on plant readiness to achieve sustainability?

In examining specifics such as facilities, we are working with the construction industry since they will be a factor in building new plants; and with key labor leaders examining labor-pool capabilities and the long-term impact of their participation.

We are looking at strategic materials used in weapon systems, with the option of using what is available; and, just as important, what is most likely to be available during hostilities. We may have to change our design concepts rather than use exotics which might not be available.

We have established a network with trade associations and professional societies representing hundreds of manufacturing companies and more than half-a-million working engineers. Yesterday, we gathered more than 200 industry, DOD and academic leaders at the National Defense University to seek a national consensus with recommendations on how to continue to move ahead, to put DOD in the lead—not just responding to what is available.

Another of our major efforts is in promoting cooperative efforts within industry. Two key examples: the semiconductor industry and the machine tool industry.

The U.S. semiconductor people are working together to create a not-for-profit consortium called SEMATECH, which will develop state-of-the-art manufacturing processes. I am very encouraged with this. It is unprecedented in that industry, and may be one of the first of its kind in this country.

This cooperative effort will be watched closely. Industry consortia may be just what we need to eliminate unnecessary duplication of effort and pooling of scarce resources, plus helping U.S. companies gain or regain a world-class competitive edge.

In the machine tool industry, we have a success story. With our help, they have created the National Center for Manufacturing Sciences, another example of where manufacturers and users have combined resources to correct a deteriorating situation. The center is sponsored by 80 leading machine tool companies and their users.

Recently, the Department of Defense has initiated the formation of two government/industry organizations which I am confident will help solve problems. They are the Defense Manufacturing Board, parallel and equally visible with the long-standing Defense Science Board; and the Manufacturing Advisory Committee, which has a goal to build trust between the two.

Let's discuss improving quality through the principles of "total quality management."

What does "quality" mean? First, the word alone means: the composite of material attributes, including performance features and characteristics of a product or service to satisfy a given need. Translation: Is the product good, and will it do the job for which it is intended?

In the Department of Defense, we have expanded application of the word quality and speak of "total quality management." This management philosophy is a strategy already being woven into the fabric of DOD's acquisition system, awaiting only the eventual institutional acceptance as daily routine. Simply, the goals are:

—Improve the quality of DOD products;
—Achieve substantial reductions in the life-cycle cost of ownership of our weapon systems.

What will it take to achieve the goals? A lot.

—We must change the traditional inspection-oriented focus on quality which comes too late in the development and production process, to emphasize a built-in quality process much earlier in defining requirements and early engineering pluses.
—We must emphasize competition based on quality as well as cost, schedule and performance, including lowest bid.
—We must motivate and exploit the ingenuity and innovativeness of our people to achieve maximum quality improvements in every program at every level. This will be the program manager's responsibility.
—We must encourage implementation of successful concepts such as statistical process control and continuous process improvements.
—We must emphasize the use of sound, proved engineering design and manufacturing practices.

Our objectives include: making our procurement system more flexible to allow streamlining of contractual requirements; improving interaction among designers, manufacturers, logisticians and users; making quality a factor in source selection; giving extra consideration to companies whose products and services embody the new concept of continuous product improvement.

To implement the strategy we will:

—Integrate current DOD management initiatives affecting quality such as acquisition streamlining, competition, improving the transition from development to production, value engineering, warranties, and gain sharing;
—Revise all product specifications to replace the "acceptable quality level" concept with a "continuous quality improvement" concept;
—Stimulate use of new technology to enhance quality;
—Guide the radical change from reliance on detecting defects during end-item inspection to an effective process control that prevents defects during manufacturing;
—Apply quality technology including automated process controls, self correcting manufacturing processes, built-in diagnostics and automatic inspections;
—Institute an integrated training program to instill quality principles throughout the government, including developing a career program for quality assurance personnel;
—Encourage contracting officers to look for ways to increase quality when preparing requests for proposals and negotiating contracts.

We are trying to change another outmoded concept, that of "minimum acceptable" quality. America's manufacturers have pursued this concept, placidly resigned to a persistent level of errors—perceived as irreducible and as being the way of life. It isn't.

The Office of the Secretary of Defense is working with the services to identify key approaches. Many excellent tools have been developed. We are exploring more ways to hold program managers accountable for quality. I want you involved and committed. Pilot acquisition programs will be selected. We will make the necessary changes to the Federal Acquisition Regulations to incorporate the new approaches.

It behooves both the Department of Defense and industry to work together. Industry must provide tangible evidence of its commitment to quality. Statistical process control and total quality management are not just floor activities; they belong upstairs as well. Management must openly assume responsibility for their product's quality and insist that "no defective products shall be shipped to the government."

Let's discuss regulatory reform. When we say regulatory, we are talking about the defense contracting system.

Our goal is to make it easier and quicker for managers and people in the field to get the quality products and services they require, when they want them, and at a reasonable price.

We want to move into a system where our contracting officers will feel at home using their initiative and innovativeness to provide the government with those products and services, while maintaining proper accountability. Defense contracting officers are not using all the authority the laws and regulations have given them—for various reasons. We are encouraging them to escape from their perceived constrained and restricted environment to one where they can exercise good judgment more in line with sound commercial practices to make good, solid business decisions. We want quality and timeliness to be decisive factors, not just price alone.

We have taken a major step in this direction with our pilot contracting activity program. This involves 31 activities of the services and the Defense Logistics Agency. Included are the Army Tank-Automotive Command and the Air Force Electronic Systems Division; the Navy Ships Parts Control Center; and the Defense Industrial Supply Center. We established this program to capitalize on the enthusiasm of people in the field. We are allowing contracting officers to show initiative and creativeness while working within the law.

We are identifying procurement laws and regulations that are unnecessarily complex and restrictive, testing new and different procurement methods, and performing more procurement actions using commercial practices. Under the test, contracting officers may issue class deviations to the Federal Acquisition Regulation and its defense supplement, and waive any DOD procurement regulation not required by statute or executive order.

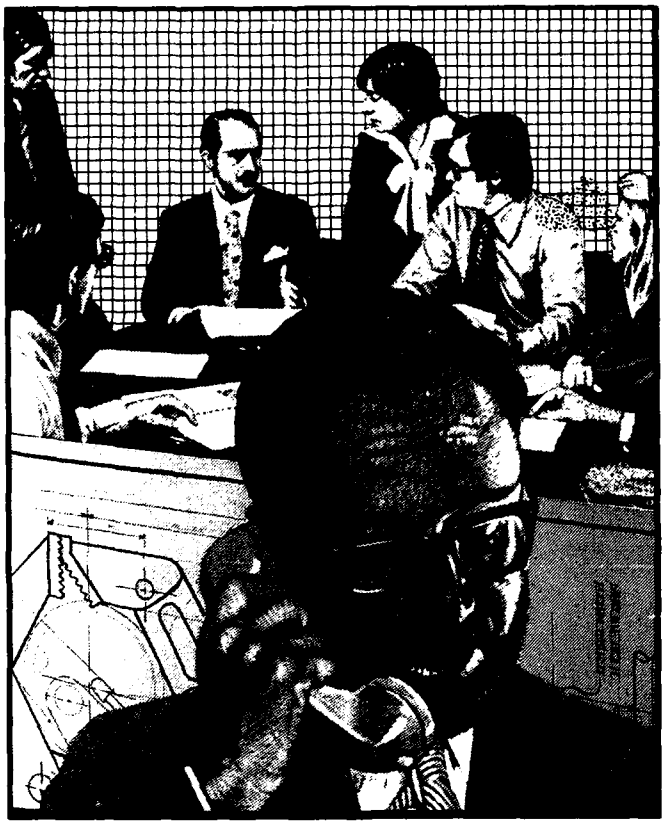
Since 98 percent of DOD's procurement actions are for less than $25,000, we are producing a new *Small Purchase Handbook*, which will be out soon, to streamline these kinds of procurements. For items already on the competed federal supply schedule of the General Services Administration, our contracting people no longer have to recompete in order to procure them.

The principle of "could cost" is a new concept in the acquisition vocabulary. It introduces competition in a sole-source environment, which amounts to some 40 percent of DOD's contract actions, and can supplement the other 60 percent of negotiations as well. We would use this concept to reduce the cost of many special access and follow-on programs; also, programs in production where we can't

(See AGENDA ITEMS, page 31)

GOVERNMENT CONTRACT PROFIT POLICY AND DEFENSE

David Westermann



One objective of this article is to discuss the matters which drive the decision-making process of the senior officers of major defense contractors. Many Defense Department managers, who have tried to induce contractors to make capital investments through the weighted guidelines profit formulas, and others concerned with defense contract profit policy, will be surprised to learn that the decision-drivers in the real world are not what they assumed.

A second objective is to demonstrate that annual fluctuations in profitability are of limited usefulness in setting government policy without taking into account the company's program mix—from initial development through full-scale production—from year to year. Profits should and do vary widely depending on which end of the development/production scale a particular program resides at any given year. The learning curve obviously has a major impact on productivity and profitability.

A third objective is to show that profit comparisons among defense firms, and especially between defense weapon system companies and commercial enterprise, are of dubious value without extensive analyses of the type suggested above.

Finally, a major purpose is to emphasize the importance of an understanding by Department of Defense program managers and contracting officers, and their superiors, that their real objective in negotiation is to select contractors who will produce the quality and reliability needed, at a reasonable price and low total or life-cycle cost to the government, not at a low price or profit. The goal in research into profitability trends should be to find better techniques for producing the financial and related incentives leading to this end result; i.e., high quality and reliability at a reasonable price and low overall cost. Intensive focus on the *low* bid and *capital* investment can be counterproductive.

Principles

Profit policy rationally should be related to the national defense objectives of the Department of Defense and its contracting officers. If it is to work it should also relate to the investment decision considerations of defense contractors.

The contracting mission is to supply the armed forces with weapons and other products that perform as required, in the needed quantitites, on time, properly supported, and at a reasonable total cost.

These products may be needed to meet a threat or to correct a weapon system deficiency. The need may be technology based. The technology may be available, or have to be developed.

The broad defense objectives are to support foreign policy and deterrence, provide fighting capability, and assure the personal safety of Armed Forces personnel.

Acquisition policy should support that mission and those objectives. This applies to contracting, financing, profit and pricing.

These objectives and mission require a healthy, innovative, efficient, competitive defense industry base.

It follows that defense industry must be competitive in advancing technology, and in product markets. Most importantly, it must be competitive in the capital market—where it seeks the equity and debt capital required to compete in the advance of technology and in selling its products. It takes cash to compete.

The Department of Defense should incentivize well-managed effective competitors and low-cost producers (not necessarily "low bidders") to invest in competing for defense business. And, indirectly, it should not only incentivize the capital market to buy stock in and lend to such companies, it should incentivize entrepreneurs to create such companies.

Department of Defense incentive policies should give consideration to all elements of a well-managed, healthy, competitive, innovative industrial mobilization base: prime contractors, subcontractors, vendors; large and small; publicly owned and private.

Assuming success in incentivizing or attracting successful and well-managed companies to compete, the Department of Defense should leave it to them to decide how to invest. Driven by defense market and capital market considerations, successful firms will make wise decisions.

The capital market invests in companies, equity and debt capital, for an adequate return on investment, considering the time value of money involved, as well as risk. Return on investment may be called ROI, or ROA (assets), or ROCE (capital employed).

To succeed in incentivizing investment to compete, the Department of Defense policy should have a rational relationship to the company manager's investment decision process. It should affect matters the manager logically thinks of as important in deciding to invest.

The policy should recognize that, in a given company at a given time, there will be a variety of investment opportunities that might be likely to increase productivity, not just "capital investment."

Company Investment Decision

Managers of a company are, in effect, trustees charged to protect the capital invested in it, and to earn a reasonable return on it (ROI). That is a serious obligation, particularly if company stock is widely owned by the public.

Managers of a company deploy resources, or invest its capital, to obtain an adequate ROI. They may invest for long-term or short-term ROI, probably both at the same time though in different projects. When the return is long-term, it must be much higher when it does come, to compensate for years when the capital was tied up not generating current return. This concept is called the "time value" of money.

We say company investment is "ROI justified." This means we make the investment only if:
—After considering probability of success, and
—After considering risk, and
—After discounting estimated *future* cash flow returns back to their "present value," to account for "time value,"
—The net positive cash flow amounts to a return on investment that
—Satisfies or meets the company's "hurdle rate" or its "cost of capital" in the financial market, and
—Is a better opportunity than other available investment opportunities. The profit we would have made on the investment we have to forego is thought of as a "cost" of the investment we do pursue. This is the concept of "opportunity cost."
—The cash investment is affordable.

The evaluation of the alternative investment opportunities (e.g., develop a weapon system, or pursue a commercial market, or automate a factory, or prevent a layoff) is done as realistically as possible. It may involve forecasting years ahead. It is done in terms of cash flows—out and back in, not just in financial accounting terms. Cash flows are reality. Financial accounting terms such as "net income," "profit margin" and "depreciation" do not always reflect cash flows. Techniques used in the process are "internal project rate of return" analysis and "discounted cash flow net present value" analysis, both technical terms for ROI justification, and by "payback" analysis which helps with risk evaluation. Payback is the number of months until the investment is recovered, without any profit.

It may be useful to think of the "hurdle rate" or "cost of capital" as the rate of return on capital the company must realize over time. If it does not, its stock price will decline and its cost to borrow money will rise; that is, it will not be competitive in the free capital market.

Affordability of the investment means the company must plan to have or generate cash required for the investment, possibly during some years ahead. The company must assure its planning protects that cash from commitment to any other use. That cash may come from another program in the company's "investment portfolio," which is now reaching its "mature" phase when positive cash return is realized.

Most company resources have a limit, and investment opportunities vary as to time span of the investment, probability of success, risk of failure of the project, and risk of financial disaster.

"Earning per share" impact of the investment decision must be considered because current market price of stock may be affected by earnings fluctuation. Stock price volatility can affect capital market strength of the company and even its vulnerability to "takeover" and "bust up" by corporate raiders. Protection of earnings per share may require a focus on short-term results, not just long-term return on investment.

The company may invest by using a "portfolio strategy," trying to pursue

long-term investments in market entry and market share capture for some products, while at the same time managing other products which are currently generating positive cash flow and financial accounting "earnings." This was recognized in the 1985 "Defense Financial and Investment Review" (DFAIR) by the Office of the Secretary of Defense.[1] This is the balanced "Portfolio" strategic management concept developed by the Boston Consulting Group (BCG). The positive cash flows from products in the mature phase provide funds for the investments.

Each firm's investment decision takes into account multiple interrelated considerations including resources, affordability and market position, technology position, market and customer behavior, competitors' positions, strategy and tactics, talent available, know-how, reputation, policy regarding maintenance of job security and avoidance of lay off, and corporate culture and values. A major consideration in corporate investment decisions is the relative degree of certainty regarding increased sales likely to result from the investment. In the case of defense, with only a 1-year congressional budget, there is extremely high uncertainty and, thus, a considerable disincentive to investment.

The company will consider risk of failure (loss of the investment or loss of better opportunity) and risk of financial disaster. In the defense business, it is dealing with an often unpredictable government customer with both monopsony (where several sellers have only one buyer) and sovereign power which the customer may exercise in damaging ways. The company is not likely to limit its risk analysis in the simple way suggested by the General Accounting Office (GAO) when it says defense business is low risk. The question is *not* simply more or less profit. (See *GAO Assessment of the Study of Defense Contractor Profitability*, December 1986, page 34, comparing defense and commercial firm risk.)

The company may be large, mid-size or small. It may be a prime contractor, subcontractor or vendor.

The company may be deciding among various investment objectives such as whether to invest in technology (research and development), market entry in a new field, cost-share or buy-in. (A fixed price contract "buy-in" may be fully disclosed in the proposal, and need not be improper or covert.) Other investment objectives may include capture or defense of market share, know-how and learning-curve position to drive down cost hiring, training, prevention of lay-off, employees' incentives, or capital facilities. The last mentioned may cover a wide range, including capital expenditures for office, lab, manufacture, quality, test, or working conditions and morale support; any may be of value and a justified investment at a particular time.

Government Profit Policy

How well is government profit policy coupled to defense contractors' investment decisions?

Consider a government view, as expressed in the GAO Exposure Draft, A Proposal for A Program to Study the Profitability of Government Contractors, November 1986:

> It is in the government's interest to offer contractors opportunities for profit sufficient to (1) stimulate efficient contract performance, (2) not discourage companies from seeking government business, and (3) promote investment to enhance productivity, and provide for an adequate industrial base, that will allow a quick buildup of defense items in case of emergency.

A number of questions arise.

— "Stimulate efficient performance?" What does "efficient" mean? Low cost, or low price? Low life-cycle cost? Quality? "Efficient" may mean highly automated. But that may mean high depreciation and, therefore, high "overhead"—and high fixed costs to carry in times of low demand—a high break-even point. Would investment in engineering hours to design a product so as to be more easily producible instead of automating contribute to "efficiency?"

—"*Not discourage* companies?" Would a less negative policy—like "encourage"—be more incentive to invest? And what "companies?" Just any company? Or well-managed, effective competitors? Low-cost producers, or "low bidders?" Prime contractors, or also subcontractors and vendors?

—"Promote investment to enhance productivity?" The GAO seems to favor capital investment to do that.[2] So does DOD. The GAO says, "For example, the Department implemented recommendations of its Profit '76 study to induce contractors to invest in capital facilities." The GAO wants it to be statutory. Section 2 of the GAO draft proposed "Profit Reports Act of 1986 used the language: "...provide profits that encourage related capital investment...."[3]

What if the policy were not to incentivize *capital* investment but to incentivize well-managed effective competitors to *compete* across the board for defense business? If that were effective could it then be left to those excellent managers to decide what to invest in and when? Wouldn't the value systems of such effective competitors and their competent managers lead them to invest for productivity, quality, and cost reduction? Absolute profit on a subsequent contract may be less if cost is less, but there should be more overall business, and a more effective and, therefore, more secure and enthusiastic work force.[4] The right investment to bring this about might or might not be capital. As noted, many opportunities to invest to improve quality and productivity do not involve "capital expenditure."

In any event, the government seems to have sought to incentivize *capital* investment by a "profit policy" applied through "weighted guidelines" used for negotiation, which, in the main, deal with "profit" as a percentage of expected cost; or deal with profit margin (net income after tax as a percentage of sales). It is far from conclusive that it has worked.

According to an Air Force Systems Command (AFSC) study, "the operating premise of the Profit '76 study team and the ensuing DPC 76-3 was that a higher return on sales for defense contracts would yield higher capital investment. Results of the

AFSC Profit Study '82 raised doubt about this premise. "...capital investment on defense contracts as a percentage of total contract costs did not change during the 1977-81 period."[5]

The AFSC Study continued: "Defense contractors perceived that the Weighted Guidelines method is not the real determinant of profit. They felt that management direction has a greater impact on profit determination. This perception was also confirmed by government contracting personnel who shared the belief that profit is largely determined by management, regardless of Weighted Guidelines computation."[6] Conclusions like this cause one to inquire whether the profit policy implementation, with all its complexity, is largely a ritual.

Even if the policy did encourage investment in capital equipment for productivity, is it reasonable to think that companies will or can make ROI justified investments in capital capacity for "a quick buildup of defense items in case of emergency," as GAO wants? Isn't a "surge" requirement for weapons, or war, a market we hope will not come? Isn't the very mission deterrence? Should the government as sovereign ensure that surge capacity is in place where it would be needed, and not rely on profit on current business as an incentive for that? Of course a healthy, innovative, competitive industry with capacity to meet current military requirements for deterrence is a necessary mobilization base.

As noted by AFSC, the government has manipulated profit margin in an effort to incentivize the desired investment in capital facilities. It should not be surprising that it has not worked. We suggest that it also would not work for the broader, and arguably more rational, objective of incentivizing effective competitors to compete across the board for defense business.

Profitability - DuPont Formula - Asset Management

Mere changes in profit margin, taken alone, do not have a sufficiently rational relationship to the matters company managers think about when making company investment decisions in the defense business.

The National Security Industrial Association (NSIA)[7] told The Office of Secretary of Defense (OSD) at the outset of Profit '76 that its approach would not work, considering the complex of considerations, beyond profit margin, involved in the company investment decision.

The company decision is ROI justified, not profit margin justified. Profit margin is only part of ROI. It should be useful to refer to the "formula" for ROI developed by the DuPont Company years ago. According to the "DuPont formula":

Profit Margin X Asset Turnover = ROI

or

Net Income/Sales X Sales/Total Assets = Net Income/Total Assets

or

NI/S X S/TA = NI/TA

Asset turnover, or S/TA, is efficiency; that is, doing more business, or getting out more product, with less assets. Efficiency reduces cost. Idle or underutilized assets slow asset turnover.

The DuPont formula is a powerful management concept, not just a financial formula. Peter Drucker says that when the DuPont Company "codified" the concept in the 1920s, it then "organized" its management around it. He said "working on the productivity of capital is the easiest and usually the quickest way to improve the profitability of a business..."; i.e., working on asset turnover, or S/TA.[8]

The concepts embodied in the DuPont formula were underscored in a letter from the President of Textron to OSD at the outset of Profit '76. Speaking of the defense industry, he said:

> *Profits on Sales*, of course, will be lower than for the average of American industry; this has been proven so many times that it hardly need be repeated. However...those companies that survive should, in the long run, make a competitive return on investment...Defense...is a business in which *asset management is a key* element, and the *turnover rate* (sales divided by net worth) can be the difference between success and failure. *High turnover* usually comes only *in the mature phase* of production contracts...*one must take the high risk in...the earlier phases...when profits are low* and development is speculative. One must *invest* for the *long haul*....[9]

Profit '76, DFAIR and GAO do, of course, refer to ROI and ROA among other profit measures. But, annual ROI in financial accounting terms must be distinguished from program ROI, over time, in cash terms, which is reality in the investment evaluation. And, DFAIR and GAO do affect turnover or S/TA when they deal with progress payments and financing; e.g., they hurt S/TA when they cut progress payments, but, mostly, they do not deal with major asset management problems. They deal largely with manipulations of the relationship of pre-tax profit to allowable cost. Those actions are hardly considered in the company investment decision; they are washed away by the asset management (S/TA) problems.[10]

To deal effectively with ROI requires consideration of asset turnover (S/TA), the measure of efficiency, and asset management. Asset turnover indicates the ability to make full, effective, continuous use of company assets, meaning its physical assets, and its people; i.e., their brains, skills, learning, loyalty, and motivation as individuals and as multidiscipline teams. It requires good management stability and continuity.

Strategic Investment Considerations—"Experience" and "Portfolio"

Learning curve and the related experience-curve phenomena enter into strategic investment decisions. Learning-curve theory holds that unit factory labor cost declines at a predictable fixed percentage every time cumulative volume of the product manufactured over time increases; e.g., 10 percent to 15 percent with each doubling. The concept is well known in defense contract pricing. Just as in the case of asset turnover or S/TA, learning by the work force requires good management and stability. Experience-curve theory, promulgated

and tested since 1900 by the Boston Consulting Group, holds that *labor hour cost* declines from factory *learning* far less than declines in the *total cost* of complex products as accumulated *experience* of the total organization increases. Both aspects of cost decline are important to asset turnover and efficiency. Both are important to product quality. Both are important to corporate strategy and long-term investment. Market share capture and market position defense are aimed at competitive cost reduction and competitive advantage, through the learning that comes with volume. Investment strategy in these terms is based on long-term discounted cash flow analysis: cash paid out to capture market share and learning and experience, matched against cash received back when low unit cost compared to competitors is achieved. Annual reported "earnings," or ROI, tell little about company health in terms of such strategic long-term investment programs. This important thing is positive program net cash flow ROA over time, discounted for time value.

The company managing that type of program well over time, with mature, low-unit-cost product lines throwing off cash to fund research and development, early start up, and pursuit of market share in new product lines, in a "*portfolio*" of ventures with different time horizons, is likely to be a healthy and valuable component of the defense industrial base (BCG Concept).

Achievement of cost declines by learning and experience depends, as does effective asset management, on several preconditions: good management, appropriate incentives for quality improvement and cost reduction, and stability of operations, so that there is opportunity for full and effective and continuous use of plant assets and peoples' skills and motivation. The company decision-maker evaluating investment opportunities must weigh the effect of probable instability on volume production quantities, learning, experience, cost decline, and asset turnover: All affect the ultimate return flow of cash which, discounted back to present value, must justify the investment in terms of a "cost of capital" or hurdle rate of return. In some aspects of the defense business, such as heavy capital investment or fixed price development contracting, there is the chance of disaster—betting the company or career.

Profit Policy, Reality

Government profit policy, based on repetitive costly studies and seemingly endless finepoint debates, deals with the relationship of pre-tax profit to allowable cost through the "weighted guidelines." It attempts to increase profit margin, or decrease it, in this way, by controlling its negotiators and contracting officers by explicit direction in the "guidelines." Section 2 of the GAO proposed Profit Reports Act of 1986 says:"...provide profits that...are reasonable in light of...profits contractors earn on... similar private sector business."[11] What considerations affect "reasonable" and "similar?" Do they include attractiveness of ROI over time to lenders and equity investors? Does "similar" take into consideration the position of the business on the experience curve; the position of the program or business or its phase in the company strategic portfolio; start-up, market-share pursuit, or the mature production phase when real return is realized? Is the competitive rank of the company—and trend—gaining market share, slipping, or liquidating? As to ROI "reasonableness," is it "annual" or "program" based? Is it cash or "book accounting?"

What makes the profit of a "similar private sector business" relevant? Are its risks "similar?" The defense company competes against *all* businesses to get cash from investors.

The government cannot say whether its "profit policy" is "effective." "Profit 82" said no; DFAIR and the GAO appear to differ on the matter. The GAO says: "...defense firms continue to exhibit low relative investment compared with non-defense firms, and the gap appears to be widening. This contradicts the DFAIR suggestion that the gap is narrowing."[12] The DFAIR appears to show concern that in the defense industry it found "building expenditures increasing at the expense of equipment."[13]

Investment and Asset Management—Instability

As noted earlier, investment is not likely to be encouraged by profit margin changes alone because efficiency, S/TA, is an essential factor in ROI. The government as sovereign and as monopsonistic customer establishes laws, regulations, policies and practices which adversely affect effective asset turnover, and make an adequate ROI unnecessarily uncertain. Defense is a low-margin business. It requires effective asset management. To induce contractor investment, problems relevant to asset turnover, and ROI long-term must be addressed.

These problems include:

—Program instability[14]
—Uncertainty
—Stretchouts
—Delays
—Indecision
—Inconsistent policy (decentralized)
—Excess regulation
—Management layering with excess requirements for recurring and multiple briefings and pre-briefings by DOD line managers at decision points
—Fad government "initiatives" not always based on full professional thought
—Annual budgeting and funding
—Annual requirements contracting
—Excessive bureaucratic staffs
—An "army" of single interest advocates, and redundant auditors and inspectors general
—Price-only competition and auctions, the "low bid focus"
—Fixed-price contracts for high-risk development
—Technology transferred among competitors covertly in "parallel negotiations," or explicity by compulsion after the investment is committed
—Transfer of risk and cost to contractors, small and large.

The DFAIR includes much useful analysis of investment behavior and deterrents to invest; e.g., Section III-19 on red tape, regulation to correct the "abuses of a few" strangling the system, and hostility, all as perceived by contractors, who make investment decisions (also, see V1-4).

All those problems may be difficult to deal with but they are reality, and it is not realistic to act as if studying and tinkering with profit margins will affect significant investment decisions in that environment.

That is what the company investment decision-maker sees, along with what the 1986 Packard Commission saw, a "total focus" on the "low bid," a "police state mentality," and an acquisition management system where the "obvious requirements for a successful program," the principles of classic, professional, decentralized line management, are "honored in the breach."[15]

There is evidence that these deterrents to investment by the company manager affect investment by possible stockholders in the company, and in the defense industry itself. The stock market evaluates a company (and its industry) by looking at annual earnings per share and the stock price in relation to that. The price/earnings multiple (stock price divided by annual earnings per share) or PE tells the capital market view of the investment. A discounted PE reflects a lack of confidence.

—"Trends appear to favor *a continuation of the industry's current 20-25% price/earnings valuation* discount vis-a-vis the broader industry averages."[16] according to respected analysts.

—"...40% to 60% discount..." of the industry PE. *Fortune* March 16, 1987, p. 66.

That would mean the company, or firms comprising the mobilization base, is at a competitive disadvantage raising equity capital (cash) to invest in competing.

It appears these deterrents to ROI justification for defense business investment have an impact that overwhelms profit policy changes, weightings, and debates among the GAO, DOD and others; in the main, they deal with profit margin, or talk about ROI without consideration of the need for effective asset management and utilization.

Recommendation-Reality

A more rational approach would be:

—Recognize the overwhelming asset management or S/TA problems.

—Do what we can about them:

As described in AFSC "Affordable Acquisition" Study 1983.

—Program and funding stability is much of the answer. Note: Stability is essential to achievement of learning and experience-curve effect.

—Learning and experience-curve effects are critical to:

—Effective asset management, or S/TA
—Unit cost reduction
—Quality
—Corporate health

—Centralize control of profit and other policy in OSD.

—Proceed with the Packard Commission 1986 "Formula for Action" recommendations—classic, decentralized, professional line management. Incidentally, decentralized management of execution of programs requires central control of policy.

—Reinvigorate the 1981 Carlucci Initiatives, including Recommendation 1, Decentralized Management.

—Put in place, or recognize, contracting officers with education, experience and authority, and go back to reliance on their informed good business judgment. Provide them, to consider but not to be bound by, quantified guidance on profit such as that in DOD FAR Supplement Part 15.

—Punish and *deter* wrongdoing, but don't try to *prevent* all wrongdoing at any cost.

—Provide broad defense industry profitability data for the information of program managers and contracting officers on which to develop their acquisition and contracting strategies, and their sound business judgment. Such industry data might be:

—After tax net income (after tax and all costs, not just allowable costs).

—Net income divided by sales, or profit margin.

—Net income divided by total assets, or ROA or ROI.

—Sales divided by total assets, or asset turnover, the measure of efficiency (to be achieved by *effective* company management, to the extent permitted by defense acquisition policy and practice and the actions of program managers and contracting officers).

—Net income plus depreciation, or cash flow, divided by total assets, or cash flow return on assets. Cash flow over time indicates the real health of the company (or the industrial mobilization base).

—Debt to capital ratios, which help indicate corporate health.

—Financial liquidity ratios, which help indicate corporate health.

—Stock market price—earnings ratios, compared to broad market, which indicate corporate and mobilization base health in the capital market where companies seek cash by selling stock or borrowing.

—Capital investment (maybe as a percentage of sales and of cash flow). How much of the cash flow is being reinvested long-term? What is happening, as a matter of fact, should indicate whether there are incentives to investment that are working over time in the national interest. Capital investment should not be an end in itself, or a favored investment.

—Investment in independent research and development. This could be one indicator of the future health of the industrial base, and of its weapons technology competitive edge vis-a-vis the Soviets.

—There probably should not be an attempt to say what is an acceptable level of profitability (ROI). At best, it could only be a range, given the variety of risks, strengths, and business portfolio characteristics of the defense companies. The ultimate question would be whether over time, the well-managed defense companies or effective competitors are meeting their cost of capital requirements, by their ability to attract equity investment (market price performance of the company stock) and debt capital (credit ratings and terms of available credit lines). If a company is doing particularly well, that may be acceptable if it is an effective competitor delivering high quality

and low total cost to the government. Ask whether it is continuing to invest and compete. What happens over time is relevant. Annual comparisons of one financial accounting measure of profit or another to non-defense industry are not relevant.

—Make sure effective competitors and low-cost producers have a fair chance to win and keep winning. Don't favor them, but don't stack the deck against them, as in the parallel negotiations "best and final" auctions and forced transfer of technology to competitors.

—Leave investment decisions to well-managed companies and their managers.

Finally, let the acquisition system and the people in it work and find the satisfaction of effective service to the nation. Stop the flood of procurement "initiatives." Where an "initiative" is necessary, see that it is thought out in advance by competent professionals. Given the volume and complexity of business done in defense acquisition, there will be mistakes and wrongdoing. As to fraud, we should rely more on deterrence. Prevention of all mistakes and wrongdoing is impossible, and efforts to prevent at any cost a recurrence of the problem of the moment can be stifling and demoralizing to the reliable people in the work force. That means the leaders must stand up to criticism. The work force deserves that.

Endnotes

1. DFAIR, III-5. "Defense Financial and Investment Review," DOD, June 1985. "...management seeks...diversification...products which are in different phases of their life cycle...."

2. GAO "Assessment, etc.," Appendix IX, p. 123.

3. GAO Exposure Draft, p. 2, above.

4. The GAO says "A major disincentive to defense contractor investment is the cost based nature of DOD profit policies—contractors' profits could decline if their investment in productivity enhancing equipment reduced costs...." It is true that absolute profit on a future contract, calculated as a percentage of cost, might be less. But profit margin or the ratio of net income to sales would not be less and asset turnover, or sales related to total assets, which reflects efficiency should be higher, improving ROI. See discussion of "DuPont Formula" in text. ROI, not "profit," is objective of the professionally managed company. Of course, given DOD's low-bid focus, it may well have contractors that are not professionally managed. GAO Assessment, p. 52. See also, DFAIR, p. VI-1.

5. Air Force Systems Command "Profit Study '82," p. 53, Finding 1.

6. Profit '82, Finding 10, p. 56.

7. National Security Industrial Association.

8. Drucker, "Changing World," 1982, pp. 70, 63.

9. As to the DuPont Formula and defense business see also Perino, "What Price Defense," *Program Manager*, DSMC, May-June 1983, and Chisholm, "Return on Assets," *National Contract Management Journal*, Volume 19, Winter 1985.

10. Asset turnover is discussed as "operating leverage" to increase return on equity (ROE), or to lower profit margin for the same ROE, in DFAIR, III-6. It can increase ROE and ROI. ROE is ROI leveraged by debt: Net Income Total Assets X Total Assets Stockholders Equity = NI SE.

11. Exposure Draft, p. 32.

12. GAO, Assessment, p. 54. Also pp. 3-4.

13. DFAIR, p. VI-19.

14. Addressed by the AFSC 1983 "Affordable Acquisition" study.

15. Packard speech, NSIA, Washington, D.C., June 10, 1986, and "A Formula for Action," Report to President, April 1986.

16. Messrs. Demisch, First Boston Research Report, April 2, 1985. (Stock price on market = annual earnings per share multiplied by price/earnings multiple: EPS X PE = Price. The PE is said to reflect the "quality" or probable durability of the earnings.)

17. GAO Assessment, p. 26.

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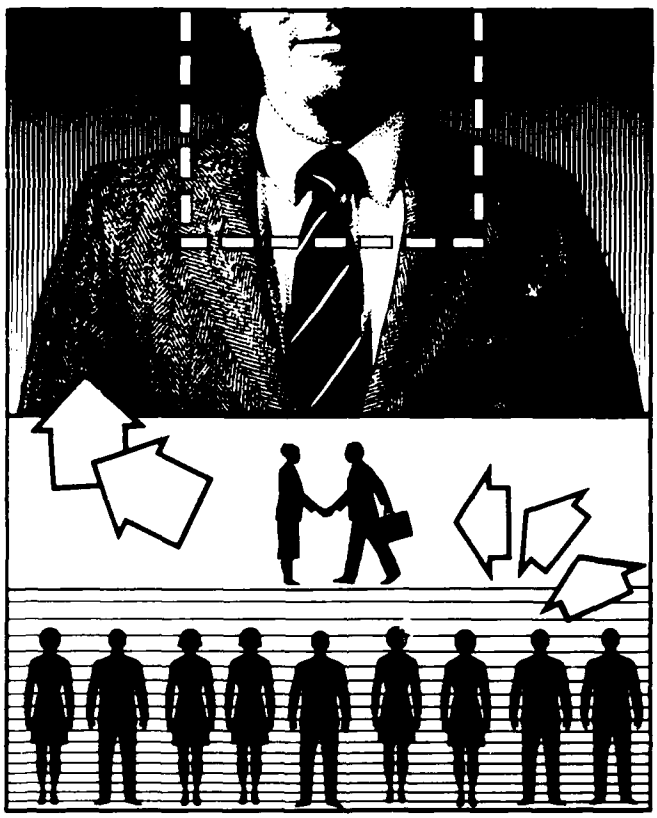
LEADERSHIP AND ADMINISTRATION IN THE TECHNICAL ENVIRONMENT

Joseph W. Lee



The objectives of this article are to examine the environment in which scientists and engineers operate most effectively and to identify leadership and administrative skills appropriate to creating that environment. The research method consists of gathering information from books and journals written by experts in the technical environment.

I examine management theories and opinions of experts and compare their findings with my personal experiences and observations. The end-product represents the value-added approach to leadership and administration in the technical environment, which consists of unique attributes and other factors contributing to leadership effectiveness. Transitioning from a technical professional to an effective technical manager requires understanding the following:

- Unique problems associated with leadership and administration exist in a technical environment.
- Skills and techniques to achieve effective leadership need to be identified.
- Current findings and merits of the Situational Leadership Theory can be applied.

Complexity of human behavior in organizations must be understood.

It appears leadership alone, without other management skills, can partially accomplish organizational effectiveness. The degree of effectiveness is a function of variables which behaviorists have not addressed adequately. It appears a proper mixture of personality traits *and* management skills are desirable in the successful development of effective leadership and the quest for the ideal manager-leader.

Technical Environment

Types of environment influence motivation, performance and job satisfaction. Effective organizations create favorable environments for their human resources to achieve high productivity and job satisfaction.

Why Engineers and Scientists Often Fail as Managers

Baird addressed the real-world environment of technical management by telling managers how to manage people and make decisions.[1] He has practical management experience and believes engineers and scientists are rarely trained for management and that competence in management can be learned.

Owen C. Gadeken, Director of the Education Research Team at the Defense System Management College, wrote a research paper and formulated the following conclusions:[2]

- According to AT&T management assessment surveys, engineers are less prepared than others for middle management. The assessments were based on management skills and abilities possessed by three categories of college majors. The humanities and social sciences group rated at 4o percent potential, business majors at 31 percent and engineers at only 2o percent. These statistics have been verified by AT&T as quite accurate and confirmed by empirical data.

- According to Pelz and Andrews, scientists and engineers performed best when conditions leading to security (in their environment) coexisted with factors creating challe[illegible]e.[3]

- Current research on managerial effectiveness supports a situational or contingency theory of management.

- Most people could be trained and assume leadership and managerial positions.

- The most important skills for engineering management are interpersonal, communication, team building, and conflict management.

Gadeken's data indicated that moving from technical specialist to manager may not be an easy transition. He quoted a management training authority, Dr. Richard Boyatzis, by stating that "It is usually not the lack of knowledge, but the inability to use knowledge that limits effective managerial behavior." Recognizing that feedback is needed to learn and reinforce management skills, the Defense Systems Management College at Fort Belvoir, Va., has made changes in its curriculum to provide simulations designed to recreate the multiple problems and complex interactions characterizing the managerial environment. I believe simulation of management concepts and applications using computers artificial intelligence and expert systems will provide breakthroughs in training managers.

It is clear that leadership and administration in a technical environment is different than in other environments such as production, wholesale-retail, and the military. Skills identified by Gadeken are extremely important in a creative atmosphere. I can confirm from my experiences that these skills, plus the ability to manage change, are necessary for success in dynamic and changing technical environments.

Skill Requirements for Engineering Managers

Specific skills needed to manage effectively in today's demanding engineering environment were investigated by H. T. Thamhain. His paper examines the association between skill-level and managerial performances, and sources for potential skill development.

Thamhain's paper focuses on the process of and criteria for identifying and developing engineering management skills, considering their actual effectiveness and success in leading engineering organizations.[4] Thamhain stated that specific skills necessary to manage effectively in an engineering environment can be categorized as leadership, technical, and administrative skills. Furthermore, managerial skills can be learned by experimental on-the-job-training through professional seminars and formal schooling. He stated that "the engineering manager must be a social architect who understands his organization, its culture and value system, its environment, and its technology. The days of the manager who gets by with technical expertise alone or pure administrative skills are gone." In general, the skills needed to be an effective manager are not normally found in engineering types.

Hersey and Blanchard said some organizations believe that the desirable executive is dynamic, imaginative, decisive, and persuasive.[5] I believe these general attributes do not adequately describe the skills and abilities needed for the technical environment. Wortman, who had practical experience as a technical manager and as a management consultant when I met him in Palo Alto, Calif., has identified some specific skills needed in technical management:[6]

- Communications
- Conflict Resolution
- Motivation Productivity
- Interpersonal
- Intergroup
- Intragroup.

Wortman, a former assistant to a vice-president in a *Fortune 500* company, was suddenly assigned the responsibility to manage more than 100 people. He concluded that "People are intensely complex. People problems are among the most common causes of mismanagement and project failures." His unique experience prompted him to write the book, *"Effective Management for Scientists and Engineers."*

Leadership Transition from Engineering to Management

W. F. Peck, technical management consultant, provided test data regarding the personality-interest profile of the scientific personality.[7] The following is a summarized description of the profile based on written tests given to technical professionals:

—High analytical interests
—Conservative
—Dependent on facts
—Low trust in support from others
—Zero defect, detail oriented
—Individual thinker and doer
—Reactive orientation.

Peck argued most engineer-managers failed to transition from technical competence into management competence because they lacked an understanding of group behavior. The following characteristics may explain why the transition can be difficult without training and conscientious effort of the technical professional to become a team builder:

Contributor

—Individual Thinker
—Decisive-Unyielding
—Task Oriented
—Self Dependent
—Autocratic Style

Team Leader

—Group Discussion Analysis
—Ability to Gain Consensus
—Goal Oriented
—Group Interdependent
—Democratic Style.

According to Peck, two specific changes must take place as a scientist develops into a professional manager. First, the leader's relationship with the

product or service must change from *direct* to *indirect* involvement. The leader who has performed so well dealing directly with projects and technical problems must now learn to deal indirectly. The orientation changes from solving and controlling technical problems to leading and teaching others to solve technical problems, and dealing directly with projects. Second, most professionals enjoy the informal atmosphere of a small group and lack the commitment to become better professional managers. As the organization grows, its leaders must recognize and support the unpopular position that more formal policies and procedures are necessary.

Real World Environment

The technical environment is a complex organization where professionals are highly educated, with definite personalities, and specialized skills. It is an environment where the specialized knowledge of a junior engineer can at times have expert power, and influence colleagues and the manager-leader. The technical environment, as observed by me, is situational because its demands by people and tasks require different management styles at different stages. Is it any wonder managing becomes more difficult because of rapid changes and constant conflicts unique in technical environments? It is apparent that legal or organizational power does not lend itself to dynamic and creative environments.

A leader-manager must recognize there is no absolute power and that the best approach is using personal power and participative management style to influence subordinates to produce at peak efficiency, and to motivate and keep employees satisfied enough to stay with the company. In my opinion, mismanagement has added to problems of employee absenteeism, turnover, and mental health. Unfortunately, U.S. corporations are too busy worrying about short-term goals and who is continually involved with reactive management. There are not enough good managers to pay adequate attention to the intervening variables and strategic planning.[8] The intervening variables represent the internal state of the organization which are influenced by organizational leadership strategies and styles, management decisions, company philosophies, objectives, policies, and structure. Strategic planning reflects the organization's mission, long-term objectives and goals, and compatibility with the demands of the environment (internal and external).

What is an ideal environment? Chris Argyris, behaviorist, challenges management to provide a work climate in which everyone has a chance to grow and mature as individuals and as members of a group by satisfying their own needs, while working for the success of the organization.[9]

leader-manager must recognize there is no absolute power and that the best approach is using personal power and participative management style to influence subordinates to produce at peak efficiency, and to motivate and keep employees satisfied enough to stay with the company.

I believe organizational factors are numerous and, at times, unpredictable and can impact a manager's success and effectiveness. One of the problems with incompetent management is stifling of creativity and innovation in technical environments. Appropriate handling of environmental situations and intervening variables (which determine the long-term effects on organizations) becomes an issue difficult to teach; the conscientious manager should be willing to learn from experiences and from available techniques during the process of managing.

Leadership and Administration

Leadership and administration concepts and theories have evolved during the years from the classical management style, scientific management movement, human relations movement and, now, the behavioral approach to management. Still, mismanagement is widespread in corporate America and there exist ineffective solutions to overcome organizational problems caused by bad managers. One would conclude that management theories and concepts are either not appropriate or not being used properly. Often, misuse of management theories stems either from the managers having been inadequately trained or from lack of genuine commitment to a positive, communicative managerial method.

Boyatzis said "It is usually not the lack of knowledge, but the inability to use knowledge that limits effective managerial behavior." According to Hersey and Blanchard, society changes make effective leadership in the future a more challenging task, requiring greater sensitivity and flexibility. I believe management of people is a complex and challenging process. Problems of management are attributable to people, manager and subordinates. Therefore, Peter Drucker's statement "Managers (business leaders) are the basic and scarcest resource of any business enterprise," should be true forever.

Effective Managerial Leadership

According to James Cribbin, there is more to being a manager than becoming a leader.[10] Leadership is one element of the overall managerial job, something many behavioral scientists have failed to recognize. Management and administration are geared to the achievement of organizational objectives but, at times, leadership may be exercised to thwart attainment of these very objectives. Reality is that many executives do not have the ability to motivate subordinates. Some are more interested in achieving personal goals and are engaged in demotivating rather than motivating.

Note that the manager is the leader of people when they *allow* him to influence their thinking, attitudes and

behavior. Influence implies the manager is accepted by subordinates, looked to with respect for guidance and direction, and perceived as capable of helping satisfy needs and aims. At the heart of the influencing process is the impact one human being has on others. It is clear that a manager making no impact on subordinates or the organization is not doing a good job.

By definition, organizational leadership is the ability to influence the thinking, attitudes, and activities of others so they *willingly* direct behavior toward organizational objectives. Cribbin claims there are four major dimensions of managerial leadership:
—Personality of manager-leader (as perceived by followers)
—Personality of group (as perceived by leader)
—The Situation: Manager must *accommodate* leadership actions to the situation, and not expect situations to meet preconceptions
—Organizational Factors: Manager must be sensitive to environment (politics, power groups, top-management beliefs, associates, superiors, followers, and situational variables).

Cribbin, professor of management, St. John's University, England, argued that a manager must recognize that the legal right to manage others does not qualify the manager to lead. The leader must earn a psychological and sociological right to do so because influence is merited and gained, not coerced and demanded. The manager must build a relationship based on mutual trust, respect, and consideration.

Leadership and Motivation Research

The concept of situational leadership is the outgrowth of the Michigan University and Ohio State leadership studies, which provide the basis for Blake and Mouton to develop the two-dimensional leadership model called the Managerial Grid. Subsequently, Fred E. Fiedler developed the Contingency Leadership Theory; Hersey and Blanchard developed the Tri-Dimensional Situational Leadership model.

Michael Wellin argued that behavioral technology (BT) differs from the conventional methods and approaches in the applied behavioral sciences.[11] In place of elegant models and theories about why people behave in particular ways, BT emphasizes the need to collect objective information about the way they *actually* do behave. By collecting solid evidence about what a person is doing, we can make accurate assessments and interpretations about factors determining this, and then plan actions to bring about desired changes (BT supports the idea that accurate assessment of the follower and environment is the key for using the situational leadership model effectively). The central concept is the use of transactional analysis (TA) as a framework for understanding what people do. Wortman and Blanchard and others support TA as a useful technique in understanding people's behavior better.

Michigan Leadership Studies

These studies concluded the *employee-oriented leader* accepts that every employee is an important individual with personal goals, whereas the *production-oriented leader* emphasizes production, viewing employees as tools to accomplish organization goals. The following behaviorists provide more supporting data to the Michigan Studies.

- Victor Vroom and Floyd C. Man
—Closely-knit units prefer employee-centered supervision.
—Those who work on their own, prefer directive approaches.
—Participative approach did not help productivity and attitudes for the less independent needs, but it did improve those people who have strong independence needs.

- Rensis Likert
—Concluded it is the management philosophy permeating an organization that is crucial, not results obtained from studying lower-level supervisors and managers. His findings in patterns of management indicated that:

—Employee-centered management gives better performance.
—Job-centered management has low productivity.
—Moderate supervision is associated with high productivity.
—Cribbin supports Likert in stating the Michigan and Ohio State Studies emphasized the wrong end of the organizational structure. It would have been far better had they studied those at the top of the hierarchy instead of supervisors who carry little or no clout.

Ohio State Studies

The studies indicated there are two orientations in leadership:

—Initiating Structure—A structured (well defined) pattern of organization, channels of communication, and methods of procedure. The focus is on corporate demands.

—Consideration—Maintain trust, respect and two-way communication between the leader and staff members. Focus is on participative management and the need of employees.

The Ohio State studies have the following implications:

—Employees desire consideration and superiors prefer structure.

—Superiors can compensate for high structure by increasing their consideration behavior, but low consideration cannot be compensated for by lowering structure (a confirmation of preference for people-oriented leaders).

—Superiors who have high consideration can increase their structure with little increase in grievances (consideration overcomes the negatives of structure).

Managerial Grid

The Blake and Mouton leadership model attempts to categorize the leadership styles by creating four quadrants of behavior for leaders. They were determined on the basis of degrees (high/low) of concern for either *production* or *people*. The model was used worldwide mainly because, for the first time, theories and behavioral patterns identified by Michigan University and Ohio State were translated into a model managers understand. The problem is this theory is an either/or situation. It does not provide for a range of behaviors ap-

propriate to the situation. The model does support the idea of participative management style and that high concern for people and production is the best style.

Contingency Leadership Theory

Fred E. Fiedler concluded there are three variables significant for leadership effectiveness:

—Leader-Member Relations—there must be acceptance and trust.

—Task Structure—the degree to which a given task can be done by the members.

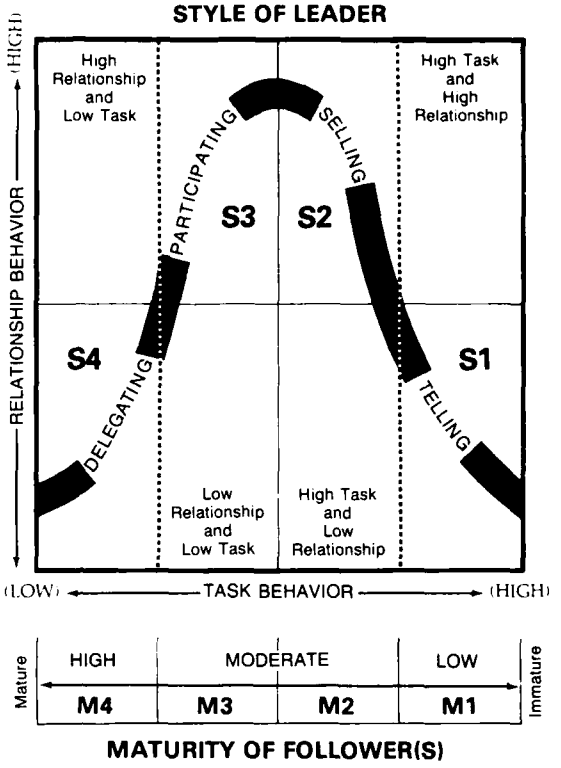
—Position Power—the degree the position enables the leader to get the group to comply to his direction (This is reward and punishment power).

These factors interact with the group leader's knowledge to define favorableness of the situation. It is interesting that Fiedler's theory allows modification of situations to fit the leadership and is often applied in the real world because task-oriented (directive) managers and human relations-oriented (non-directive) managers can be successful in certain conditions. The caveat is that managers should relate their actions to Rensis Likert's Theory on Organizational Effectiveness where he identified three variables (casual, intervening, and output) which are interrelated and affected by management/leadership actions. The effective manager should be sensitive to short-term achievement and to the long-term impact of intervening variables affected by casual variables, leadership strategies, management decisions, organizational objectives, and policies.

Situational Leadership Model

Hersey and Blanchard, using the Managerial Grid concept, further improve it to account for the maturity (competence and motivation) level of the followers. Their theory is based on the leader's behavior, the degree of task, or relations orientation. The leader decides on an approach by knowing the situation relating to the task at hand. Success of this model depends on the leader to *diagnose correctly* the follower's competence and commitment to accomplish each goal. To motivate people effectively, management must use appropriate leadership styles in working with *differing* people. The situation is a function of the follower's maturity, competence, and motivational levels. The major difference of their theory is that it provides for changing the leadership style as the follower increases in maturity (therefore needs less task orientation). Situational leadership (Figure 1) focuses on appropriateness or effectiveness of leadership styles according to the task-relevant maturity of the followers.

FIGURE 1. SITUATIONAL LEADERSHIP (BLANCHARD AND HERSEY)



Rensis Likert's Management Systems Theory

—System 1 (Exploitative)—Task oriented, highly-structured authoritarian management style.

—System 2 (Benevolent)-Manager still makes decisions, but employees have some degree of freedom in performing their jobs.

—System 3 (Consultative)—Manager consults with employees before establishing goals and making decisions.

—System 4 (Participative)—Relationship-oriented management style based on team work, mutual trust and confidence.

Likert believes System 4 is the most productive style of management. It has the following characteristics:

—Leadership
—Motivation
—Communications
—Decision-making
—Interaction and Influence
—Goal Setting
—Control Process.

These attributes, in my opinion, are appropriate and definitely represent minimum requirements for a manager-leader to achieve organizational effectiveness in a technical environment.

Implications and Observations

The following represent observations and opinions as a result of the literature search.

—Leadership can be counter productive if it is directed toward personal goals, thereby disrupting the organization. The effective leader knows leadership is the sharing of credit, blame, ideas, opinions, and experiences. The leader must ensure that individual goals and organizational goals are not in conflict. Organizational effectiveness can be accomplished only when all goals are in harmony and when society's needs are satisfied; otherwise, the organization will eventually fail.

—The profile of engineering graduates indicated they are generally not people-oriented. Engineering schools should put emphasis on interpersonal skills. Courses in managing, humanities, ethics, and value systems can be of great value to prepare people for management. Note that additional demands are made on management because of the increasing size and complexity of organizations, acceleration of technology, and changes in the demands of society and employees.

—In addition to management skills needed in planning, organizing, influencing and controlling, the manager-leader must develop necessary skills to manage conflict and change. Futhermore, development of ethics and convictions is important for accomplishing long-range organizational goals instead of just personal goals.

—The earlier leadership studies of personality traits are useful in providing answers to the missing link of why there are few effective managers. Although experts believe managerial skills can be learned, training takes years to implement and depends on the quality of instruction but, to a greater degree, on willingness and commitment of the trainees. The answer has to be the lack of positive personality traits, which are important to make or break a potentially effective manager-leader.

—It is generally accepted that to change managerial styles is difficult and time-consuming. Fiedler claimed it takes 1-3 years of intense conditioning to effect managerial style changes. Likert found it takes 3-7 years to implement a new management theory effectively. Therefore, top-management commitment is required to make changes which will have long-term effects. This fact may explain why mismanagement continues; it is because great effort is required to overcome resistance to personality changes.

Although experts believe managerial skills can be learned, training takes years to implement and depends on the quality of instruction but, to a greater degree, on willingness and commitment of the trainees.

—Understanding human behavior is crucial in management and in applying the Situational Leadership approach. Managers must have the ability to diagnose the environment and adapt their leadership styles to meet demands of their environments. Central to the approach is the consideration of situational variables and behavior of the leader in relation to followers. The crucial element in the Situational Leadership model is that the leader must be able to diagnose the environment and situational variables *correctly*.

Leadership and Organizational Effectiveness

Leadership and administration are aimed at achieving organizational objectives. Organizational effectiveness is achieved by competent leadership and application of managerial skills. These skills are technical, conceptual, and human factors which include the manager-leader's sensitivity to psychological, sociological and anthropological concepts. Mastering these concepts and functions of management (planning, organizing, influencing, and controlling) increases leadership and organizational effectiveness.

I believe it is more important for the manager to make *correct assessments* of the situation; understand what kind of behavior and which characteristics are likely to attract or alienate the work group. The theories should be understood and apply at appropriate situations.

—Contingency Theory

Fiedler's theory provides for a range in leadership behavior, varying according to the practical situation the manager faces. It allows for a change in behavior as the favorableness changes. It is less rigid to adherence to a given approach regardless of circumstances of a particular group.

It can be implied that the controlling and directive technique works best for either the accepted manager or a rejected manager. The reason is because the accepted manager can be forceful because he is accepted, whereas the rejected manager must be forceful because he has no alternative (if he tries to be non-directive, the group might abandon the task entirely). This agrees with the finding that the structure can increase if consideration is high, but lowering structure does no good if consideration is low. Managers who resort to pressure, power, and punishment to get things done are using a short-term technique, which will fail eventually.

—Situational Leadership

The Tri-Dimensional Leadership Effectiveness Model improves Fiedler's theory with a third dimension (effectiveness) by allowing the combinations

of task and relationship orientation along the continuum in question (at a particular situation). It is apparent that the situational approach to leadership was evolved from the studies by Michigan University, Ohio State University, Fred Fiedler, and Hersey and Blanchard. Recent findings suggested leadership is dynamic and situational.

The leadership process is a function of the leader, followers, and situational variables. Therefore, the leader-manager should understand there is no single, all-purpose behavioral style effective in all situations. Effective leadership behavior, management style, is situational. According to Hersey and Blanchard, the key to effective leadership is to identify the maturity level of the individual or group, then bring to bear the *appropriate leadership style.*

It can be implied that the behavioral approach requires continual adjustment and reinforcement of behaviors between leader and follower; influencing power is earned and that raw power is delegated by organizational structure. The effective manager has proper attitudes and interactions toward subordinates for reinforcing their acceptance and for satisfying expectations (accomplishment of individual goals) of the subordinates.

—Motivational Theories

The leader cannot be effective without understanding what motivates people. The following motivational theories provide a framework for the leader to incorporate into the management process:

—McGregor's Theory-X and Theory-Y: Leader should understand that it is only an attitude or assumption about people (not the people's behavior).

—Maslow's Hierarchy of Needs: Leader should always determine motivational level of people/followers.

—Herzberg's Motivation-Hygiene Theory: Leader should ensure the environment (job security, working conditions, supervision, interpersonal relations) are being satisfied and the motivators (recognition for accomplishment and challenging work) are present at the work place.

—McClelland's Achievement-Motivation Theory: Leader should understand people like to set goals that are potentially achievable. Therefore, participative management and MBO are effective techniques.

—Berne's Transactional Analysis: Leader should use this framework as a tool for understanding what people do and, in particular, the variety of feelings they express. Understanding human nature helps the leader apply the situational approach in leadership.

—Management Traits Approach

Ghiselli's Trait Approach to Leadership has identified the six most significant traits of personality and motivation. I believe leaders should develop or learn these attributes, which could make their job of managing more effective:

—*Supervisory ability:* Performance of the basic functions of management including planning, organizing, influencing, and controlling work of others.

—*Need for occupational achievement:* Seeking responsibility and desire for success.

—*Intelligence:* Creative and verbal ability including judgment, reasoning, and thinking capacity.

—*Decisiveness:* Ability to make decisions and solve problems capably and competently.

—*Self-assurance:* Extent to which individual views himself or herself as capable of coping with problems.

—*Initiative:* Ability to act independently and develop courses of action not readily apparent to other people. Self-starter—able to find new or innovative ways of doing things.

Management Model

I believe organizational effectiveness can be achieved only in an environment that encourages creativity, trust and open communications. Effective managers should use participative management styles and build relationships with subordinates based on mutual trust, respect and consideration. The manager must be flexible and apply a holistic approach to the management process. First, the manager must ensure the Herzberg environmental/hygiene factors be satisfied in terms of providing a desirable climate for productivity; second, use the Hersey and Blanchard Situational Leadership theory to motivate subordinates; third, to be effective the manager must understand and apply the following concepts and disciplines.

—*Integration.* Goal attainment depends on individual goals (superiors and subordinates) in harmony with (not opposing to) organizational goals. The organization should create a climate in which one of two things occurs: Individuals *either* perceive their goals as being the same as goals of the organization, *or* believe personal goals are being met through achievement of organizational goals. The effective manager has the responsibility to unify people through leadership, motivation and communications skills, behind organization goals and strategies.

—*Participation.* Research data confirms participative management techniques, involving employees in the decision-making process, tend to be effective in our society. Therefore, the leader-manager should permit mutual establishment of goals and increase subordinate commitments to organizational objectives through the use of management by objectives (MBO).

—*Attitude.* Theory-Y, according to McGregor, is an assumption that people are mature and responsible. Work is as natural as play. People can be self-directed and creative at work, if *properly motivated.* These assumptions are not only necessary, but demanded by employees in the technical environment. Note that these theories represent attitudes (not behaviors) toward people, and that Theory-X attitudes have no merit in creative environments.

—*Motivation.* Maslow's hierarchy of needs explains different levels of human needs. Herzberg's motivation theory supports Maslow's and provides a framework that explains the relationship of human goals (incentives) and needs (motives) that produce behavior in organization. Herzberg claims that the environmental (hygiene) needs must be satisfied before a person can be properly motivated. This conclusion is con-

firmed by Pelz and Andrews that "scientists and engineers performed best when conditions leading to security coexisted with factors creating challenge." Environmental needs are physiological, safety, and social; they include company policy, supervision, working conditions, interpersonal relationships, money, status and security. Motivational needs are esteem and self-actualization; they include achievement, recognition for achievement, challenging work, increased responsibility, growth and development.

—*Leadership Style.* Leadership is to influence the behavior of others to achieve (any) goals. Management is a special kind of leadership for achieving *organizational goals.* Leadership is dynamic and situational; current research indicated that leaders must adapt their style of behavior to meet the particular situation and the needs of their followers. Effective leadership (L) is a function (F) of the leader (l), the follower (f), and situational variables (s). It can be defined as L=F (l,f,s). The key for success is to diagnose the environment *correctly* and use the appropriate leadership style compatible with the follower's maturity level. Environmental variables are the leader, followers, superiors, associates, organization, job demands, and other variables. Note that no all-purpose leader behavior style is effective in all situations. The type of leader behavior needed depends on the situation; therefore, leadership is situational.

—*Management Style.* Many skills are needed to be effective, and the most important skills in the technical environment are *technical* skills for interfacing with technical people; *leadership* and *motivational* skills for team building; *communication* skills for coordinating ideas and concepts verbally and in written form; *integration* skills for unifying of strategies, goals, and concepts. It is apparent that the management process is complex and demanding; therefore, many skills and abilities are required to manage in a technical environment. These realities suggest that the technical manager must be flexible, able to manage change, and able to use a holistic approach in managing.

Conclusions and Recommendations

The current research data support the Situational Leadership Theory, which addresses behavioral patterns between leaders and subordinates. However, leadership effectiveness is influenced by top management, the leader's superior and the firm's culture. It is useless to expect human relations courses to improve supervisors and lower-level managers when their superiors and the climate of the organization do not change. Furthermore, the manager must have many other skills to deal with in the real world. Note that leadership effectiveness may or may not be management effectiveness. The degree of management effectiveness is a function of many variables. Leadership alone, without management skills, only partially accomplish organizational effectiveness. Mastery of the form basic management functions (planning, organizing, influencing, and controlling) is not enough. I believe the effective manager should have skills in analysis, coordination, integration, negotiation and communication plus the ability to manage change in a dynamic and technical environment. The difficulty in combining so many qualities may explain why mismanagement is prevalent and consistently erodes our ability to compete in world markets.

There exist significant factors which directly influence organizational effectiveness. These factors are organizational structure, top management philosophy, company focus and politics. The successful manager understands human resources and interactions and the use of positive power to accomplish organizational goals. The degree of success will depend on the manager's *technical, people,* and *conceptual* skills to overcome a host of problems existing in the technical environment, where ability to manage *change* is a critical requirement. According to Cribbin, "There is much more to being a manager than becoming a leader. Leadership is but one element of the overall management job." Baird, Wortman, and I can confirm the fact that managing involves many other skills that must be brought to bear in the technical environment.

The theorist claimed that management skills are learnable; why then, do we have so many deficiencies in management? In my opinion, personality traits play a more important role in managing than the theorist can hope to quantify. Personality attributes such as judgment, courage, motivation, integrity, fairness, intelligence, ethics, creativity, decisiveness, flexibility, influence and compassion represent some of the most sought-after traits in a manager. It is apparent these attributes are important factors affecting the leader's power base and influence. It is fair to say that most people in management positions lack many of these attributes.

I believe behaviorists do not have complete answers to the problem of mismanagement. The personality *and* appropriate skills must exist to hope for and develop an effective manager-leader. There might be hope over the horizon due to technology advances in artificial intelligence and expert systems. They will provide excellent management simulation training systems by providing repetition, practice, and reinforcement of skills and habits (which cannot be altered without serious and concentrated efforts). Learning technologies of the future will replace existing management training approaches efficiently and effectively.

To achieve organizational effectiveness, the manager must be *flexible* and use a *holistic* approach in management. It is apparent understanding management science is only part of the answer; an effective manager must be the catalyst, who can make an impact on the organization, and be an implementor of *ideas* and *changes* to achieve organizational effectiveness. One important task for the manager is to ensure that individual goals are compatible with organization goals. It is the duty of the leader to communicate and influence the people above, around, and below to ensure the organization is moving in one direction.

I conclude neither management theories nor leadership alone can make an effective manager. This has been confirmed by the abundance of training programs and endless problems

created by mismanagement. Nor does experience mean that a person can, or has, become a good manager. Ten years of experience is worthless if based on one year of substandard experience repeated ten times. A person cannot acquire effective leadership attributes and management know-how without first having the capacity (intellect) to learn *and* the *proper attitudes* (commitment). The "commitment" is a personality trait separating the successful from the unsuccessful.

Obviously, many managers rely on raw power and show little interest in developing effective management techniques. They view learning these skills as a monumental task, especially since it involves understanding themselves and modifying their behavior.

At this point, the personality trait approach to leadership makes sense and begins to separate the manager-leader from the ineffective manager. I believe a proper mixture of personality traits and management skills are desirable in the succcessful development of effective leadership and the quest for the ideal manager-leader.

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AGENDA ITEMS

(Continued from page 15)

compete because duplicative tooling would be too costly.

What is it? It's what a program could cost if we, the government and contractor together, eliminate the nonvalue added work, or waste, done by the contractor and ourselves. This waste unwittingly may be required because of regulations driving up contractor overhead. It also bears on what the program could cost if the plant were being operated efficiently.

"Could cost" does not replace competition and also can be used in competitive situations. It is different from "should cost," which is based on lessons learned and other historical factors. It can be used at any point in the acquisition process, but is best if introduced early so advantages accrue all along. It means looking at everything—type of contract, number of audits, contractual organizational structure, required documentation, quality systems, every aspect of business. Contractors with whom I have discussed this tell me it's possible to reduce costs a minimum of 25-30 percent, and that's significant.

Since government has the leverage, advantages to the government are obvious. But what about the contractor? It's like this—a forced streamlining and belt tightening. By playing "could cost," his competitive position will be enhanced. In these days of fewer defense dollars, he needs every advantage. What better incentive?

The big items I have mentioned are extremely important to us, and we are working hard on them. The ultimate requirement is cultural change. Outstanding leadership and management are mandatory if we are to make it happen.

I earnestly encourage your participation. Spread the word.

Dr. Costello was on the DSMC Campus in December. These remarks are excerpts from his graduation address to the Systems Acquisition Management Course for Senior Officials.

CAN THIS PROGRAM BE SAVED?

Kenneth B. Stinson

No one can say the life of a program manager is without its ups and downs. You're a successful program manager in your company. Your multi-million dollar program is ahead of schedule, well within cost, and meeting all of its technical goals. After months spent building a team and getting the design off the ground, you've reached the point where you finally have a little spare time on your hands. It wasn't easy, but you kept ahead of things, paid attention to small problems and never let them become big ones. Every time you pass the water cooler, the office wags are talking about Program B which is in real trouble. But you're enjoying your moment in the sun so you don't pause to ask what "real" trouble means. After all, you're riding the crest of success and the existence of a troubled program is not your concern.

Then comes the unexpected call from your boss. He wants to see you first thing in the morning. You can't imagine what he wants to talk about since your program is in such good shape. When you get to his office, he starts the meeting by telling you how much your program's success means to the company. So far so good. Next comes the discussion about Program F. He tells you that "we all know" that it really needs help and he believes that you're the person to step in and get this mess squared away. You come out of your boss's office in a slight daze, saying to yourself, "What did I do to deserve this?"

But wait. Don't despair. You just might be in for the most fun you've ever had as a program manager; meeting the challenge of doing the best job you can to turn a program around, get it on its feet, and watch it go. When you undertake this assignment with a planned approach and a sense of direction, this could be one of the most rewarding efforts of your career.

As you start to consider ways to proceed, your first task is to discover what your boss means when he says that the program is in trouble. Trouble is a generic term which has multiple meanings. Symptoms of a program in trouble could be: behind schedule, overcost, failure to meet technical requirements, or combinations of the above. But these are only symptoms of the problems which trouble the program. Problems which result in these symptoms can vary. Your boss has a responsibility to you to identify the cause of the program difficulties as he sees it. When he does this, he provides you with your marching orders. Your research may even bring other problems to light.

In a further effort to determine the cause of the trouble, you should talk to various persons who have worked on the program at different levels and times and, therefore, have different perspectives. Once you have gathered all the interview information you can, spend some time evaluating everything you've heard, being sure to plug in your knowledge of the people with whom you have talked. Don't spend an excessive amount of time elaborating on the problem.

Let it suffice that you know what the major cause of the trouble is and have succeeded in further identifying other areas of concern. Steer a middle course between your drive to learn everything there is to know about how the program reached this point and your equally strong drive to begin to turn the program around. Because both of these considerations are important, do not confine yourself to one at the expense of the other. Always remember, however, that although your objective is to turn the program around, you cannot achieve this without knowing what caused the trouble in the first place so that the same mistakes are not made again.

At this stage you are attempting a difficult balancing act in which you want to keep the program moving but, at the same time, change its direction and develop a new plan for completion. Decisions you make now will be instrumental in getting the program back on its feet as soon as possible. Various management tools and techniques are designed to provide the program manager with the structure on which to build a healthy, successful program. This key element is the recovery plan which will be discussed.

Before a plan can be developed and a team put together, a program manager's first step is to ask what the requirements of the program are. In other words, "What is the objective?" To assist in this task, a program manager has a variety of documents available. The first document is the contract signed by the company and the customer. Another source of data is the proposal. Both documents will provide the new program manager with details of what has beeen agreed to and all other aspects of the program. Don't forget that the proposal may have been modified as a result of negotiations. Get a copy of those changes. Within the basic question is another similar question: "What does the contract say?" This question must be answered in the presence of the customer and with complete customer agreement. This is not to say that reasonable persons can't disagree because we all know they can. However, any perception on the part of a company which is not agreed to by the customer is completely useless as the foundation of a program plan. If there is an honest disagreement, we all win if that disagreement is brought out as soon as possible. It is totally futile for a company to proceed with a plan which is based only on its own perceptions and to which the customer has not even been asked to lend its agreement.

The second step critical to the successful completion of this task is picking the staff to work with you on this problem. It is possible there will be no need to adjust personnel on the program, with the exception of the program manager. If identifying the program's problem spots pinpointed key personnel as being part of the problem, their duties may have to be changed, or other assignments found for them. However, it is more likely that the program will profit by the addition of strong persons who are highly skilled in specific areas. Good candidates might be persons who are knowledgeable in planning. If the program involves design, development, and production, strong configuration management or quality assurance personnel might be added. Adding competent personnel to a program will generally be accepted by personnel already on a program. This, however, becomes a more difficult situation when the program is in trouble.

A major point to be remembered is that every effort must be made not to replace personnel now working on the program. Often, personnel working on a troubled program are not highly motivated at this time. Therefore, the new program manager must make changes very carefully to maintain current program momentum. Finally, when competent persons are added to a program, and are accepted by existing personnel, they bring new ideas and a fresh approach to existing problems. Keep in mind that new is not always better. Beware of the "new broom sweeps clean" syndrome.

Now that you have asked the question of what the program requirements are and determined what staff changes, if any, you should make, you have to get down to the business of developing plans for completion of the program. You will start with the list of requirements which you identified when you reviewed the contract and the proposal. These requirements must be handled one at a time. For each requirement you must show the contribution of that requirement to the program work breakdown structure (WBS), program schedule, cost plan, and technical plan. This may seem like a simplistic approach to the development of a new program plan but it is absolutely essential to have these four documents in total agreement.

The key to saving ourselves a lot of effort is to utilize the existing program documents for the initial cut at developing the plans. Allow yourself to make required changes or you might lead yourself down the "yellow brick road" and recreate situations which caused part of the problem at the start. Have confidence in the decisions you have reached as a team.

Reworking these plans is probably the most demanding and detailed activity you will undertake to get this program back on track. It may be the most important of all tasks. When this task is completed, which may take weeks, you will have provided the total work breakdown structure, program schedule, cost plan, and technical plan for the completion of the program. One major caution to observe as you develop the cost plan and schedule is that you must have an understanding of these points with the personnel who will be directing each cost account. Completion of these documents without the agreement of these individuals is wasted effort.

At this point, you have reviewed the requirements. You have reached agreement with the customer, and have developed an understanding as to what each requirement means. You have then analyzed each requirement to show its cost and schedule impact. The result is a work breakdown structure, program schedule, cost plan and technical plan which is realistic and agreed to by all program personnel.

Before proceeding to the next phase, let's talk about these documents. We have noted they are based on requirements as defined in the contract. In addition, information available before starting the effort on this troubled program has been used.

The work breakdown structure is obviously one of the key documents in any program. In the particular situation with which we are dealing, a work breakdown structure most probably exists. As the new program manager, you will make every effort to use this document to the highest degree possible. Should a situation arise where it becomes necessary to make a major modification to the program WBS, it will require the approval of the customer. Whether or not changes are required, the final WBS must be the expression of the total program you will be directing.

The program schedule you develop, based on your review of the requirements, can take almost any form. It should be a form with which you are comfortable. Whatever form you chose, it must be totally consistent and driven by program requirements. It must be consistent with the WBS you have developed.

The major usefulness of the schedule in monitoring the conduct of the program is twofold. First, the schedule is the key "sheet of music" from which everyone sings. Second, each program milestone is identified on this program schedule. From this schedule, we can draw a list of these milestones and sort them by responsible individual by month. This then provides a tool you can use monthly to ensure you are doing everything possible to keep the program on schedule. You now have identified tasks which must be accomplished, responsible individuals, and due date for each task. Milestones should be posted for all to see and understand.

The third major output of the analysis of the requirements is a cost plan. The cost plan is a detailed listing of the monies to be spent through the completion of the program. It must show each task and the expenditures planned. The plan must be consistent with the WBS and the schedule which has been developed. It must list expenditures to be made by task and by month.

The way that you use this cost plan is directly related to the cost system existing in your company. If you are fortunate, you can receive actual expenditures weekly by cost account. I will make that assumption during this discussion. If you get this data monthly, you should follow the same general procedures we will be discussing. Of course, you only will be able to analyze the program cost status monthly.

Finally, you come to the technical plan. This is a description of the tasks required to accomplish technical requirements for the program. It includes all the design, development, manufacturing and test efforts leading to program completion. This plan should be prepared by senior engineering personnel working on the program. It should directly relate to the WBS, in that it identifies and provides many of the tasks which make up the structure. This leads to the major input of the preparation of the program schedule and the cost plan.

> The program schedule is the key 'sheet of music' from which everyone sings, and it identifies each milestone, which all should see and understand.

Now we will consider that phase of the effort easiest to ignore; that is, the follow-through on plans you have established. The reason it is easy to ignore follow-through is that it requires tremendous attention to detail; following problems through second and third order questions will find the program manager tired of repeating the same detailed questions. Major words in your vocabulary are why, when, and why not?

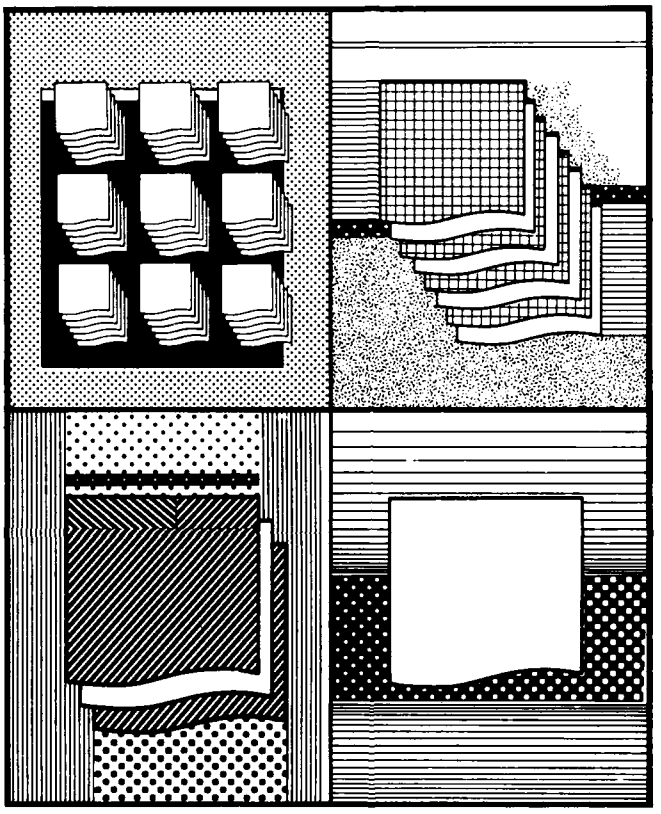
Two tools you will use during the second phase of your recovery plan are weekly cost reports, plus your mission report. Weekly cost reports will vary depending on the type of information you get from your company's management information system. This will allow the program manager to determine two points about each cost account. Ideally, the program manager should be able to track actual versus plannned cost expenditures on a weekly basis. Variations between planned and actual costs are the first indications that you will need to delve into the particular cost account using the "why" and "when" technique. It is probably more important to the program manager when the cost account manager is underspending than as when one is overspending. When underspending is occurring, it probably means that work is not being done. It is probable that you will see a slip in the schedule. Of course it may be the work is being done for less than the original estimate. This is the best of all worlds. Overspending is the more obvious data to be followed in great detail.

The second point to consider when reviewing cost data is any change indicated in the final cost of each account. At first glance, you may think that this indication is easy to visualize. It is not so clear cut, however, when you look deeper. There are three possible variations when you look at changes in the indicated final cost (IFC) during a period of time: (1) that the plan has not changed, (2) the newer IFC has decreased, or (3) the IFC has increased. If the IFC has not changed and all milestones are being met, then the cost account is under control. Growth of the IFC is a danger sign which must be investigated until the program manager understands the cause of the cost growth. Finally, a decrease in the IFC is good for the total cost of the program *only* if milestones are being met. This means that you didn't have a particularly good estimate in the beginning. You can live with those types of mistakes.

A full analysis of the indicated final cost must be done in conjunction with the milestone schedule. It is critical that

(See SAVED, page 39)

Alton R. Brown *Judith J. Gordon*



This paper discusses and provides an example of how management control of acquisitions can be increased through the use of fundamental management principles in tailoring Department of Defense standards. As defined in DOD Directive 5000.43, acquisition streamlining is any action that results in more efficient and effective use of resources to develop, produce, and deploy quality defense systems and products.[1]

Overspecification is the use of overly restrictive, inappropriate, or extraneous standards and specifications, in part or in whole. Thus, in its application to defense solicitations and contracts, acquisition streamlining seeks to avoid overspecification by ensuring that only the standards and specifications[2] appropriate to each stage of the acquisition process are utilized and that the standards and specifications are tailored to the circumstances of the particular acquisition. Acquisition streamlining, as used in this paper, addresses the tailoring of military standards.

Background

Overspecification is an expensive and cumbersome acquisition control process. Yet, our experience on numerous system acquisitions reveals that overspecification is common. The 1977 *Report of the Task Force on Specifications and Standards* of the Defense Science Board provides the results of an extensive study on the use of standards and specifications to project needs, thereby avoiding overspecification.[3] The MIL-HDBK-248, however, did not result in improved use of standards and specifications, as the Board had recommended.[4]

More recently, the President's Blue Ribbon Commission on Defense Management (the Packard Commission) made recommendations for improving acquisition organization and procedures.[5] These and other recommendations are being implemented through the reorganization of the Department of Defense and restructuring of the acquisition management process. Program managers and managers in the newly established position of Program Executive Officer must now operate in an environment in which efficiency and control of major system acquisitions are principal and highly visible objectives. In this context, it is useful to consider the role of standards and specifications in achieving management control and to identify ways in which they can be used more efficiently and effectively as management control tools.

Standards and specifications generally are based on sound management principles and cumulative industry experience for achieving desired results. However, in the standard and specifications themselves, this information has been converted into sets of prescribed activities, to the exclusion of the principles and experience on which they are based. Although it is intended that the standards and specifications be tailored to the specific acquisition program, the focus on activities fails to provide managers with the necessary tailoring information. Emphasizing the management prin-

ciples and desired results underlying the standards and specifications will lead to simpler, more cost-effective program controls and to more streamlined acquisitions.[6]

Purpose of Standards in Management Control

To identify areas in which standards can be streamlined, it is useful to examine their purpose. Military standards are intended to provide the controls necessary to assure that the project work proceeds smoothly, properly, and according to accepted methodologies. Controls are information and measurements that provide a means to an end—management control or direction of the project work. Tailoring of standards requires an understanding of the characteristics of effective controls and of how controls are used to provide project direction.

Peter F. Drucker points out that in the context of management, the word "controls" is not the plural of the word "control," and that more controls do not necessarily give more control.[7] Drucker identifies criteria that control must satisfy to give managers control.[8] Among these criteria are that controls must be appropriate to the character and nature of the phenomena measured. In addition, controls must be economical and simple. That is, they must provide the minimum information needed to understand a phenomenon; they must not be overly complicated. Too much information and complexity will cause confusion and misdirection, thereby undermining management control. Further, controls must focus on results and key objectives. Whereas control of a few factors can yield a significant impact on performance and results, control is lost by trying to direct the infinity of events that are marginal to performance and results. Finally, controls must be focused on action; they should not generate information for its own sake.[9]

Military standards provide methodologies for carrying out specific types of work, such as engineering management, configuration management, and software development or for developing management or technical tools, such as a work breakdown structure, a trade-off study, or a test and evaluation plan. Standards, when cited in contracts, prescribe the methodologies to be used to develop and execute the program baseline; i.e., the critical cost, schedule, and technical information against which progress will be measured. Thus, invoking standards is invoking a system of controls on how management will be carried out, and implementing the standards on a project generates the management controls (i.e., information and measurements) for that specific project. Project direction is based on the information provided by the project-specific controls.

For example, the MIL-STD-490A system specification standard provides a set of controls for developing the system's functional and performance characteristics.[10] Once developed, the system specification becomes a control for subsequent engineering work. The MIL-STD-881A work breakdown structure standard provides controls for developing the cost and scheduling baseline.[11] Once developed, the work breakdown structure in conjunction with the project cost and schedule data becomes the project cost and schedule controls. The MIL-STD-1521B establishes the controls for conducting formal program reviews.[12] The reviews themselves are controls on the stages of project work.

Because military standards describe generic methodologies, they do not provide controls that satisfy Drucker's criteria. Without modification, these standards will not support management control. Therefore, to increase management control, standards must be tailored to be appropriate to the specific acquisition project. The absence of correct tailoring can result in a program baseline that is excessive, inappropriate, or confused. Directing project work according to such a baseline can lead to the conduct of inappropriate work and to the inability to assess project status or progress.

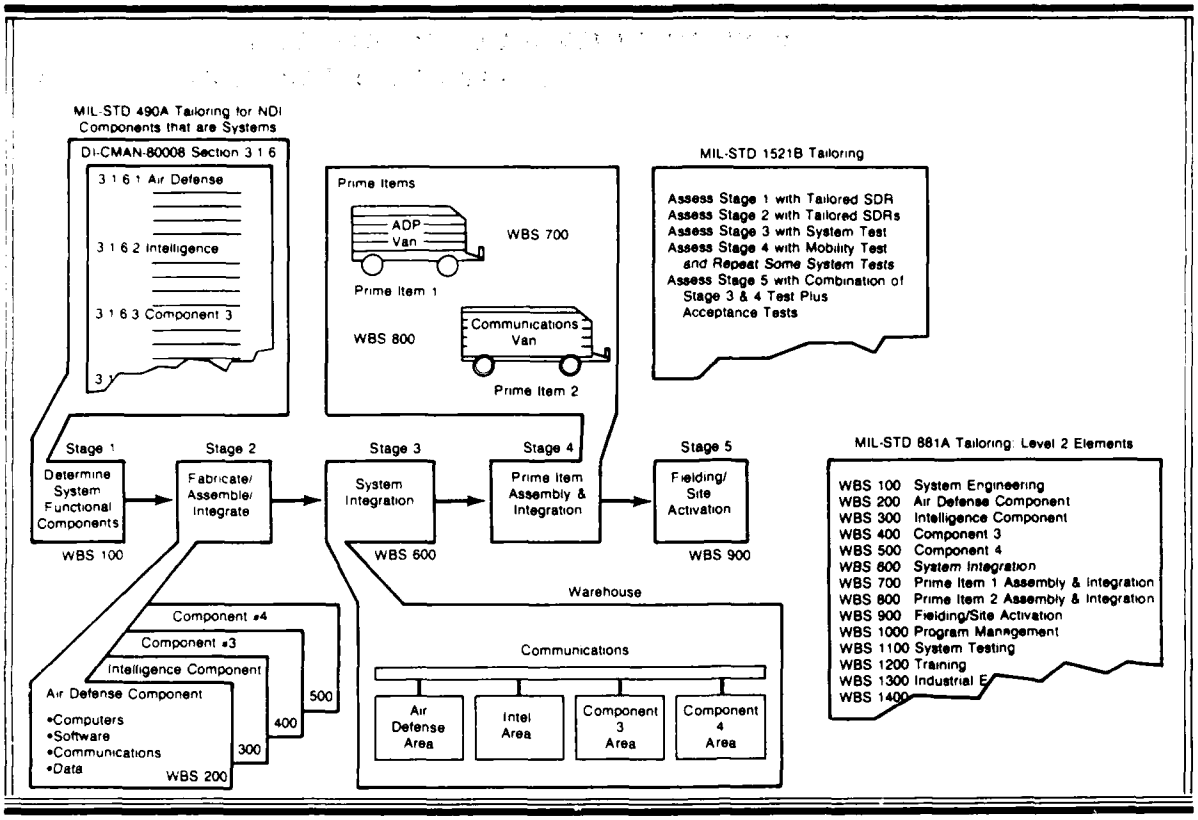
Enhancing management control takes on particular importance in view of recent legislation and Department of Defense policy. Specifically, the Defense Acquisition Improvement Act of 1986 implements the Packard Commission recommendation that managers of major new programs prepare a baseline agreement describing functional specifications, cost, schedule, and other factors critical to the program's success.[13] Within the terms of the agreement, the program manager is expected to be given full authority to execute the program. The Packard Commission recommended that program managers who adhere to their baseline be given DOD support before the Congress for multiyear funding. Tailoring of standards is essential to developing a well-defined, achievable program baseline and to providing the management control to stay within that baseline. Therefore, the adaptation of military standards to provide effective controls is essential to attaining stable and autonomous acquisition programs.

Management Principles

Successful streamlining begins by analyzing the work according to fundamental management principles. These principles are as follows: (1) organize the work according to the objectives of the project, (2) organize the work into homogeneous stages that are individually assessable in terms of operational requirements, and (3) organize the work in each project stage according to its outputs.[14] This analysis of work allows us to organize the acquisition project so that it can be directed and controlled. After completing such an analysis, we can streamline the standards for system specifications, work breakdown structures, and reviews and audits for the specific requirements of the project.[15] Tailoring the standards to the project provides tools and information to support management control. In our example, we will streamline these standards for acquisition of a hypothetical transportable C³I system that is composed primarily of commercial off-the-shelf equipment.[16]

Streamlining a Transportable C³I System Acquisition

Streamlining of a transportable C³I system is illustrated in Figure 1. The objective of acquiring transportable C³I systems,[17] as opposed to fixed facilities, introduces certain peculiarities into the acquisition process that prevent the direct application of standards. That is, while the prime



items[18] of a transportable C³I system are the individual shelters and their contents, none of the shelters necessarily performs an operational end-use function. This is because the system must be broken down into configurations that will fit the physical limitations of the shelters. This concept is shown in Figure 1 in which Stage 2 is organized according to operational end-use functions (air defense, intelligence, fire support) and Stage 4 is organized by prime item (i.e., the transportable shelters and their contents. In this example there are two prime items, a shelter containing the communications equipment and a shelter containing the automated data processing equipment.

The prime items of fixed systems perform distinct end-use functions, and the standards for system specifications, work breakdown structures, and reviews and audits are directed toward the development of prime items that perform end-use functions. In contrast, for a transportable system the early stages of work must be defined according to end-use functions. In contrast, for a transportable system the early stages of work must be defined according to end-use functions, while the later stages of work are defined according to prime items. Thus, the standards must be tailored to accommodate this difference.

This unique feature is an important factor in determining the work to be performed to build a transportable C³I system. Proceeding backward, the work can be determined as follows: The last step is the fielding of the system. Prior to fielding, the system must be completely fabricated and qualified. The last step in fabrication is placing the equipment into the shelters. It is important to assure that the system works properly before it is placed into the shelters to reduce the risk of having to remove any part of the system after placement in the shelters. To accomplish this, the system must be totally assembled in a single location and all the major functions verified. Prior to that stage, the individual system components must be assembled and qualified. Prior to the assembly and qualification of the individual components, these components must be identified.

Based on this analysis, the homogeneous stages of work are as follows: (1) identify the system components through trade-off studies and other analyses, (2) fabricate the components, (3) integrate the components into the complete system, (4) assemble the system into the shelters, and (5) field the system.

Streamlining has been achieved, in part, by adapting the work to the nondevelopmental nature of the acquisition. The component fabrication stage has been substituted for the conventional configuration item design, development, and fabrication stages. The result is that the government project office manages a larger unit of work and eliminates unnecessary work, and the contractor is relieved of the burden of producing performance and fabrication specifications for small components of the work.

Additional streamlining may be achieved in selecting the size of the components receiving management attention. These components can be systems, subsystems, or configuration items. Selection of these components affects the degree of management control of the project by the government and is a decision that the project manager must make. When the acquisition comprises primarily commercial off-the-shelf items, the independent components can be complete systems or subsystems without unacceptable loss of control, rather than the usual hardware or software configuration items called for by the system specification standard.

The work breakdown structure follows directly from the stages of

work derived for the system acquisition.[19] In particular, the work breakdown structure uses the stages as major elements and supplements these elements by the work that cannot be attributed to any specific element, such as project management. The work in any stage is organized around the output of that stage. The output of Stage 1 is the system specification. The outputs of Stage 2 are the components that perform specific end use functions. The output of Stage 3 is the totally integrated system. The outputs of Stage 4 are the prime items; i.e., the shelters and their contents. The output of Stage 5 is the operational system.

Streamlining of the standard on reviews and audits follows directly from the definition of the stages. The completion of each stage represents a milestone in the project. A major review is conducted to verify that work within a given stage has been completed and that the next stage can proceed without serious risk of having to repeat or correct work performed previously.

Tailoring of these standards is guided by the requirement to maintain project management control. Management control is achieved in this example by designing each stage of work to be operationally assessable. Consequently, the reduction in the number of work stages, the selection of relatively large system components receiving management attention, and the reduction in the number of reviews and audits do not expose the government to an unacceptable level of risk since at each project milestone meaningful feedback on program progress can be obtained. A further benefit of operational assessability is that the responsibility for completing the project can be transferred to a new organization at minimum expense at the end of any single stage of work, if necessary.

Conclusion

We have shown how fundamental principles of management can be used to streamline acquisitions significantly. We have reduced the stages of work receiving management attention, simplified the work breakdown structure, and reduced the number of milestone reviews. This has been done by careful analysis of the work required to build a transportable C³I system. We have used the results of our analysis to tailor selected standards to the unique characteristics of the project.

This approach to streamlining will increase management control. By condensing the standards to produce only essential information, we have made our control mechanisms economical and relevant. By carefully specifying stages of work and milestone reviews, we provide the necessary control information at appropriate places in the development process. Finally, by designing the stages of work to produce operationally assessable outputs, we obtain the information necessary to determine whether the project may productively proceed to the next stage of work or whether and what additional actions are required to complete the current work stages.

ne benefit of operational assessability is that the responsibility for completing the project can be transferred to a new organization at minimum expense at the end of any single stage of work ....

By reducing the number of controls, the span of control of individual managers may be increased, thereby allowing a small project office to manage effectively a large acquisition.

Our streamlining example satisfies the recommendations of the Packard Commission Report[20] encouraging streamlining of military specifications for commercial off-the-shelf items and invoking neither minimum nor maximum but only relevant, requirements. Our proposed streamlining principles support the development of achievable program baselines for major system acquisitions, which contribute to program stability and autonomy. These principles support implementation of the Packard Commission's recommendation to reduce substantially the number of acquisition personnel.

These management principles may be applied to acquisitions requiring high-risk developmental items, such as new software. By utilizing principles discussed here, the project manager may tailor the management controls to be commensurate with the risk posed by developmental items.

Endnotes

1. DODD 5000.43, *Acquisition Sreamlining*, January 15, 1986, p. 2-1.

2. Defense Science Board, *Report of the Task Force on Specifications and Standards*, Washington, D.C., April 1977, pp. I-4-I-5.

3. MIL-HDBK 248, *Guide for Application and Tailoring of Requirements for Defense Materiel Acquisitions*, April 1, 1977.

4. A draft of MIL-HDBK-248 has recently been reissued under the title, *Acquisition Streamlining*. Although this draft represents a considerable improvement over its predecessor, it omits many management principles needed to assist the reader in applying management judgment to streamlining decisions.

5. President's Blue Ribbon Commission on Defense Management, *A Quest for Excellence*, Final Report to the President, Washington, D.C., June 1986, pp. 39-71.

6. The concentration on activities in the system of standards and specifications in pervasive. For example, the stated purpose of MIL-STD-483 entitled, *Configuration Management Practices*, is to set forth the activities of configuration management. The MIL-STD-490 entitled, *Specification Practices*, prescribes a set of practices or activities. The MIL-STD-1521, *Technical Reviews and Audits for Systems, Equipments, and Computer Software* lists review activities. Finally, MIL-STD 881, *Work*

Breakdown Structures for Defense Materiel Items, focuses on practices. These standards are among those identified by the Defense Science Board study as having considerable financial impact on a project. All are focused on activities, not results.

7. Peter F. Drucker, *Management*, Harper &Row, New York, 1974, p. 494.
8. *Ibid.*, p. 498.
9. *Ibid.*, pp. 499-504.
10. MIL-STD-490A, *Specification Practices*, June 4, 1985.
11. MIL-STD-881A, *Work Breakdown Structures for Defense Materiel Items*, April 25, 1975.
12. MIL-STD-1521B, *Technical Reviews and Audits for Systems, Equipments, and Computer Software*, June 4, 1985.
13. Defense Acquisition Improvement Act of 1986, PL99-661.
14. Drucker, pp. 198-206.
15. MIL-STD-490A, *Specification Practices*, MIL-STD-881A, *Work Breakdown Structures for Defense Materiel Items*, and MIL-STD-1521B, *Technical Reviews and Audits for Systems, Equipments, and Computer Software*.
16. Military standards and specifications were developed for acquisition of weapons systems. Applying standards and specifications to C³I systems requires more tailoring than for weapons systems.
17. Transportable C³I systems as used here refer to those systems that are housed in shelters that can be transported by air, sea, rail or road carriers.
18. A prime item is a complex item such as an aircraft, missile, launcher equipment, fire control equipment, or radar set, which is formally accepted by the government. A prime item typically performs an end-use function.
19. Good work breakdown structures will correspond to the standard only in the case of familiar weapons systems. Appendix B of the standard, the work breakdown structure for electronics systems, is not suited for C³I systems.
20. President's Blue Ribbon Commission on Defense Management, pp. 39-71.

Mr. Brown has 14 years experience in system acquisitions management at MITRE, IBM, Lockheed and Litton. Judith Gordon has 12 years experience in economic and policy analysis and system acquisition management at MITRE, Aerospace and elsewhere.

(Continued from page 34)

the person responsble for the cost account keep the plan updated as ...e situation changes on the program.

The second tool is a milestone report. The source of data you use to generate the milestone report is the program schedule. You must recall that you developed the schedule by sitting with the individuals responsible for program milestones and developing each phase together. As you sat with those individuals to discuss the total program schedule, you identified details supporting overall program schedule. This resulted in the milestone report.

The structure of the milestone report is such that each task to be accomplished is identified chronologically by month, by individual. For very large programs, you might only show milestones to be accomplished during the present month, and the next two months. One major point is that you never remove a milestone unless it has been accomplished. Therefore, you continue to show milestones which have not been completed even though the scheduled completion date has passed. The analysis of this report must be completed in conjunction with the cost report. When you do that we add to the usefulness of each report.

In summary, as the newly assigned program manager on a troubled program, your first task is to gather data initially from your boss, and then from individuals working on the program. Next, you form your team, utilizing qualified and knowledgeable existing team members and adding to that team where necessary. Then, a review of requirements is begun so that you can build the foundation for the completion of the program. This review results in cost, schedule and technical plans to drive the actions to be taken to complete the program. Publication of your monthly plans lists the report cards against which you are going to measure the performance of your team on these tasks. The proof is if you are able to meet your milestones and maintain cost control on the program.

When you are tasked to take charge of a troubled program, take comfort in the fact that there are definite actions that you can pursue which can lead to one of the most rewarding assignments in your career. This almost undefined task of monitoring and checking the daily, weekly, and monthly program performance will contribute greatly to your program's success. The greatest plan in the world, if not monitored, will not yield the desired results.

The challenge is tough but rewarding.

Mr. Stinson graduated from the Defense Systems Management College with PMC 72-2. He served in the REMBASS Program Management Office, Fort Monmouth, N.J., and retired from the Army in 1977. He since has been a program manager for GTE and for HRB-Singer on four major programs.

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Michael G. Krause

The search for managerial excellence can be challenging and fun. Some students in the Executive Management and Program Management Courses at the Defense Systems Management College (DSMC) have the opportunity to participate in the Looking Glass organizational simulation. Mirroring the Department of Defense world of acquisition management, participants ascertain what it means to be a manager in a world of pressure, conflict, ambiguity, imperfect communication, and resource constraints.

Looking Glass, Inc., a 50-year old glass company with eight plants, 4,000 employees and $200 million in sales, is the setting for this top-rated commercial simulation. The corporation has three divisions. Each division has a vice president, and directors of sales and marketing, manufacturing, and product development. The eight plant managers report to their division's director of manufacuring. In addition to their line responsibility, the president and three vice presidents serve on the management committee.

For six and a half hours, 20 students are the company's top management team and deal with typical tasks such as resource allocation, public policy, long- and short-term planning, personnel, lawsuits, acquisitions, and issues which might face managers in a corporation of this magnitude. Many of the day's tasks are apparent from materials provided to participants. There are challenges and opportunities which can be identified through memos, chance meetings, telephone calls, planned meetings, or newspaper articles. This is a day in the life of a manager.

How does Looking Glass help managers who are students at the Defense Systems Management College? By freeing participants from their real organizational life which is bounded by policy and procedures, they are able to concentrate on management. Running a glass company becomes a useful tool for identifying or verifying one's managerial style, and reflecting on how that style influences other people. The glass industry content is not important. For example, participants do not need a marketing degree to be successful as a director of sales and marketing, or an engineering degree to be successful as a director of product development. How the day's work is done, how problems are managed, and how decisions are made are the simulation's essence. To paraphrase Mark Twain, you can't change a person's point of view if their job security is at risk.

Participants are introduced to the simulation the day before the action begins. They view a narrative slide show to gain more understanding of the corporation. Additional realism is added as participants receive a glossy and embossed *Looking Glass Annual Report*. They learn ground rules for the simulation, and are told the plant managers are at corporate headquarters for a bimontly meeting. At this point students usually select positions they will assume.

An in-basket is given out of memos and reports the incumbent in each position sent and received the previous day. The DSMC faculty member conducting this introductory session suggests that participants should not spend more than 2 hours processing the materials before the simulation.

At home, the participant is free to review and prepare the information in any fashion. Reading the materials often triggers ideas of what the company needs, and an awareness of the work which must be done during the simulation. The way a student deals with homework often replicates work taken home from the real job.

As the next day begins, Looking Glass managers go to their offices, the telephone switchboard is turned on, and the business of running a multimillion dollar firm begins. The 20 participants have been told they are free to run the company as they please.

Arriving at work, each participant finds an office area with a desk, phone, in/out basket, office supplies (paper, pencils, pens, and stationary), waste basket, and chairs. Meeting tables are available. Vice presidents usually share a room, and each of the divisions have personnel clustered in three other rooms furnished in similar manner.

Soon, telephones start ringing, meetings are scheduled, memos are written, and people start talking. There is an opportunity for chance meetings at the coffee pot or water fountain. For the skeptical participant, running Looking Glass, Inc., becomes real. It does not matter if they have private sector experience. Their true personality and managerial style takes over as they respond to senior managers or handle managerial tasks unfolding during the simulation. Reflecting on his Looking Glass experience, Colonel Wendell B. Wood, USAF, said participating made him realize that effective managerial practices work in all organizations—profit and nonprofit; and, that it reinforced his managerial style.

A buffet is set up so that Looking Glass managers may eat when it is convenient. This allows the momentum of the simulation to remain high. It also may be the first opportunity for some managers to meet. A working lunch is not out-of-the-question. Often, problems discussed earlier reemerge and may be redefined based on new information learned during lunch conversations.

As the last part of the simulation, the president has scheduled a speech on the state of the corporation. When it is complete, the simulation will be over. Decisions were made, memos were written, meetings were held or scheduled, phones were used, and studies were initiated. Participants are surprised to find out that the *simulation has no last-minute surprises or mid-course corrections.* They really were able to run the firm in any manner.

Next, participants complete questionnaires to provide additional insights regarding how they ran the corporation, what they knew, who they worked with, and what problems they worked on. Participants now adjourn to their divisions to discuss Looking Glass experiences.

During the simulation, faculty facilitators have unobtrusively observed what is happening. The facilitators help the participant reconstruct, and assess what happened during the simulation. Exchanges following are the heart of the learning process. Participants are able to discuss and reconstruct what took place, activities they initiated, what they were thinking about when they took an action, or how another manager's words or actions affected their behavior. Like an onion, simulation events are unpeeled, layer by layer. This leads an individual to see how his or her managerial style worked, and how it affected other participants. Recalling his Looking Glass experience, Colonel Bruce M. Garnett, USA, said being able to see group dynamics in operation and get timely feedback "made this a very useful experience for me and, if given the opportunity, I would participate again."

With positive and negative feedback, the student is able to identify managerial strengths and weaknesses, and develop plans to improve effectiveness. Debriefings give the participant an opportunity to reflect on the organizational climate and hierarchical relationships which developed, how information flowed, where time and energy were invested, how decisions were made, and how well the division and company performed.

How does the Looking Glass organizational simulation differ from a case study? A lot of management data is in the material. The simulation is so realistic that data generated usually represent the participant's typical work behaviors. As in real life, the job is done based on people's knowledge, skills and abilities, and from what they find out. Problems become apparent through the various forms of communciations.

The information is not laid out neatly as might be the case where all participants start with the same material. While both may hint at a division or corporate problem at hand or in the process of developing, the simulation has real work to do. When that work is done, additional work is created as the simulation moves ahead. This is far different than the question-discussion mode which predominates the case method. Also, Looking Glass requires elaborate "classroom" space, and has a high teacher-to-student ratio.

The Looking Glass simulation allows the participant to:

—Do
—Look
—Think
—Grow.

Looking Glass began its development in 1976 when the Center for Creative Leadership received a 3-year contract from the Office of Naval Research to observe managerial behavior, and assess differences between effective and ineffective managerial performance. When participants clamored for knowledge of how well they did, a feedback component was added. This lead to the current simulation which has been widely accepted. With more than 480 runs, the number of participants is approaching 10,000.

Public and private sector organizations have used Looking Glass for:

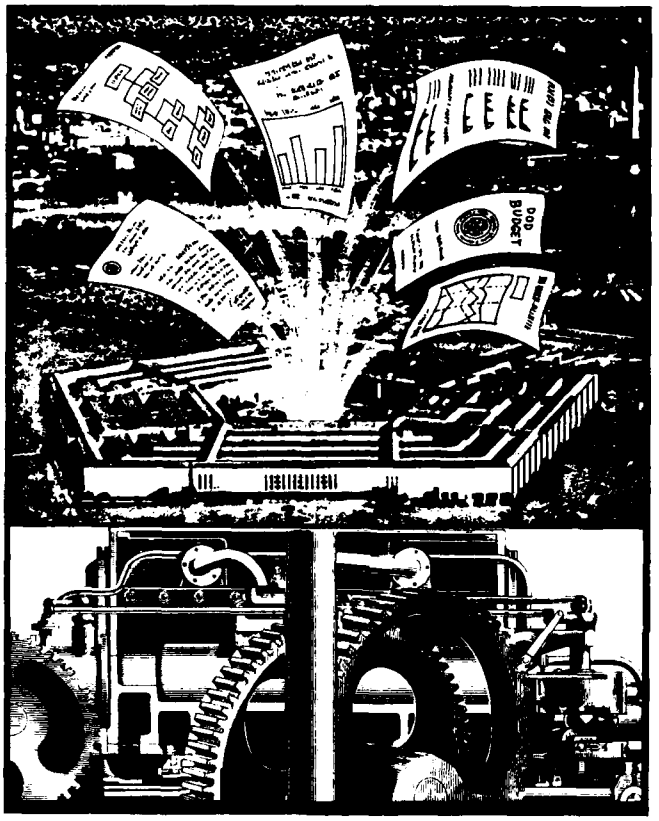
—Self assessment
—Team building
—Analysis of training needs
—Network building

(See LOOKING GLASS, page 81)

ACQUISITION ARCHITECTURE MUST IMPROVE

(Second of Series on Acquisition Management Productivity)

Dr. Andrew P. Mosier



As we look toward the future after celebrating the bicentennial of our constitution, the budget deficit and Gramm-Rudman-Hollings (GRH) legislation seem, at first, to require us to choose among three alternatives, all negative. Either reduce the appropriations that provide for the common defense—and risk not maintaining an adequate defense; or reduce appropriations for vital domestic programs—and "demote" the general welfare; or reduce both—and endanger our freedom and our well-being. There is, however, a positive choice: Increase productivity *substantially* in management of defense acquisitions—and provide adequate common defense and promote domestic well-being.

By "substantially," I mean, perhaps, doubling productivity or increasing it at least to the level believed possible by President Reagan's Blue Ribbon Commission on Defense Management (hereafter referred to as President's Commission). It notes that many accept the 10-15 year acquisition cycle as normal, even inevitable, but states, "We believe that it is possible to cut this cycle in half.[1]

Key to Productivity

Achieving such a substantial increase in productivity cannot be achieved by piecemeal improvements. It requires broadly based action: to improve and integrate major DSAM (defense system acquisition management) processes; to develop a more constructive defense acquisition environment; and to improve DSAM knowledge and information aids for managing integrated processes more productively in a constructive acquisition environment.

Managing acquisition of defense systems needed to support national military strategy is a complex process, a hierarchy of many dynamic and interdependent subprocesses. These DSAM subprocesses interact within and with the complex defense acquisition environment which helps shape the defense management culture.

At the apex of the hierarchy is the process of establishing national security objectives and formulating the national military strategy. This long-range strategy should be the strategy that best attains the national security objectives *within* the constraints of expected resources. Unfortunately, this ideal has not been achieved. The President's Commission found that the long-term, 5-year fiscal planning guidance for strategic defense is affected by changeable near-term factors in the environment of defense systems acquisition; i.e., the previous years congressional decisions and the current budget debate in the Congress. These induce instability into the long-range planning process. The Commission found that the Administration and the Congress induce more instability in the budgeting process.[2]

Acquisition programs bear the brunt of this fiscal instability, since acquisition of defense systems takes more of the discretionary part of the defense budget. The problem is exacerbated by GRH legislation. Thus, at the apex the DSAM process starts behind a funding instability "eight ball" in a troubled defense acquisition environment.

Below the apex the DSAM process continues down through the interactive processes of determining the needs and affordability for the hundreds of different systems required to perform the missions which support the long-range military strategy. The process twines through the interdependent processes of planning, programming, budgeting, and allocating funds at all levels, through research, intelligence, needs determination, congressional liaison, and oversight processes; and through contracting, designing, developing, testing, procuring, producing, provisioning, training, and other processes to field each system required to perform the missions. The DSAM process continues, through processes of modernizing and extending the life of useful systems, or selectively replacing obsolete systems, in support of the current national military strategy.

Many thousands of DSAM professionals[3] are required to accomplish these intertwined DSAM processes. Increasing productivity of these professionals, working at all levels in the Executive Branch, the Congress, the defense industry, other businesses and academia, is the key to achieving substantial increases in productivity in defense systems acquisition. If we focus on improvements that will significantly increase productivity of these DSAM professionals, we can achieve substantial cumulative increases in the productivity of all acquisition organizations. This would increase productivity in defense systems acquisition substantially.

Questions of Sufficiency

Maintaining our defenses in this dynamic world requires increasingly complex defense systems. Acquiring systems that are superior and affordable, in turn, requires DSAM processes that are increasingly complex and more productive. Getting ahead in this race—between the complexity of defense systems and the productivity of management processes—requires continual improvement in the processes and the environment of defense acquisition and, particularly, improvement in aids to increase productivity of DSAM professionals.

To this end, we should review past DSAM approaches and improvements, seeking to identify proven successes and past insufficiencies, judging whether or not each approach or improvement increased productivity substantially. To get ahead, we must use results from this research in a broad three-pronged endeavor:

—To continue successful approaches and build upon proven successes
—To remedy past insufficiencies that are correctable
—To find out how to cope better with insufficiencies or problems inherent in complex DSAM processes and in the environment of defense acquisition.

The ominous shadow cast across our future by the tremendous federal deficit, and by threats of more arbitrary defense budget cuts generated by GRH legislation and the new INF Treaty environment, demands concentration on improvements which will be sufficient; i.e., which will increase productivity substantially. We can no longer afford to throw money at national problems, including maintaining adequate defense. A main payoff of future improvement in acquisition management must be increased defense acquisition productivity. This new criterion requires asking hard questions about every prospective management improvement: Is it sufficient to increase productivity substantially? What related actions will boost productivity even more?

In applying the criterion we must focus on the key to productivity—DSAM professionals throughout the acquisition community. Our objective must be to select, integrate and implement management improvements and aids which are sufficient to increase productivity of DSAM professionals substantially—individually and collectively in organizational and multi-organizational DSAM subprocesses.

Productivity Review

Faced with current world political and national financial conditions and the present state of defense acquisition, we must search for new ideas and concepts to substantially increase productivity in DSAM processes. In my first article, I described problems consequent to the inherent large scope, complexity and "interactiveness" of the DSAM process. I proposed a framework for analyzing management improvements and identifying new opportunities to increase productivity of DSAM professionals. The framework included five elements: three traditional organizational elements (objectives, processes and structures) and two types of acquisition process inputs (tangible resources, and intangible job- and task-related DSAM knowledge and information resources).[4]

The Final Report of the President's Commission supports the addition of a sixth element to this framework. The serious destabilizing consequences of present national planning and budgeting processes (cited above from the Commission's report) and "the increasingly troubled relationship between the defense industry and government" (emphasized by the Commission as meriting greatest concern)[5] are strong evidence that all endeavors to increase productivity must consider environment and culture of defense acquisition management as the sixth element of the productivity framework.

I have used the first three elements of this framework to research past efforts to improve management of acquisitions, organizing results according to the traditional organizational elements. Under each organizational element, I tried to identify three things: successful approaches to continue and build upon; insufficiencies—oversight failures, inadequacies, and inabilities—which must either be remedied or coped with better to increase defense acquisition productivity substantially; and crucial underlying issues which must be addressed to assure steady progress in increasing DSAM productivity.

History shows, however, that substantial increases in productivity have come through innovative application of new ideas, concepts and

technologies to current problems, not through more intensive application of traditional practices. So, I have also been using the last two elements of the framework to focus my research and help identify new innovative ways to significantly improve the DSAM process.

This article summarizes selected examples, findings and conclusions of the first part of my research, with numerous references for more information. My purpose is to provide a foundation for considering the last two elements of the framework—DSAM knowledge and information aids, and the environment and culture of defense acquisition—in more intensive future explorations of new ideas for substantially increasing the productivity of DSAM professionals.

Objectives and Strategy

Consider the first element of the framework: each organization's objectives, priorities, constraints, and strategy. The concept of acquisition strategy to cope with the complex organizational objectives problem has been evolving for more than a decade. The general problem is how to focus job actions in each organization of the organization's objectives, but within the framework of the hierarchy of defense acquisition objectives, priorities, resources, constraints and policies.

The Office of Management and Budget (OMB) issued Circular A-109 in 1976 to establish government-wide policy for acquiring major systems. Its cornerstone was policy to tailor acquisition strategies for procuring all new systems. This policy was transmitted down through DOD Directive 5000.1 and DOD Instruction 5000.2 into military service regulations. There was no common working definition of "acquisition strategy," or a consistent agreement on its structure and composition during tailoring.

Four years ago, the Defense Systems Management College (DSMC) tackled these problems. It assembled information about acquisition strategy and published the *Acquisition Strategy Guide*, which addresses the "what?" "why?" "when?" of acquisition strategy, and the "how?" "who?" "where?" of its development, execution and modification. It presents 13 alternatives/issues for tailoring an acquisition strategy to a particular program's requirements and objectives. The *Guide* offers a comprehensive framework for structuring, developing, and executing an acquisition strategy in accordance with Department of Defense guidance. Discussing the definition of acquisition strategy, the Guide states: "A specific framework is needed for planning, directing, and managing the program. The acquisition strategy encompasses program objectives, direction, and control through the integration of strategic, technical and resource concerns."[6] It defines and explains these terms and their relationships.

> Considering limitations inherent in the DSAM process, shouldn't higher priority be given to developing aids providing faster, easier and selective access?

Ideally, the acquisition strategy: (1) is designed at the outset of a program, clearly stating the program's objectives, and providing an organized and consistent approach to meeting these objectives within known constraints, including higher-level objectives and priorities, and approved resources; and (2) is updated throughout the program as more information is acquired.

Not Sufficient

Development of this concept of strategy has proved sound, but this has not been sufficient. The DSAM professionals must apply it more effectively to increase defense acquisition productivity substantially.

Published guides always will be essential and, until recently, had no alternative; but, all published guides have inherent limitations. For example, ephemeral information in the 1984 *Guide*, particularly "who" and "where," began to obsolesce immediately after publication. Furthermore, newer alternatives/issues developed for tailoring an acquisition strategy (e.g., the recently published *Evolutionary Acquisition: An Alternative Strategy for Acquiring Command and Control [2] Systems*[7] are not referenced in the earlier Guide.

Even if DSAM professionals successfully locate all useful "how to" guidance, a more serious insufficiency limits their productivity. The DSAM professionals continually require many items of specific, current, relevant, general DSAM knowledge and information (e.g., policies, direction, reports, feedback, how-to, lessons-learned) that are applicable to all or many programs and process functions. Specifically, professionals need such generally applicable information to design implement and update acquisition strategy decisions for continued "integration of strategic, technical, and resource concerns" of the organization. No published guide can provide more than a small fraction of this kind of general DSAM knowledge and information, and this fraction may be current only on the publication date.

All professionals, using present inadequate DSAM knowledge and information aids, waste time searching inefficiently for specific DSAM knowledge and information that each requires in his/her job and tasks; they also lose opportunities when available relevant information is not found.

Considering limitations inherent in the present DSAM process, shouldn't higher priority be given to developing aids that provide faster, easier and selective access to particular relevant DSAM knowledge and information by DSAM professionals, whenever they require it? Such DSAM knowledge and information aids would increase substantially the productivity of DSAM professionals and their organizations.

Another critical insufficiency has seriously limited productivity—the failure of policy-makers to require all organizations involved in acquisition management to maintain and use organization strategies. Policy-makers failed to see the generality and power of the concept of strategy to solve the complex objectives problems of all organizations. Other organizations than those acquiring a system can benefit from using an organization strategy. The President's Commission recommended essentially that this strategy concept be applied by organizations at highest levels of the Administration to establish national security objectives and a national military strategy to achieve the security objectives.[8]

Department of Defense policy should require every DOD organization involved in defense acquisition to use the strategy concept to relate its objectives, priorities, constraints and policies, and those of higher-level DOD and external organizations. It should require each organization to develop an organization strategy which, within the organization's expected resources, best supports national military strategy. Then, DSAM professionals in each organization could use their organization strategy in decentralized execution of DSAM processes to achieve the organization's and higher-level objectives in accordance with all applicable policies.

Program stability and, thus, defense acquisition productivity would be increased substantially by explicit application of the strategy concept by every organization involved in the hierarchy of defense acquisition—from the National Security Council (NSC) in the apex down to each program/project office (PMO) managing the acquisition of a system, and to each organization that oversees or supports PMOs.

This would help the Administration provide a more stable framework within which system acquisition strategies could be developed and implemented to support the long-range national military strategy. In turn, this would contribute to moving the DSAM process from behind the budgeting and funding instability "eight ball," which, alone, should enable tremendous increases in productivity of the DSAM process.

Then, in a more constructive acquisition environment, the Congress could debate and negotiate with the President concerning national security objectives and national military strategy (and other national strategies, diplomatic and domestic) to achieve the objectives, instead of micromanaging line-items of defense budgets.

The potential of this constructive change in the defense acquisition environment—focusing congressional attention on national military objectives and strategies instead of budget-line items—is enormous for reducing tremendous waste and increasing productivity substantially in defense system aquisition. There would be less time and temptation for members of the Congress to "deal with defense issues mainly in terms of currying favor with their constituents," as former Senator Barry Goldwater feels many do. He believes that, "As a consequence, Congress, in the aggregate, syphons off billions of dollars every year from modernization programs and military payroll by keeping open no-longer-needed bases and facilities and by foisting unneeded and unwanted weapon systems on the Pentagon."[9]

This example of the power of only one constructive change in the acquisition environment emphasizes another serious insufficiency—failure through passive acceptance of the present environment to establish acquisition objectives concerning the sixth element of the productivity framework. The Department of Defense should establish an objective to "manage" changes in the defense acquisition environment and culture—changes that would allow and support substantial increases in acquisition management productivity.

In summary, past directed acquisition improvement efforts in the objectives and strategy element, have not been sufficient due to:

—Lack of effective aids to help DSAM professionals get specific relevant DSAM knowledge and information whenever they need it to design, update, and implement an acquisition strategy; or to oversee and support implementation of several defense system acquisition strategies

—Failure to recognize the generality of the strategy concept, and require that every organization involved in defense acquisition develop, maintain and implement an organization strategy which best supports the National Military Strategy within available resources

—Failure to establish a defense objective to manage constructive changes in the environment of defense systems acquisition so that high-level government and public attention is focused more on national military objectives and strategies, and less on budget-line items.

Organizational Processes

Consider next, the second productivity element: systematic organizational DSAM processes and subprocesses used to achieve the organization's and higher-level objectives. These processes and subprocesses function as highly interactive elements of the whole defense systems acquisition process. They operate in a dynamic environment of constantly advancing technologies, and of ever-changing national and world political and economic conditions.

Ideally, these DSAM processes should function in six levels or areas:

—To establish national military strategy within the framework of national security objectives, and within resources allocated and planned in a provisional five-year defense budget

—To select and support DOD programs for acquiring all systems needed to carry out the military strategy

—To develop an achievable acquisition strategy for each system acquisition program

—To develop organization strategies for all other "non-program" DOD organizations involved in defense acquisition (e.g., that develop acquisition policy, or that oversee or support more than one system acquisition program)

—To support decentralized implementation of acquisition strategies of all system acquisition programs and organization strategies of all "non-program" organizations and, thus, im-

plement national military strategy to achieve national security objectives which the military strategy supports —To adjust any of the above interactive elements (below the long-range national military strategy apex) as needed, so that they function together as an integrated productive defense acquisition process.

Ideally, these functional DSAM processes should be fully integrated within constraints of the current provisional five-year defense budget. Together, processes should support each organization's integration of its strategic, technical and resource concerns. They should help integrate strategy and operations of every organization, all constraining hierarchical concerns and priorities, and all applicable policy guidance from the Executive Branch and the Congress, Defense Department, and respective military services.

Unfortunately, neither ideal has been achieved. Concerning the functional process ideal, present defense acquisition processes usually support mainly the second and third, and part of the fifth function.

The first function—establishing a resource constrained national military strategy (which can be used to develop more realistic and stable defense acquisition programs and budgets)—cannot be performed well until the following recommended PPBS processes are developed and integrated. In June 1986, the President's Commission recommended: that the Joint Chiefs of Staff (JCS) develop the first national military strategy with 5-year fiscal constraints; that a Presidential decision selecting a national defense program include 5-year fiscal guidance and 2-year budget guidance; and that the Congress use national military strategy as a basis for reviewing the defense program and budget.[10] The Administrtion has begun to prepare 2-year defense budgets, but the Congress apparently intends to continue its 1-year budget reviews. Even if the three recommendations were fully accepted and full implementation began, successful implementation could take several years because the present DSAM information base may not adequately support the whole first function.

Regarding the fourth function, present DOD policy does not require every organization involved in the DSAM process to develop, maintain and use an organization strategy to coordinate and achieve its objectives—only those organizations which manage the acquisition of a defense system. Finally, successful performance of the sixth function depends on regular effective performance of all five other functions.

> Like the fabled blind men touching an elephant, everybody in defense acquisition comprehend DSAM processes that each 'touches' in compartmented activities.

Concerning the DSAM process integration ideal, overall progress in integrating DSAM organizational processes and subprocesses during the past 40 years has been slow because of the large scope and complexity of the whole DSAM process. Like the fabled Indian blind men touching an elephant, everybody in defense acquisition comprehend mainly the DSAM subprocesses that each "touches" in his/her organizationally compartmented acquisition activities. Few can "see" across boundaries of larger DSAM processes well enough to anticipate disruptive interactions that will result from first attempts to integrate the processes; thus, much error in past trial-and-error improvements. Serious failures "see" and recognize critical needs for change until something (e.g., "horror" stories of alleged mismanagement) forcefully demonstrates that a corrective action is overdue.

Nevertheless, a few major organizational processes that transcend functional areas and organizational boundaries have been developed which help managers increasingly intergrate major DSAM processes and their functional subprocesses. During the past 30 years, I personally observed the following examples which provide useful lessons for future emulations.

Robert S. McNamara, appointed Secretary of Defense by President John F. Kennedy in January 1961 and retained by President Lyndon B. Johnson, directed development of the planning, programming, and budgeting system (PPBS). The PPBS was to coordinate and control all strategic planning and resource management processes in the Department of Defense. One of its important uses for defense acquisition today is to plan, program, budget and allocate all funds for acquiring and moderninizing defense systems.

The new PPBS was a major change from, not an evolutionary development of, past DOD management practice. Its initial development throughout the 1960s was guided by new and well-researched theoretical concepts and analyses documented initially in two complementary classics: *The Economics of Defense in the Nuclear Age*, and *Planning and Control Systems: A Framework for Analysis.*[11] Their respective authors, Charles J. Hitch and Robert N. Anthony, were management professionals in academia. They were sequentially appointed by Secretary McNamara as Assistant Secretary of Defense, Comptroller (February 1961 through July 1968) to adapt and implement in the PPBS and related management systems, many management theories and concepts presented initially in their books.

David Packard, appointed Deputy Secretary of Defense by President Richard M. Nixon, quickly instituted the Defense System Acquisition Review Council (DSARC) in May 1969. The DSARC (now known as the DAB, Defense Acquisition Board), led the great departure from DOD management practice of total package procurement in the McNamara era. Drawing on his successful experience

in civilian high-tech product development, Mr. Packard directed a major change in processes for acquiring major systems (including fly-before-buy testing) by issuing the first DOD Directive 5000.1, "Acquisition of Major Defense Systems," July 13, 1971.

These are examples of past successes we should emulate by searching for opportunities to integrate other major DSAM processes and their functional subprocesses; and, to build upon with continued improvements to increase substantially the productivity of DSAM professionals.

It is important to recognize that the highly successful PPBS and DSARC efforts to increasingly integrate major DSAM processes were based on a well-thought-out and comprehensive new theory, not on evolutionary improvements in defense management practices. Many practical DOD managers entrenched in functional subprocesses resisted both initiatives. Fortunately, these efforts to integrate major DSAM processes were both instituted successfully before a new Administration could appoint new policy-makers with different improvement perceptions. (This issue will be addressed below as "Change Triggers.") Now enhanced by continued improvements in the cost- and schedule-oriented PPBS, and in the performance-oriented process, they have substantially increased productivity in acquisition management. However, substantial progress in integrating the PPBS and the DSARC has been elusive.

Now, after another 16 years, a third major change (recommended by the President's Commission) promises to enhance the process capability through better integration with the PPBS. The change promises a mechanism for challenging stated user requirements for a new system through informed user-aided trade-offs between stated performance requirements on one hand, and schedule and cost on the other. This change involved replacing the DSARC with a restructured Joint Resources Management Board (JRMB).[12] Today it is the Defense Acquisition Board (DAB).

Deputy Secretary of Defense William H. Taft IV began to implement this important recommendation June 3, 1986, before release of the Commission's final report. He replaced DSARC with a restructured JRMB and directed that it assume expanded DSARC capabilities, including examining trade-offs between system cost and performance.[13] Full implementation of the Commission's recommendation required congressional establishment of two new DOD positions whose responsibilities would include chair and vice chair of the newly established JRMB (now DAB). These will be considered below as "Organizational Structures."

Change Triggers

I have discussed successful examples of proven successes in organizational processes that we should emulate and build upon. Before looking at major insufficiencies, however, we should pause to consider major issues of organizational change, and of problem discontinuities that have impeded progress in substantially increasing organizational productivity. If we understand the issues and recognize causes of discontinuities, we can better understand sources of the insufficiencies and judge what should be done to remedy them or to cope better.

The large complex interactive DSAM process has many management issues and problems that need resolutions, each an appropriate focus for new acquisition improvement initiatives. Many are long-standing, since the solution of a complex problem from one perspective often appears as an unresolved or new problem from another persepective. Consequently, most *ad hoc* group reports of problems and recommended solutions have not brought a feeling of steady progress, but rather a sense of *deja vu*.

Seeking to learn from history, I have considered many changes made to improve DSAM processes since the DOD was established. First, I tried to learn what triggers major change actions in the continuing evolution of defense acquisition management processes. Then, what determines the scope of a major change, and what determines its content and emphasis. And finally, how the frequency of new major efforts for change affect steady improvement of the DSAM process.

I found three main triggers. All are perceptions of influential people empowered or activated by events, either by successions of policy-makers, or by reports of policy-makers, or by reports of alleged fraud or mismanagement. The main triggers are:

—New perceptions (of the most critical national and DSAM issues and how to handle those issues) resulting from changes of Administrations appointing new top defense policy-makers with new different perceptions

—Adjusted perceptions (of the critical DSAM processes and issues) resulting from change during an Administration in a top official who makes or strongly influences acquisition policy

—Public perceptions (of mismanagement of defense acquisition) precipitated and re-enforced by media reports of alleged fraud, abuse and mismanagement of DOD weapon system and spares acquisitions.

I found that the scope of a triggered change depends mainly on the degree of the trigger's influence. Changes of Administration, which often bring quite different perceptions, can initiate significant changes in DSAM processes, often with little congressional involvement. During an Administration, change of a key policy official with different experience and perceptions often adjusts emphasis or adds new initiatives in support of an already established defense acquisition course. Public perceptions of acquisition mismanagement, however, tend to get the Congress actively involved with directive and enabling legislation, and cause substantial changes in DSAM organizational processes and structure.

On the other hand, the specific content and emphasis of a change depends on the perceptions of the actual change-maker(s), including the Congress when enabling or directive legislation is involved. When the Congress gets concerned, a mix of acquisition management perceptions, not an integration, may shape the content and emphasis of changes. However, changes may be shaped by shared

perceptions, if the Congress and Administration are guided by the same integrated set of recommended changes, as they were for parts of the Commission's report. Even then, public perceptions may influence the Congress to legislate additional non-integrated possibly counterproductive, changes.

Frequency of the first trigger, new perceptions, depends on whether the President is elected for one or two terms. Since Dwight D. Eisenhower, there have been six Presidents; none have served two terms; only three—Johnson, Nixon and Reagan—have served longer than one term. The shorter terms have increased the frequency of defense acquisition policy-maker turnovers, and, thus, of new and different perceptions of the most critical DSAM issues and how best to deal with them. The frequency of the second trigger is much higher than change of Administrations. The frequency of the third has been increasing, prompted by more frequent high-media attention to defense related problems.

Together, as the drivers of change, these frequent triggers since DOD was established have brought frequent, often significantly different, perceptions of the key DSAM issues and of how to deal with them. This has made DSAM change sporadic, and management improvement intermittent. Because of the long time required to institutionalize new initiatives in large bureaucracies, good DSAM process improvement initiatives often die when another trigger sparks new and different change actions. This has retarded critically needed progress in DSAM process improvement. A brief examination of past effects of each trigger on the DSAM process will provide useful lessons for future improvements.

New Perceptions

A change of Administrations brings new top policy-makers with different experiences, and thus different perceptions, to trigger change. Rotations of political party (four out of the last six changes of Administration) bring policy-makers with different philosophies and experience, and, thus, different views of the relative importance of defense among national issues. All new top policy-makers bring new perceptions of the most crucial DSAM issues and processes in defense acquisition, and of how to handle them. Results have been frequent shifts in the priority of defense among national issues, and frequent changes in DSAM processes to cope better with new perceptions of the crucial defense acquisition issues and major problems.

> The main effect of turnovers of key policy-makers during an Administration is to increase frequency of changes in perceptions disrupting continuity guiding long-term improvements.
>
> **Packard Commission Report**

Too often, top officials in new Administrations start less well prepared than did Mr. McNamara and Mr. Packard. Each did his homework. Each was prepared with well-developed new theories and concepts to institute big changes in defense management to improve it significantly, not just incremental improvements in current practices as needs are perceived.

Always, top officials in a new Administration start without a good corporate memory of past actions on the perennial DSAM issues and problems. Never, do they find much organized information relevant to each major issue. Usually, there is substantial delay while the new policy-makers gather essential information, decide which problems are most critical, and act to remedy or cope better with those problems. Often, Administrations have ended before late initiatives were institutionalized.

The Reagan Administration's early DOD Acquisition Improvement Program (AIP) provides an example of how Administrations can expedite initial development of truer perceptions. Then Deputy Secretary of Defense, Frank C. Carlucci (now the Secretary of Defense), quickly identified many needed actions through intensive 2-month reviews. On March 2, 1981, he chartered five, full-time groups to recommend initiatives for improving the PPBS and the overall acquisition process. On April 30, three months after the Reagan Administration began, Mr. Carlucci issued a DEPSECDEF memorandum, "Improving the Acquisition Process," to direct 32 AIP actions. For more information, see the Summer 1982 *Concepts* special issue devoted to "The DOD Acquisition Improvement Program" a year after its initiation.[14] This emergency expediting process is not, however, an apt substitute for continued maintenance of truer perceptions of the critical DSAM issues.

Adjusted Perceptions

The Administration's overall view toward national defense issues tends to limit drastic change when a key acquisition policy-maker is replaced. However, the successor often, in effect, adjusts perceptions that guide the Administration's acquisition improvement initiatives. Relying on personal perceptions stemming from different acquisition experiences than the predecessor, a new policy-maker often changes previously established actions through selective emphasis, or by directing other initiatives which he emphasizes. By not emphasizing an initiative until it is institutionalized, the successor can let earlier-directed actions die through neglect.

The main effect of turnovers of key policy-makers during an Administration is to increase the frequency of changes in perceptions, thus disrupting continuity of the perceptions which guide long-term improvements in the DSAM process. Discontinuities resulting from successive differences in personal perceptions are illustrated by the five who have served as the chief defense acquisition policy-maker during the first 7 years of the Reagan Administration—Deputy Secretaries

of Defense Carlucci, Thayer, and Taft; and Under Secretaries of Defense for Acquisition (USDA) Goodwin and Costello. We can expect more adjustments in policy-making perceptions since Mr. Carlucci's confirmation as Secretary of Defense, replacing Caspar Weinberger. I will summarize examples, but list references for more information.

Then Deputy Secretary of Defense Carlucci directed the 32 AIP actions in April 1981. Four months after replacing Mr. Carlucci in January 1983, Mr. Thayer selected 12 of the original 32 AIP actions and consolidated them into 6 for his personal emphasis.[15] One year after appointment, Mr. Thayer expanded part of another AIP Action into a new DOD Streamlining Initiative.[16] Thayer's adjustments left 7 of the original 32 DOD initiatives for his emphasis in DOD acquisition.

Mr. Taft replaced Mr. Thayer in February 1984, and within 5 months instituted a new Defense Industrial Base Initiative to begin integrating industrial base considerations into the DSAM process. The General Accounting Office (GAO) listed this as No. 33 of the DOD AIP Initiatives[17] but from a DOD emphasis standpoint it appears to be treated more as an eighth initiative. Mr. Taft continued to strengthen the Streamlining Initiative in many ways, including three annual Defense Acquisition Streamlining Conferences, and publication of a new DOD Directive 5000.43. "Acquisition Streamlining," mandating use of acquisition streamlining initiatives on all new programs.

Mr. Goodwin, appointed to the newly created position of Under Secretary of Defense for Acquisition (USDA) on September 30, 1986, began to implement those parts of three enactments by the Congress which supported the Commission's recommendations.[18] He began by streamlining and simplifying the DOD acquisition system through defense reorganization,[19] and by trying to fulfill out his responsibilities as the new USDA according to DOD Directive 5134.1. Mr. Goodwin resigned in September 1987 after revised DOD Directive 5000.1 was issued giving the Defense Resources Board (DRB) authority to revise acquisition program plans without prior approval of the Defense Acquisition Board (DAB) chaired by Goodwin.[20] Later, in testimony before the House Armed Services Committee, the former acquisition Chief proposed legislation that would dramatically increase the authority of the USDA.[21]

Dr. Robert B. Costello, confirmed USDA on December 18, is initially emphasizing changes in long-term DOD strategies for mobilization and production. He has proposed a multifaced strategy for enhancing the defense industrial base.[22] This was one of his main concerns as Assistant Secretary for Acquisition and Logistics.

Mr. Carlucci, confirmed Secretary of Defense on November 20, 1987, is top DOD policy-maker. Because of his earlier active roles in DOD acquisition during this Administration, we should expect to see more examples of how turnover of a key policy-maker adjusts the perceptions which initiate and guide changes in the DSAM process.

At least four important lessons can be learned from these and other results of the first two changes triggers:

—Turnovers in top policy-makers are inherent and cannot be avoided

—Turnovers bring different perceptions of what are the most crucial acquisition problems and issues, and of how they should best be resolved

—These discontinuities in perceptions of "what" and "how" often trigger new changes in the DSAM process before earlier changes can be institutionalized, and so impede steady improvement in the DSAM process. This fact emphasizes the need for better DSAM knowledge and information aids to track new initiatives and retain lessons learned—insufficiencies to correct, mistakes to avoid repeating, and successful initiatives to continue

—Lack of a DSAM-information corporate memory prevents maintenance, over changes in policy-makers, of truer perceptions of the most critical DSAM issues and problems, and of how best to resolve them.

Public Perceptions

The third trigger, public perceptions of mismanagement in defense acquisition—overpriced spare parts, cost and schedule overruns, and test deficiencies—sparked establishment of the President's Blue Ribbon Commission on Defense Management in July 1985.[23] President Reagan established the Commission with Executive Order 12526, assigning it a scope of study that included both acquisition management and the larger environment within which DSAM processes operate.[24]

The President chose Commission members with widely respected experience in government, industry, business and academia; including experience in the U.S. Senate, general/flag officer experience in the Pentagon, and national security affairs experience in the White House.

Three members, having served in key OSD and industry positions in defense systems acquisition, brought extensive DSAM knowledge and perceptions. Chairman David Packard and Frank C. Carlucci had been Deputy Secretaries of Defense; Dr. William J. Perry was an Under Secretary of Defense for Research and Engineering. Each was the top defense acquisition policy-maker when in DOD. Each knew, from personal experience, specific improvements needed in the DSAM process and organization including the great need for better long-range planning and better DSARC-PPBS integration. They and other members brought perceptions from widespread experiences showing alarming deterioration in the defense management culture, and the need for major changes in the environment of defense acquisition management.

The Commission's, *A Quest for Excellence: Final Report to the President* (see Endnote 1), with its interim reports and appendix is, perhaps, the most comprehensive report ever made on the whole defense acquisition management process including its environment. One chapter, "Acquisition Organization and Procedures," has recommendations for the acquisition system, a.k.a. DSAM process. Equally important, other chapters, "National Security Planning and

Budgeting," "Government-Industry Accountability," and "Military Organization and Command," recommend changes in three different aspects of the acquisition environment within which DSAM processes operate, and with which they interact.

Following are short commentaries on all except the chapter on "Military Organization and Command." Creation of the new position, Vice Chairman of the Joint Chiefs of Staff, which enables direct military user representation in system acquisition decision-making, is treated later as "Organizational Structure."

Acquisition Organization and Procedures

The Commission concluded that the defense acquisition (DSAM process) has basic problems that must be corrected. They recommended many changes to correct these problems, grouping them under 9 headings.[25] The 9 sets of recommendations encompass many of the 32 DOD AIP actions hurriedly assembled in 1981, but also some changes not in the AIP. Unfortunately, no information linking the 32 AIP actions directed by then Deputy Secretary Carlucci in 1981 appears available to provide background, problems encountered, status, lessons learned, and other information that would be useful in judging AIP progress since 1981, and in implementing the 9 sets of changes recommended in 1986. The Commission concluded that meaningful improvement from these recommended changes will come only with major institutional change in the defense management environment and culture within which the changed processes would operate.

National Security Planning and Budgeting

Considering the national planning and resource allocation environment, the Commission focused first on an aspect which has always been the chief source of program instability in defense acquisition. It perceived the necessity to improve national security planning to establish the nation's security objectives—diplomatic, domestic, and military. Focusing on defense acquisition processes, they perceived the need to bring together the military security objectives, the forces needed to achieve them, and the resources available to support these forces; and to clearly establish this relationship using a national military strategy. Furthermore, they perceived the accompanying need for improvements in the PPBS itself, particularly in long-range planning and programming. These improvements in the PPBS are needed to track resources expected to be available to acquire "right" defense systems—those which can best achieve the national military strategy within available resources. They are needed to achieve stability in defense acquisition programs through more stable congressional budgeting, authorizations and appropriations.[26]

> "...Excellence in defense management will not be achieved through legions of government auditors, inspectors and investigators. It depends on the honest partnership of thousands of responsible contractors and DOD...."

Government-Industry Accountability

Considering the broader government-industry environment and defense management culture, the Commission perceived that "nothing merits greater concern than the increasingly troubled relationship between the defense industry and government."[27] The Foreword of the final report states "...ways must be found to restore a sense of shared purpose and mutual confidence among Congress, DOD, and industry. Each must forsake its current ways of doing business in favor of a renewed quest for excellence." It ends, "Excellence in defense management will not be achieved through legions of government auditors, inspectors and investigators. It depends on the honest partnership of thousands of responsible contractors and DOD, each committed to proper control of its own operations."[28] By implication in other parts of their report, the Commission included the Congress in this honest partnership, committed to proper control of its budgeting, authorization, appropriations and oversight operations in support of a more productive defense acquisition process.

The report calls for a new spirit of cooperation among the Executive Branch, the Congress and Industry. It recommends starting with more effective contractor self-governance, including implementing defense industry initiatives on buisness ethics and conduct. It recommends that DOD and the Congress foster effective contractor self-governance through more constructive defense acquisition oversight.[29]

The Commission's recommendations sparked what could be the greatest (and most controversial) changes in acquisition management since the Defense Department was established 40 years ago.[30] However, progress since June publication of its final report, and October 1986 completion of legislation supporting many of its recommendations, has been slow.

One year after the final report, Chairman Packard noted in a letter to President Reagan that an excellent start had been made. Much has been accomplished organizationally as DOD and the Congress worked with common purpose. But he was critical about other areas, noting that:

—Funding stability, needed to obtain more defense per dollar through programs that are stable, sustained, and predictable over several years, has not been achieved due to opposition in the Congress. More defense can be provided per dollar if programs are stable, sustained, and predictable over several years. Packard states "That stability has not been achieved....Opposition in the Congress to adequate and stable levels of funding for defense...is begin-

ning to pose serious problems for our long-term national security."

—Personnel policy is the keystone of virtually all reforms proposed by the Commission, but efforts last year failed to obtain government-wide reform of the Civil Service system, which does not allow for contracting officer educational criteria. The Commission urges specific legislation to ensure senior DOD civilian acquisition personnel can be promoted, paid and educated adequately.

—The USDA has not been given adequate authority, due partly to present legislation and partly to DOD policy implementation.

—Several problems remain in government-industry relations.[31]

Important lessons can be drawn from the Commission's Final Report and from Chairman Packard's follow-up letter.

The report identified basic deficiencies in the acquisition system processes and organizational structure.

The report identified major deficiencies in the environment and culture of acquisition management which must be remedied to realize meaningful improvement from the Commission's recommended changes in the acquisition system. Deficiencies are in the national security planning and budgeting environment, which induces instability into system acquisition programs, perhaps doubling acquisition times and significantly increasing system costs; also, government-industry environment, which is almost devoid of a sense of shared purpose and mutual confidence among the Congress, DOD and industry; Military organization and command environment, where the real users (Commanders-in-Chiefs of Unified and Specified Commands) are not adequately represented in weapons requirements decision-making, and resource-constrained, long-range defense planning is not supported.

The Administration, the Congress and the Defense Industry must do much more to generate a hospitable acquisition environment and promote a new defense management culture so that needed changes in the DSAM process increase productivity substantially in defense acquisitions.

The Commission was concerned about two findings: the increasingly troubled relationship between the defense industry and government, and the depth of public mistrust of defense contracting. The Commission is dismayed by the lack of effective action to remedy these conditions. I believe the Commission recognizes that restoring a sense of the Congress-DOD-Industry shared purpose and mutual confidence is a prerequisite to:

—Gaining better congressional support for longer-term planning and budgeting procedures needed to improve program stability and, thus, substantially shorten schedules and reduce costs of acquisition programs

—Cleansing current adversarial atmosphere harming our industrial base and, thus, assure our future capability to acquire systems needed for adequate defense

—Restoring public confidence in our defense acquisition system and, thus, public support for adequate national defense.

We as a nation can ignore these lessons, and accept present DSAM process deficiencies and corrective action inadequacies, only at our future peril. Or, we can use them to motivate and achieve greater DOD-Congress-Industry cooperation to increase productivity substantially in defense acquisition, and, thus, provide adequate economic national defense in a budget deficit environment.

Underlying Problems

These three frequent triggers of change in the acquisition process have sparked spasmodic, trial-and-error but, overall, evolutionary development of management improvements in DSAM processes. Some changes to increase process integration (e.g., initiation of PPBS development and institution of the DSARC) have proved to be outstanding management improvements and bases for continuing evolutionary improvements. Other changes, like development of Total Package Procurement, have required time-consuming and dollar-wasting corrections in the whole DSAM process. A long-term evaluation indicates enormous overall improvement in the process, but a review of results shows many crucial issues are unresolved by current processes. Research results indicate most improvements in DSAM processes were necessary, some outstanding, but many were not sufficient. They did not keep pace with the need for more productive management of increasingly complex programs in a dynamic environment, and did not reduce acquisition times or costs dramatically to increase acquisition productivity substantially to assure adequate defense in a budget-deficit environment.

The Department of Defense was established 40 years ago to integrate U.S. defense operations and improve defense acquisition processes to support those operations. It took 40 years to improve DSAM processes to their present state, which now seems so logical and necessary for management of complex defense system acquisitions. Yet, this progress was not sufficient to increase productivity substantially. These facts raise two important questions whose answers can profoundly affect our future: Why did it take so long to improve DSAM processes to their present level of integration and productivity? How can DSAM process improvement be accelerated to increase defense acquisition productivity substantially?

The above discussion indicates that a partial answer to the first question is turnovers—seven turnovers of Administrations with five rotations of political parties since the Department of Defense was established; also, turnovers of key acquisition policy-makers during Administrations.

Another partial answer is turnovers in members of congressional committees having significant influence on aspects of defense acquisition legislation. The adverse effect of these turnovers on defense acquisition is exacerbated by the propensity of the Congress toward line-item management of annual budgets, which is reenforced by pressures for individual members to curry favor with their constituents when dealing with defense issues. The lesson here is that all three—congressional turnovers, the congressional propensity, and attendant constituent pressures—combined to stifle motivation of members of the Con-

gress to develop shared truer perceptions with the Administration of critical national defense and defense system acquisition issues.

The second and more crucial question is: "How can DSAM process productivity be increased?" Before answering, we must identify past insufficiencies and, equally important, their causes.

I have observed the effects on defense systems acquisition of six changes of Administration, from Eisenhower to Reagan. Four were changes of political parties. In each of the four, I saw major shifts of direction and emphasis in the management of defense system acquisitions, as well as visible shifts after most changes of key defense acquisition policy-makers. Why the shifts?

Are real acquisition management needs, or are new perceptions of new policy-makers, the primary determinants of directions and emphasis of new DSAM process developments that are crucial to our country's defense? How can we develop truer perceptions of emerging real acquisition management needs, and document them in long-range plans as drivers for continual improvements which increase productivity substantially in DSAM processes?

Turnovers of Administrations, key policy-makers, and the Congress, bring discontinuities in the perceptions that drive DSAM process improvements, disrupting endeavors to steadily improve and integrate DSAM processes. These disruptions stem from four interrelated problems.

Analysis of results of the first and second triggers reveal a set of three problems. These inherent problems must be coped with continually to counter adverse effects of turnovers of Administrations, and during Administrations; also, to dampen large swings in perceptions guiding efforts to improve the overall DSAM process. The problems are:

—How to develop truer perceptions to guide specific improvements in DSAM processes;

—How to maintain the truer perceptions over turnovers to guide consistent steady improvement and integration of complex DSAM processes; and

—How to sustain truer-perception-guided actions directed in acquisition improvement programs long enough to institutionalize them.

The most recent result of the third trigger, public perceptions of acquisition mismanagement, is the 1986 report of President's Commission. Findings reveal an equally important fourth problem: How to foster shared truer perceptions among Administration policy-makers and members of the Congress.

> re real acquisition management needs, or new perceptions of new policy-makers, the primary determinants of directions and emphasis of new DSAM process developments that are crucial to our country's defense?
>
> **Packard Commission Report**

Not Sufficient

Having considered management-change triggers stemming from changed perceptions, policy-maker and public, we are ready to consider insufficiencies in organizational processes having limited increases in acquisition productivity.

Failure to fully recognize and the inability to deal with these four interrelated problems was the most crucial insufficiency of all past endeavors to improve and integrate DSAM processes enough to increase acquisition productivity substantially.

The third trigger indicates a second insufficiency. Why did it take public perceptions of acquisition mismanagement to prompt the President to appoint a Blue Ribbon Commission to study accumulated long-standing acquisition problems? Many of their recommendations are recognized as long-needed changes in defense acquisition processes and organizational structures. Why were the changes not started earlier? The answer: failure or inability to identify emerging real management problems for timely policy-decisions and corrective actions.

The root of this crucial insufficiency was failure to periodically review the complex DSAM process as comprehensively as the President's *ad hoc* commission did, but with an importantly different objective: To assure continual management improvement to cope with real problems as they emerge in the dynamic environment of acquisition, before they do costly damage and cannot be ignored. The failure results from a misapplication of the practical management philosophy, "If it ain't broke, don't fix it," by prefixing it with a complacent ostrich-like twist, "If you don't see it's broke, it ain't." The current troubled relationship between government and defense industry, and the loss of support for adequate national defense by a disillusioned public are two perilous consequences of this failure.

Regular comprehensive reviews of the oveall DSAM process to resolve this second insufficiency will not, however, be sufficient. Timely indentification of emerging real acquisition management issues and problems is essential, but more is needed—ability to do something about all identified problems. If we consider the 1985-86 comprehensive review by the President's Commission as the first of continuing regular top-level reviews of the whole defense acquisition process and its environment, this will help identify other major insufficiencies in past efforts to improve the overall DSAM process.

The Commission took a year to review the defense acquisition system (DSAM process) and its environment. Its report shows a way to achieve

substantial increases in productivity if we are willing to use new innovations in industrial management and apply promising new concepts and technology instead of clinging to inadequate management practices. The Commission said in the Report's Foreword that it intended recommendations to help establish strong and sound policies rigidly adhered to throughout the DOD. It emphasized that execution of these policies should be decentralized; that decentralized execution in the large complex enterprise of national defense requires cultivation of "resilient centers of management excellence dedicated to advancing DOD's overall goals and objectives."

Other Commission statements in the Foreword concerning the requirement for "centers of management excellence," provide evidence that past progress in improving acquisition management has not been sufficient in two critical aspects of the DSAM process.

First, the Commission states, "Excellence in defense management...requires...responsibility and authority placed firmly in the hands of those at the working level, who have knowledge and enthusiasm for the tasks at hand." This means that besides responsibility and authority, excellence requires knowledge and enthusiasm; but, enthusiasm without knowledge is disastrous. So a first requirement for excellence in decentralized implementation of acquisition management is that every working-level professional (from top policy-maker to lowest program implementer) given responsibility and authority for a job, must possess all relevant DSAM knowledge and have all DSAM information needed for tasks at hand. There is wide variance in the degree that relevant knowledge and information requirement is met in the real world, but usually less than 100 percent.

This requirement for every DSAM professional to have the relevant DSAM knowledge and information for his/her job and tasks highlights the third insufficiency of past acquisition improvement efforts—lack of aids to provide supplementary DSAM knowledge and relevant DSAM information when needed in a job or task. This insufficiency is crucial whenever management is decentralized as envisioned by the Commission. It must be resolved before the proposed "centers of management excellence" can function effectively in "advancing DOD's overall goals and objectives."

Second, the Commission concludes, "To accomplish this (excellence in defense management), ways must be found to restore a sense of shared purpose and mutual confidence among Congress, DOD, and industry." Past efforts to improve acquisition management have not been sufficient to induce such changes in the culture of defense management. If anything, some past improvement actions have reduced the sense of shared purpose and mutual trust; e.g., new audit policies, and several unintegrated functional policies whose combined effect has been to increase contractor risks while reducing their ability to deal with the risks.

Furthermore, the Commission recommends major constructive changes in the present environment of defense acquisition: national security planning and budgeting, in government-industry contracting, and military organization and command. This is more evidence that past progress was not sufficient; it had not achieved such constructive changes in the larger environment within which DSAM processes operate.

These Commission conclusions and recommendations highlight the fourth major insufficiency of past improvement efforts—inability to continually induce essential changes in the defense management culture, and to "manage" constructive change in the larger environment, within which DSAM processes operate and with which they interact, to enable substantial increases in acquisition management productivity.

Organizational Structures

The third productivity element is efficient organizational structures. The purpose of any organizational structure is to support organizational processes. The large, complex and highly interactive DSAM process encompasses many organizations and transcends many organizational boundaries. So do its major subprocesses (e.g., PPBS and DAB processes) and its many functional subprocesses (e.g., planning, budgeting, contracting, developing, testing, producing, training, modernizing).

Each organization's structure should support its own internal processes and larger DSAM processes in which the organization interacts, and in a way that assures greatest overall acquisition productivity. Ideally, an organization's structure should not be changed without considering all acquisition processes that will be affected.

The complexity and "interactiveness" of DSAM processes make it difficult, if not impossible, for individuals to identify beforehand all processes that will be seriously affected by a change in organizational structure. So most changes in organization are based upon consensus of *ad hoc* groups. Strengths and weaknesses of *ad hoc* group consensus can be seen in the reorganization recommendations of the President's Commission.

The Commission recommended and the Congress created two new DOD positions: Under Secretary of Defense (Acquistion) in OSD,[32] and Vice Chairman of the Joint Chiefs of Staff.[33] Both recommendations and the follow-on congressional enactments are seen as significant improvements in defense acquisiton management.

On February 10, 1987, DOD Directive 5134.1 made the new Under Secretary of Defense (Acquisiton) the full-time Defense Acquisition Executive (DAE) with responsibility for supervising the entire DOD acquisition system. This reorganization consolidates most OSD acquisition staff responsibilities under the USDA; makes him/her the DOD Procurement Executive; vests in him/her authority for both acquisition policy-making and decision-making; and makes him/her a powerful Chairman of the Defense Acquisition Board (DAB).

The role the new Vice Chairman of the JCS can now play in decision-making on all major service and joint acquisition programs should greatly improve management of defense acquisitions. As Vice Chairman of the DAB, which can make early trade-offs

between system cost and performance, he provides for direct top-level DAB consideration of the complementary and competing requirements generated by the real defense system users—the unified and specified combatant commands.[34] (Also see Endnote 13.)

These changes mainly affect the organization of DOD acquisition at OSD and JCS levels, above the military departments. As shown earlier, these are DOD organizational areas in which the Commission had great breadth and depth of personal experiences. However, the Commission recommended extending DAE direct supervision of acquisition programs down into each military department to program managers.[35]

This last reorganization recommendation has raised questions. We are not concerned here with questions concerning the merits of this recommendation, but rather with questions about the sufficiency of *ad hoc* group consensus as the main basis for recommendations concerning very complex organizational structures. Can any *ad hoc* group consider every acquisition process that will be affected by changes that the group recommends in organization structure, and foresee all critical effects of the changes on the processes? Can any *ad hoc* group, even the President's Commission, have sufficient collective experience to determine, for very complex organizations with complex interactive processes, the best reorganization structure (e.g., that structure which supports the whole DSAM process in a way that assures greatest overall acquisition productivity) for overall structure?

As far as I can determine, however, no Commission member had high-level experience in oversight, support or execution of acquisition programs in a military department.General Robert T. Marsh, USAF (Ret.), former Commander of the Air Force Systems Command, has extensive experience in these positions in a military department. Based on his experience, he challenged the Commission's recommendation to restructure the military departments by creating System Acquisition Executives responsible for all acquisition programs. He showed how the recommended restructuring would interface with numerous oversight and supporting functions provided by the acquisition commands, and suggested alternatives to reorganization for achieving the Commission's objectives of better acquisition program control.[36]

Insights from the Indian fable about six blind men touching an elephant and their different perceptions apply here. The different experiences of the Commission members (at military department levels in program execution, support and oversight) produced different perceptions of the problem, and how best to solve it. When the blind men recognized their perceptions problem, they reasoned: "Each of us knows only a part. To find the whole truth, we must put all of the parts together."

Assuring that *ad hoc* commissions/working groups are large enough to represent every kind of relevant experience would be impractical, if not impossible. We need a better way to "put all of the parts together":

—To meld results of wider relevant defense acquisition experience, so that all acquisition processes seriously affected will be considered in major organizational restructuring recommendations

—To avoid suboptimized solutions based mainly upon a particular level of perceptions (e.g., OSD, military department, congressional)

—To asure better availability of timely relevant current DSAM information which can help groups develop organizational-structure solutions that maximize productivity of the whole DSAM process.

"Putting all of the parts together" requires information from many sources concerning process operations over time. It requires integration of information over time concerning all elements of the productivity framework—objectives and strategies, processes, structure, knowledge and information resources, and the overall environment in which the restructured organizations will function.

Not Sufficient

Although employing an *ad hoc* group is the best known to find solutions to complex organizational structure problems, past *ad hoc* groups have had three serious insufficiencies with perennial problems.

The first stems from the "for this case only" nature of *ad hoc* groups—usually formed after a crisis to deal with some management problem that has grown so large it can no longer be ignored. The group provides its findings and recommendations for a one-time solution of its assigned problem, usually with no formal provisions for follow-up to make adjustments and assure steady progress on recommended improvements.

This is not sufficient for complex perennial problems like those addressed by the President's Commission. *Ad hoc* group reports seldom include information relating to earlier *ad hoc* reports on the same problem; or any between-report information on the problems encountered implementing earlier recommendations or documenting specific progress, which would be useful in making adjustments and assuring steady progress on the problem. For example, I found no information in the 1986 report about the 32 actions directed in the 1981 DOD Acquisition Improvement Program, or on implementation problems encountered and progress made on each action.

The second insufficiency is that *ad hoc* groups addressing complex problems are seldom large enough to include every kind of relevant DSAM experience needed to address competently all aspects of their assigned problems. No group can foresee all crucial effects of the organizational structure changes they recommend, on all acquisition processes that will be affected by the changes. Each group needs relevant supplemental DSAM knowledge to fill voids in its experiential knowledge.

The third is the nature of information available—hastily assembled, incomplete, irrelevant, a snap-shot at a point in time, not well tailored to the problem; also, lacking are DSAM information aids to remedy this insufficency. Needed aids should integrate, over time, information from all elements of the productivity framework—objectives, processes,

structure, DSAM knowledge and information resources, and the overall environment in which the restructured organizations will function. Such DSAM knowledge and information aids could serve as institutional memory aids to augment the experience of groups like the President's Commission. These aids could provide timely and relevant, current and historical DSAM knowledge and information to assist regularly appointed, qualified top-level groups in periodic overall reviews of the DSAM process.

To overcome the present *ad hoc* group insufficiencies and collect relevant DSAM knowledge and information for these aids (much not available elsewhere) we need thorough, regularly scheduled, periodic, Presidential Commission type reviews:

—Of the whole DSAM process for acquiring defense system

—Of the acquisition environment—political, economic, ethical—in which DSAM processes operate and with which they interact

—Which report problems and recommendations and identify actions to be tracked, progress to be reported, and information to be continually collected for use in the next scheduled periodic review.

Then information aids with integrated current information from successive reports of each periodic Presidential Commission review, augmented by information about related progress and problems between reviews, should do much to overcome the insufficiency of past *ad hoc* reports, supplementing the experience of periodic presidential-level commissions, and better assuring substantial increases in defense acquisition productivity.

Summary of Insufficiencies

One of my research objectives is to identify past insufficiencies which can be remedied, or coped with better, to increase defense acquisition productivity substantially. I have done this. Many insufficiencies scattered throughout the article stem from similar sources and need the same remedy. To help identify remedies and aids for coping better, scattered insufficiencies are organized by the productivity elements used in the analysis and summarized below.

Objectives and Strategy

—Lack of DSAM knowledge and information aids to help DSAM professionals design, update, and implement an acquisition strategy, or to oversee and support strategy implementation

—Failure to recognize the generality of the strategy concept, and direct every DOD organization primarily involved in defense acquisition, to develop, maintain and implement an organization strategy, not only those organizations that acquisition a defense system

—Failure to establish a government (DOD-Congress) objective to manage changes in the environment of defense systems acquisition so that public and high-level government attention is focused on overall national military objectives and strategies, instead of on budget line items.

Organizational Processes

—Inability to deal with four interrelated problems that result from turnovers of top policy-makers, and policy-influencers in Administrations and the Congresses

—How to develop truer perceptions of crucial DSAM issues and problems to guide development of sound initiatives for improving and integrating DSAM processes

—How to maintain truer perceptions of discontinuities that result from turnovers of Administration policy-makers and congressmen

—How to sustain directed acquisition improvement initiatives until they are institutionalized

—How to foster shared truer perceptions among Administration policy-makers and members of the Congress

—Failure to comprehensively review periodically the whole DSAM process and its environment, with objectives to:

—Identify emerging acquisition-management issues and problems for timely policy-analysis, decision, and corrective action and, thus,

—Reverse the deterioration of relationships between government and the defense industry, and the loss of support for adequate national defense by a disillusioned public

—Lack of aids to provide each DSAM professional with the relevant DSAM knowledge and information when needed in a job or task

—Inability to induce crucial changes in the defense management culture, and "manage" constructive change in the environment of defense acquisition, both critical to substantial increase in DSAM productivity.

Organizational Structures

—Insufficiency of "for this case only" *ad hoc* reviews to solve perennial complex organizational structure and process problems due to lack of scheduled periodic follow-up to make adjustments and assure steady progress on the recommended improvements

—Inability of *ad hoc* commissions, panels, or working groups to include all relevant experience needed to foresee all crucial effects of the organizational structure changes they recommend, on all acquisition processes affected by the changes

—Lack of DSAM knowledge and information aids that can supplement the knowledge and experience of DSAM process review groups to improve their recommendations for organizational structure changes.

This list of insufficiencies provides opportunities and valid objectives for improving management of defense system acquisitions. Remedying these insufficiencies would increase the productivity of DSAM professionals at all levels throughout the defense acquisition community. Then, operating in "centers of excellence" in a supportive environment (e.g., with "shared purpose and mutual trust" and with stable long-range resource-constrained planning and budgeting) as envisioned by the President's Commission, DSAM professionals could increase, not just substantially but tremendously, the productivity of the DSAM process.

This may sound idealistic, but if we use this objective to guide steadfast innovative efforts to improve the defense acquisition process, we can make pro-

gress and increase acquisition management productivity substantially. The rewards of increased DSAM productivity will be great.

Increasing Productivity Substantially

I began this research with goals to identify past proven approaches and successes that we should continue to emulate and build upon; to identify past insufficiencies that we can remedy; and to explore innovative new ideas and concepts for building on successes and remedying insufficiencies to substantially increase productivity in the DSAM process. My objective is to identify management improvements and aids which would be sufficient to increase the productivity of DSAM professionals substantially—not only individually, but also collectively interacting in organizational and multiorganizational DSAM subprocesses.

Consider proven approaches first. One has been to increasingly integrate major DSAM processes. Two outstanding examples of successes were the development of the PPBS and the DSARC process through increased integation. The institution of the new Defense Acquisition Board (DAB) to increase PPBS-DSARC integration through user-aided trade-offs between system cost and performance is another promising example. We should build upon such successes.

We should continue the increased integration approach and apply it on other major DSAM processes; for example, to achieve greater integration of DSAM research and DSAM information processes by actively involving users in a direct closed-loop process (problem-identification, research, new information-distribution, new problem-identification, new research). Or, greater integration of profit policy, system development policy, and defense industrial base policy—in an integrated Defense Industrial Base Enhancement (DIBE) process—to ensure future capability to acquire superior defense systems, and future surge and mobilization capability in war emergencies.

Then, DSAM professionals involved in more integrated DSAM processes would act more in unison to provide adequate defense within available resources. Much too often today, due to its large scope and complexity, the DSAM process appears to reflect different collections of independent organisms. Each with its own professional subculture seems to work at wasteful cross-purposes in support of the common objective, adequate national defense. For example, contracting officers and auditiors, operating in different DOD Acquisition and DOD Inspector General hierarchies, often seem to work at cross purposes in motivating maximum contractor productivity, and in developing an environment of shared purpose and mutual trust. Other functional groups seem to work at cross purposes trying to reduce government acquisition risks in the short term and maintain a viable defense industrial base in the long run.

Consider the list of insufficiencies next. Analysis as to cause shows they generally fall into two groups: failures to recognize a need, and to act productively to meet the need; or inabilities to act productively, either due to lack of timely relevant DSAM knowledge or information, or due to the present environment of defense acquisition. New policy direction, or DOD-Congress cooperation in matters involving both the Congress and the Administration, can remedy the failure insufficiencies. However, to remedy those insufficiencies which result from inabilities, we need innovative new ideas, concepts and approaches.

I propose further exploration of two new approaches, one concerned with each kind of inability. My research to date indicates these approaches could help remedy both inabilities and substantially increase productivity in DSAM processes. The approaches are:

—Providing DSAM knowledge and information aids that can increase greatly the productivity of each DSAM professional, substantially increasing productivity of their organizations, and thus, of the whole DSAM process

—Achieving constructive changes in the present environment of the DSAM process within which DSAM processes function and with which they interact, including positive changes in the present adversarial defense management culture. These changes are prerequisites to achieving substantial increases in acquisition management productivity.

These new approaches and the already proven approach of increasing integration are highly interdependent. Significant progress in intergrating major DSAM processes depends on DOD ability to "manage" constructive change of the environment of defense acquisition. However, substantial progress in both—increased integration, and management of constructive changes of the environment—depend on development of better DSAM knowledge and information aids.

We urgently need progress on all three fronts to increase productivity substantially in acquisition of defense systems. We must begin now to develop more relevant DSAM knowledge, information and communciation aids that are more easily and selectively accessible by DSAM professionals to increase productivity in their jobs and in tasks at hand. This is a prerequisite to progress on the other two fronts.

Endnotes

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2. *Packard Commission Report*, pp. 10-11.
3. The term DSAM professional, as used in this article, includes any government, contractor, academic or other knowledge worker who uses DSAM knowledge and information in his or her job in the defense systems acquisition process—for example, DSAM policy-makers, program/project managers/directors and their staffs, support managers, educators, researchers, decision support system (DSS) developers and operators, and DSAM information managers, including librarians who maintain documented DSAM knowledge and know other accessible sources of DSAM knowledge and information for ready access when needed by a professional.

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24. Executive Order 12526, July 15, 1985.

25. *Packard Commission Report*. Chapter 3, "V. A Formula for Action," pp. 52-71.

26. Ibid. Chapter 1, "National Security Planning and Budgeting," pp. 7-31.

27. Ibid. p. 75.

28. Ibid. "Foreword," pp. xii, xiii.

29. Ibid. Chapter 4, "Government-Industry Accountability," pp. 73-111.

30. Ibid. "III. Implementation," pp. 3-5. Also see Endnote 18.

31. Procurement Associates, Inc. 1987. "XI Acquisition Policy: Follow-Up to Packard Commission Report Cites Inadequate Implementation," pp. A-13,14. *Government Contracts Service: The Complete Information System*, No. 14-87, July 31.

32. *Packard Commission Report*. p. 53. *PL* 99-348, July 1, 1986. Title V, Sec. 501, "Under Secretary of Defense for Acquisition," established the new position. *PL* 99-500, October 18, 1986. Title 10, "Defense Acquisition Improvement Act of 1986," Part A, "Management of the Acquisition Process," includes a definition of the powers and duties of the USDA.

33. *Packard Commission Report*, p.35. Ulsamer. "Goldwater's Parting Shot," p. 81. *PL* 99-433, October 1, 1986, established the new position, Vice Chairman, Joint Chiefs of Staff.

34. *Packard Commission Report*, p. 57.

35. Ibid, p. 54. *PL* 99-500, October 18, 1986. Title 10, "Defense Acquisition Improvement Act of 1986," Part A, "Management of the Acquisition Process," Sec. 905. Defense Enterprise Programs.

36. Marsh, Robert T., Gen. USAF (Ret.). 1986. "Packard's Partial Fix." *Air Force Magazine*, 69 (May): 198-201.

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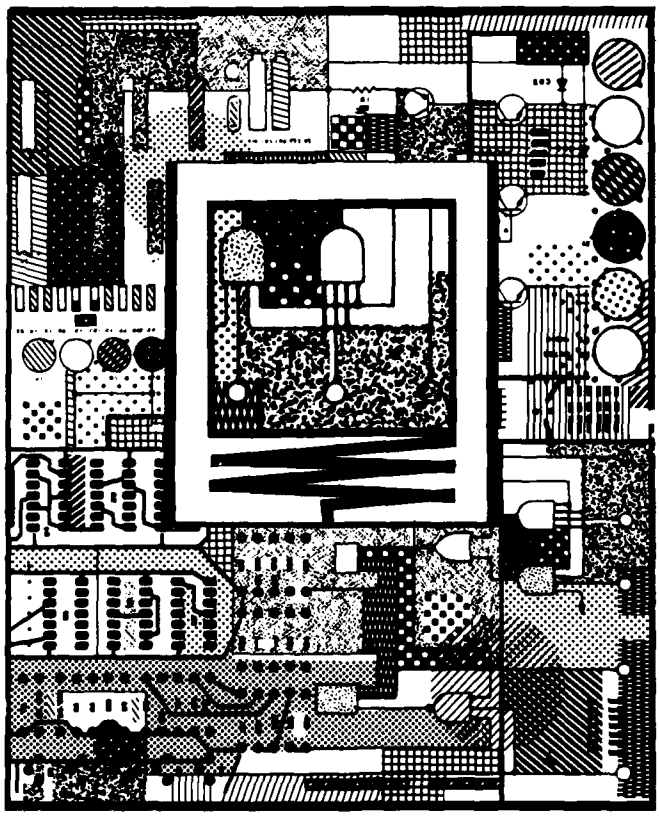
SOFTWARE TESTING MANAGEMENT

Captain John D. Burke, USA



All major military systems developed during this decade use or will use some type of computer system in their architecture.[1] In U.S. Army communications-electronics (C-E) systems, the majority of product improvements, and performance enhancements will come from the inclusion of computer software. Currently, the clear majority of C-E programs have a significant software development effort as part of the system acquisition. The distinctive nature of software, and the methods by which it is developed, make software acquisition unique to the normal weapon system lifecycle management process.

The Department of Defense has used computers and the attendant software since the early first-generation computers. Major emphasis until the late 1970s had been on hardware due to the stand-alone nature and employment of computers on weapon systems. At the end of the last decade, emergence of the integrated circuit and, in particular, the very high speed integrated circuit (VHSIC), allowed the widespread implantation of computer resources within other operating systems. As the use of VHSIC became greater, so did reliance on software to drive the circuitry. Software on DOD systems is reflected by its expected $30 billion investment in mission-critical software by 1990.[2]

Increased dependence on embedded computers in C-E weapon systems has increased to the point where the user cannot diagnose problems as they occur.[3] Thus, as the use of embedded computer systems increases, so too must there be an emphasis on delivering the most reliable, lowest cost and schedule conforming software. The current defense acquisition process is replete with examples of expensive weapons which don't perform as envisioned, and require extensive post-production modifications. In the context of a complicated and lengthy procurement system, this paper seeks to develop and recommend a software testing management guide to reduce some software testing problems. Therefore, the guiding theme is: "How can the software testing process be managed to improve weapon system acquisition?"

This paper is constructed to develop a baseline of information on software testing management through a discussion of program manager issues, terms and methodology used in software testing, relationship of software and hardware development, software cost estimating techniques, and concludes wtih a program manager checklist on software testing management.

Program Manager's Problem

The program manager is faced with the dilemma of how to produce a software package meeting the user's needs or specifications at an acceptable level of confidence, which cannot be tested completely and with certainty. A counter question becomes, given these conditions: How does the pro-

gram manager assure himself of the software's reliability and quality of conformance?

Few, if any, military projects are exclusively concerned with software as a separate entity. Weapon system program managers must concurrently develop both the hardware and software as the system progresses through each phase of the acquisition process. Attempting to balance cost, schedule, and logistics with the highest attainable operational availability relies on the extent and validity of software testing before system issuance to the operational forces.

Program Manager Guidance

Several authors contend that a major portion of the difficulty in managing software, especially for DOD program managers, is the lack of clear policy from the government regarding software quality and software quality assurance.[4] This is compounded by the few restrictions placed on software project managers due to the great deal of latitude when tailoring or interpreting them.[5]

The need for software testing and software quality standards was recognized in 1982 and two DOD documents were produced to overcome the ambiguity of the then-current guidance. The DOD Standard 2167 (Defense System Software Development) is the authoritative guidance for software development, and DOD Standard 2168 (Draft) (Software Quality Assurance) is the guide for product assurance and test guidance. An earlier standard, MIL Standard 1679 (Weapon System Software Development), was the definitive publication before DOD 2167 and 2168. Many current programs still use requirements of MIL STD 1679 since this was the guidance in effect when the programs began.

Background on Software Project Management

As a basis for discussion on the program manager's decision methodology, a brief background of software project management considerations is presented. The project manager must be conversant in such topical areas as software reliability, embedded computer software and hardware, problems inherent in managing a software/hardware combination project, and different types of software lifecycle models.

Software Reliability

A variety of articles and texts have been written in the past several years in an attempt to produce a model, heuristic, or procedure which will either completely verify software's accuracy or determine an achieved reliability rate. Although not a perfect analogy, software reliability may be compared to hardware reliability in that the reliability index, or mean time between failure (MTBF) can be defined as the probability that the software will perform its intended function for a prescribed time under a set of specified conditions.

Three terms commonly used in referring to software reliability are reliability, quality assurance, and verification and validation (V&V). Each represents a concept which overlaps the other to some degree; thus, quality assurance in one project may be considered testing in another. Regardless of the word used, the essence in assessing software reliability is the degree and extent of software testing.

Embedded Computer Software/Hardware

Software, especially in military applications, is part of larger, more intricate systems. This firmware or embedded software is a subset of systems software, and is the most common type of software in military systems. The DOD Standard 2167 defines firmware (embedded hardware/software) as the combination of both the hardware and software that reside as read-only software on the hardware device.[6]

The concept of embedded computers implies that the user expects a certain level of system performance to occur under a given set of conditions, provided the software is functioning properly. This absence of unexpected errors should lead to user satisfaction. Dr. Michael Paige identifies four events which the user expects to have minimized through identification and correction of software errors:

—No unexpected behaviors at either the system, or functional levels
—No loss of data
—No unrecoverable events
—No incorrect functional operations.[7]

In theory, satisfaction of these four criteria should assure the program manager and user that the embedded software can be operated with confidence. Yet, it is these same goals which become elusive in software quality assurance and testing.

One approach represents a testing philosophy rather than a test procedure. Dr. Paige has developed a priority schema which outlines a technique and sequence to reduce software errors through prioritizing the testing effort.[8] In it, fatal errors are given top priority, while nuisance bugs are lowest. The testing effort from program inception is directed toward reducing this hierarchy of program errors until the software can be unconditionally released. This represents a simple strategy, but also a very efficient method of conducting software quality assurance.

Hardware and Software Problems

Most of the CECOM managed programs have a high degree of software and hardware integration, with program managers being responsible for both. A major portion of the program manager's interest lies in reliability of software. However, two different management strategies are needed as there are significant differences between the hardware and software development. Rook describes some of the more distinct differences as:

—Software has no physical appearance
—Few software quality metrics exist
—Software is more complex than hardware
—Effects of change in software propagate explosively
—Software makes very little use of preexisting components.[9]

In addition to the actual differences between hardware and software, there are differences in their management. Program managers have developed a great deal of expertise in managing

hardware development and acquisition. However, successful software projects are predicated upon a different set of criteria than hardware. Wingrove cites six major problems which influence software projects:

—Rapidly changing technology
—Difficulties in resource and cost estimation
—Inability to predict and measure reliability
—A lack of agreement on test metrics
—Problems with software and equipment interfacing
—Problems with integration of different parts of the software package.[10]

In DOD weapon system acquisition, the problems of hardware and software integration are compounded by the length of the acquisition process where relative technologies of hardware and software improve at a much faster rate than the overall program can manage. In fact, the rate at which the hardware technology and improvements develop seldom paces the software enhancements. This difference in hardware and software development schedules causes obsolescence or, at least, continuous turmoil in the software and in the system's development.[11]

Software Project Management

Due to the nature and complexity of a hierarchy of prime and subcontractors, the program management office may be considerably distanced from the inner workings of the software developing contractor's activity. Furthermore, they have little visibility into the developmental test and evaluation process employed by the contractor.[12] By not being able to monitor and evaluate the test and evaluation effort, the responsible agency places a much higher degree of faith in the contractor's internal software quality control and assurance.

Although the program management office may deal exclusively with the developing contractor, a separate team, usually a separate contractor, conducts the independent verification and validation (IV&V).[13] This IV&V function is the responsibility of a separate independent testing office (ITO). In performing its function, the ITO maintains a healthy adversarial relationship with the developing contractor through its conduct of tests and reporting of test discrepancies.[14] A more in-depth discussion on the role and function of the IV&V contractor is presented later in this paper.

Software projects, by themselves, are difficult to manage and extensive problems may arise when software becomes part of a larger project. Hardware and software project management becomes more difficult when the program manager is neither a hardware nor software specialist.[15] Risks associated with software development increase as the software itself moves toward new technology and away from re-use or transferred technology. In many systems, the software has overtaken hardware as the dominant part of the project.[16]

Other factors have compounded management of software projects. Software programs have increased their burden on the project management through system cost overruns as the result of the soaring cost of software development and support.[17] One major cost impact is the high cost of software directly related to difficulties in defining requirements.

Performance criteria for software depends on the degree of conformance to specified requirements. Problems in software management stem from poor requirements definition, weak management, the inherent size and complexity of the system, and a critical shortage of software professionals.[18] Thus, estimating project size and duration is a difficult undertaking.[19]

A further issue in the management of software projects is the lack of clear and consistent guidance to the program manager. This void ranges from incomplete topical coverage in military standards to guide the IV&V efforts to the contention that specific guidance is overused.[20] For projects which must integrate hardware and software, there appears to be a void of guidance on how to integrate its development. Furthermore, efforts devoted to rectifying this situation may not catch up with the natural technological evolution in the mission critical computer resources discipline. In light of this situation, available guidance on how to manage software projects tends to be scattered, diffuse, and sometimes confusing.[21]

Software Life-Cycle Models

Software projects follow an iterative development which begins with the software portion of the system requirements. One way to represent this process is Boehm's "Waterfall" model; it shows software development from requirements definition through design phases, coding, integration, and eventually into an operations and maintenance phase.[22] An example of the "Waterfall" model is shown as Figure 1.

The "Waterfall" model is used extensively in software engineering literature and in DOD standards and guidance. An alternative model is proposed by Klucas which displays the software development process in six phases:

—Requirements Analysis
—Preliminary Design
—Detailed Design
—Code and Unit Testing
—Software Integration and Testing
—Software Performance Testing.[23]

Other authors have proposed modifications or different representations of Boehm's model, but the essential elements are the same. The Institute of Electrical and Electronics Engineers (IEEE) adds a retirement phase, while Booch places more emphasis on the requirements phase.[24]

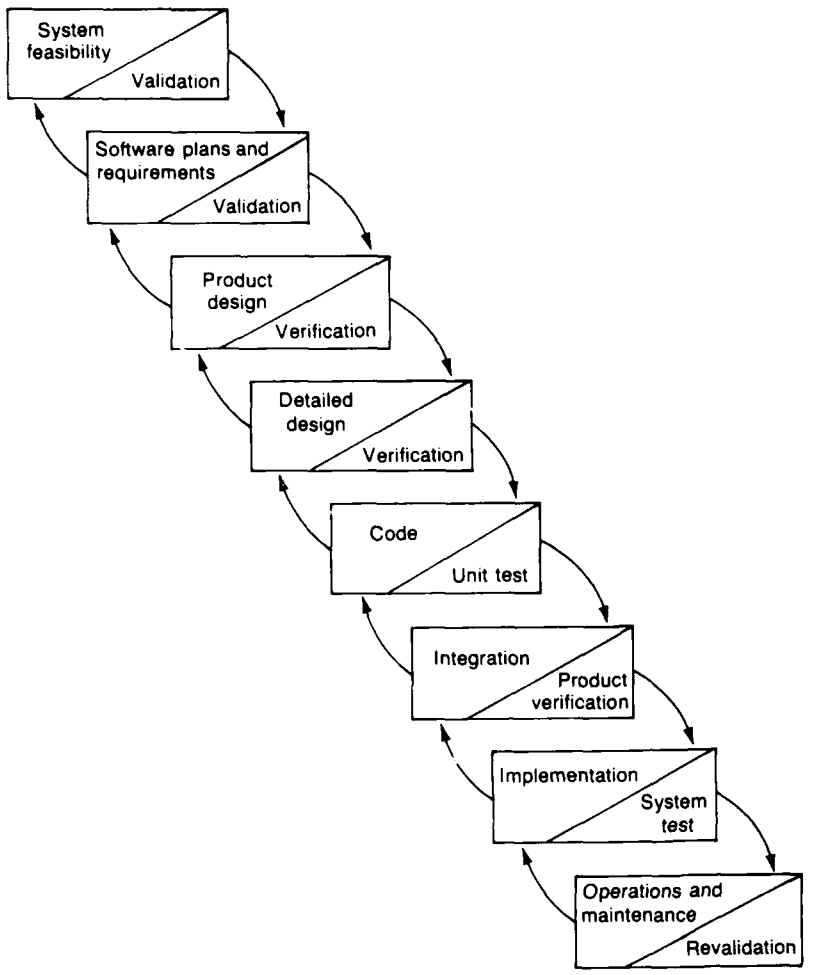
Software Testing

Software testing is usually done in an iterative process beginning with a strong emphasis on the proper definition of the user's need, further refined into requirements statements. This concerns types and sequence of software testing, test phases, and differences between parametric and empirical software testing.

Types and Sequence of Testing. All software testing assumes the requirements and the user's needs have been adequately stated from which test criteria can be written. Software testing is structured into two types, verification and validation.

Verification is the first testing step in minimizing unexpected errors. The verification function tests the operating code to assure the software developer that the program functions as

FIGURE 1. BOEHM'S "WATERFALL" MODEL



designed. While simple in concept, the difficulty in testing a simple embedded software program can be shown in an example in which a block of executable code is written to monitor and correct a temperature sensing control.

With only a hundred lines of code and five possible paths, this subprogram would require about 12,000 iterations to test for proper execution. Depending upon where in the software test cycle this verification is conducted, 40 or more errors could be found. This method is clearly inadequate when the system software contains hundreds of thousands, or even millions, lines of code.

Thus, testing all possible combinations of path and code isn't feasible for most applications. Because of various hidden paths and the injection of programming creativity, even if the program could be completely line-and-path tested, there is no guarantee the program will run error-free each time it is executed.

The verification function systematically checks path and code correctness, but does not assure the user of program application and usefulness. This is the function of validation.

Validation is the second step in the software development process beginning when agreement can be reached on the verification testing. This phase of testing consists of translation, complete understanding, execution, and feedback to the project manager that the software performs as intended. Furthermore, validation testing essentially assures the user that the software meets his stated needs.[25] When validation testing is performed under formal test guidelines, this is known as independent verification and validation (IV&V).

There are many techniques to perform validation testing. These range from a relatively simple set of managerial rules to a sophisticated stochastic model of software errors, all of which assume a common denominator of correctly stated requirements. Several of these techniques are generalized below.

—Design walk-through. A separate set of experts systematically examine the code and its execution to detect design and execution flaws.[26]

—Design inspection process. The design is reviewed by the program author's peers, recommendations are recorded, and software development folders maintained.[27]

—Automatic test drivers. Uses a designed data base of "bugs" and coprocesses the test driver with the code. Reliability is inferred by the failure rate measured by the number of hits the code makes on the database.[28]

—Stochastic mathematical derivations. Examines the output and draws reliability inferences from that output.[29]

The most frequent procedure is to use a combination of two or more of these techniques to validate the entire program design and code. As the software test process moves from a decision point of whether or not the code executes properly (verification), to a point of complete usefulness (validation), the more subjective and random the test method. Verification and validation are not successive, exclusive steps, but integrated levels of confidence. Unfortunately, the pivotal question of how realistically and completely to test for both types has not been universally agreed upon.

Software Testing and Test Phases

Given that verification and validation are essential elements of any software test, the program manager must integrate these functions into the actual software testing process.

Software testing, as defined by Goel, is the symbolic or physical execution of a set of test cases with the intent of exposing embedded faults in the program. Regardless of the extent of software testing, it is an imperfect tool for assuring program correctness.[30] Janusz lists four types of software test methods to assist in determining how well the program is functioning according to the test requirements:

—Static and Dynamic
—Set Theory Analysis
—Graph Theory
—Structured Testing.[31]

Software testing is an iterative process done in phases. Each of the phases: unit, module, integration, and acceptance testing builds upon the previous phase to eventually determine if one or more of the stated requirements has been met. A brief description of each test phase is described below.

Unit testing is verification of the written code, usually done informally, which becomes more formalized as the test process is expanded.[32] Furthermore, aspects of unit testing are that it is usually the responsibility of one programmer, and it is the lowest level of a module independently documented and controlled in the system.[33]

Module testing is the testing of an individual module before being combined with other modules. A module is an element of the overall program which can be separately identified, and usually performs a particular function. A unit is the lowest (smallest) type of module. This type of testing is done typically by the developing programmers.[34]

Software Module Integration testing is the process of adding a new module to the evolving software system, testing this new combination, and repeating this process until the entire system has been brought together and thoroughly tested.[35] Integration testing follows module testing and is designed to test the performance of the software to demonstrate complete processing functions. Integration testing is usually done at the contractor's facility.[36] If test cases are used to conduct integration testing, they may be generated either stochastically or deterministically.[37]

The objective of integration testing is the interface between modules, with the focus being the exposure of integration defects. One theory of integration testing is to only test the connection between modules; unfortunately, faults are often buried within each module's own internal operation.[38] For this reason, it is infeasible to turn integration testing over to an independent test team[39] and this phase of testing is done best by the group which also has the programming responsibility.[40]

DeMillo found that the decision on how much integration testing is necessary and sufficient is usually a subjective one. Furthermore, the basis of integration test completion depends upon the continuous execution of the test code to verify correction of the errors.[41] This continuous execution of the code is done through preliminary qualification testing (PQT).[42]

Acceptance testing is the final phase of the software test process which occurs before system testing (hardware and software integration) to demonstrate complete processing functions. Regardless of the degree of testing done at lower levels (unit, module, integration), some errors will remain until software system test-out.[43] The basis of whether the software has met the requirements of the acceptance test is determined by the conformance to test specifications. Thus, acceptance testing should be done under conditions agreed to by the user; the objective being to demonstrate that the system satisfies contractual requirements.

Parametric or Empirical Testing

Conferences and proceedings have been held to define and decide exactly what degree of testing will meet the confidence level requested by the user. However, these have met with limited success. Hall, quoting findings of the State-of-the-Art Overview, reports:

—There are no general-purpose, valid and reliable test selection procedures
—There is no conclusive proof on whether or not software can be proved correct
—Data are not available on comparative test methodologies for large-scale development efforts.[44]

Decisions regarding the degree and complexity of the software testing must be made early in the project.[45] Essentially, there are two fields of thought on how to define the testing process environment. The first position relies on a set of assumptions which must be applied to the software testing process to establish sample parameters and construct a forecast of software testing faults.

The second viewpoint contends that software should be completely fault tested (stress tested) with all possible inputs and operating environment variables allowed to run their range. In light of safety and criticality of mission, this second view is the one the DOD prefers in its testing requirements.

Dr. Amrit L. Goel supports the first position, parametric testing, with seven assumptions under which software testing is conducted:

—No new faults are introduced during the fault removal process
—Failure rate decreases with time
—Failure rate is proportionate to the number of remaining faults
—Reliability is a function of the number of remaining faults
—Time is used as a basis for failure rate
—Failure rate decreases between failures
—Testing is representative of operational usage.[46]

Satisfaction of each of these points results in a decreasing exponential curve of failure incidence. Although these assumptions will lead to a clean and decisive test, they do not provide the necessary confidence either to the program manager or the user that the software and, in turn, the system may be used without concern of random failure.

The DOD requires that all of its software projects be put through a partial stress test (empirical test) before acceptance. Through Military Standard (MIL STD) 2168 (Software Quality Assurance) and 1679 (Weapon System Software Development), the DOD requires software to undergo stress testing for a representative percentage of the executable code. The stress testing concept consists of the execution

of a complete program to the designed limits of its capacities and beyond in order to ensure that program failure is not catastrophic.

Parametric testing and empirical testing viewpoints differ in several critical areas, the most important being a test which is representative of operational usage. The concept of stress testing implies complete line and path testing; however, in practice, this approach is unable to completely uncover every single fault or failure. Thus, some of Dr. Goel's assumptions must be allowed. While "total reliability" is sacrificed, the final result is software which cannot be certified as true and proved, but can be indexed with an expected mean time between failure. It is at the point where software reliability and probability of mission critical failure intersect that the program manager has reached a position of software testing optimization.

Independent Verification and Validation

Each element of the test process whether unit, integration, or acceptance, involves two types of analysis: verification and validation. Within the development effort, the contractor or software developer will perform a series of preliminary tests to conduct informal unit, module, or integration tests.

Formal verification and validation analysis may be applied to any phase of the software test effort; however, they are usually conducted during the later phases as independent verification and validation (IV&V).[47] The IV&V effort may be the responsibility of the developing contractor, the independent IV&V contractor, or a combination of the two. Within the contractor's activity, the IV&V effort is distributed among three line organizations: systems engineering, software development, and the ITO (Independent Testing Office).[48] To assure independence and objectivity, the ITO office and, in turn, the IV&V function should not be part of the developing contractor's activity, but under the government or a separate contractor. It is the sense of independence which must be preserved in the IV&V process,[49] and these separate independent tests must be accomplished before release to the user.[50] Results of the ITO test efforts are listed as discrepancies in test reports.[51]

Further support for use of an independent test agency is provided by Deutsch who lists these three reasons:

—Engineering of a test program is a major task
—An independent test organization preserves objectivity
—Cost of test effort can exceed that of the software construction.

Role of the ITO will vary from project to project. The ITO may follow the software development effort from requirements analysis through system acceptance testing for large, complex projects. For smaller and focused efforts, the ITO may elect to conduct formal testing, beginning with integration testing. Basic elements for which the ITO is responsible are as follows:

> Visibility and scope of work must be addressed to reduce friction and enhance productivity . . .

—Ensure all performance and maintenance requirements are met
—The engineering of test program is consistent with lowest life-cycle cost
—May be responsible for integration of products into the system configuration
—Responsible for formal qualification testing of each computer program configuration item (CPCI)
—Prepares draft test procedures for integration tests, updates CPCI test plans, and updates the system test plan.[52]

Not all IV&V testing is done by the government ITO. This function usually is transferred to a separate IV&V contractor if the project is large, complex, or critical to the degree where a software failure would be catastrophic. The IV&V contractor may be known as the system integrating contractor, according to Deutsch, who says the following are functions which a program manager would expect the IV&V contractor to perform on unit, module, integration and CPCI software testing:

—Review and critique test programs, plans and methods
—Participate in formal reviews and audits
—Monitor developer's integration activities
—Integrate developer's products into system products.

Deutsch provides one caution in having a separate IV&V contractor perform IV&V testing; that is, relationship between the two is at best fragile, and the IV&V contractor must focus on substantial and relevant discrepancies. Special care must be taken when the IVV effort itself is extensive and the IVV contractor may become a competitor of the developing contractor. The visibility and scope of work must be addressed to reduce friction and enhance productivity between the two contractors.

Other Considerations

Besides actual planning, conduct, and review of software tests, other aspects of software development and corresponding testing should be considered. Among these are error to test relationship, real time systems, and automated testing.

Error to Test Relationship. Janusz contends one principal reason for the high cost of software is the difficulty of the error removal process.[53] Of critical importance is the place or time the error is discovered. If a fault is found and fixed early in the developmental phase, it only costs five percent of what this same error correction would cost in the operational phase. Moreover, faults indentified during early phases can reduce residual faults by more than 20 to 1. Unfortunately, the principal procedure to conduct this fault identification is the IV&V test. This is particularly critical considering the cost of conducting IV&V testing may exceed 70 percent of the software development cost.[54]

There are unlimited possible errors that can be revealed during software testing. Through categorization, the program manager may construct the test effort to focus on those appearing

to be most applicable to his project. Janusz identified 12 classes of errors which can be discovered during testing. Among these are logic, overflow or underflow of range, timing, data base, incorrect reporting, and specification and requirement conflict.

Dunn and Ullman concur with Janusz regarding the ability of a linear test effort to uncover all possible errors. One method of conducting a software test is to perform output analysis for a given set of inputs. However, this type of "black-box" testing may prove to be no more than the evaluation of a generation of a statistically insignificant number of possible execution states.[55] Yet, reliability testing allows the software tester and program manager the latitude of performing sensitivity analysis on the software to achieve an acceptable reliability index.

Real-Time Systems. Real-time software driven systems present unique problems to the software test effort. These require more intensive testing to achieve a reliable operational status, and are more difficult to satisfy a higher level of testing standards, according to Deutsch. He quotes Robert V. Head, and identifies attributes of real-time systems which complicate the testing effort. They are:

—Magnitude of programming effort in terms of the interconnection of program modules
—Difficult to repeat a test since the real-time system is time sequence dependent
—Multiprocessing requires that equipment interaction be precise
—Multiprogramming causes a host of problems without strict control of interfaces
—Inherent logic complexity
—Random access storage makes it difficult to discover and isolate problems.

Due to the nature of the real-time system, relative complexities in the interface of hardware and software, and ability of the software test to discover error, testing in the real-time environment is inherently more difficult. In particular, acceptance testing of real-time programs must ensure that the software possess a degree of reliability far exceeding that of the overall system.[56] Identification of the location of the fault is more difficult since ability to preserve a baseline control scenario is almost impossible. Thus, analysis of real-time system software testing becomes much more input-output dependent.

Automated Testing. Current literature suggests one method of providing higher confidence and reliability in software testing is to use automatic test generators or test drivers. These are separate programs which emulate the system test bed. Baker states that generating a method of clear, cost-effective test methods is one of the most technically challenging tasks in the software development. In view of this, any effort to automate and create repetitive tests will result in significant relative cost savings.

Janusz emphasizes the value of automated test case generators in that they are the most desired objective of the methods of software testing. He believes automated testing has the most promise, and will provide an additional means (including normal, current practice) of finding errors and reducing the effort and man-hours required for software testing.

One method of automating the test effort is through test drivers. These are software programs which provide data for exercising and testing software that has been completed or is under development. An example is a test driver which passes data to a module under test and receives the processed data in return, performing an analysis on the expected and actual results.

Test Management and Test Integration

Perhaps the most difficult part of managing the development of a system is the planning and organizing of the test effort. Resources, personnel, documentation, and funding are dependent upon the identification of test tasks and an integrated schedule to support them. The program manager may not, and probably cannot, determine whether the contractor is integrating the software and hardware schedules to conduct conclusive, system integrated tests. He therefore controls the program process through a system of test monitoring and documentation reviews to determine passage from one test phase to the next.

The first step is to establish a test and development environment which will ultimately achieve the performance stated in the requirements document. Janusz, quoting from DOD 5000.3, provides four points strongly related to software development and testing:

—Stated performance objectives for each test phase
—Test and evaluation will be used to determine whether to proceed to the next phase
—Realistic testing for operational use before release to the user
—Operational test and evaluation agencies shall participate in early stages of software test planning.

To digest the entire test and evaluation effort, the software and, eventually, the system must be broken down into manageable pieces. Deutsch proposes that there are four parts of the software test process: test planning, test case design, test execution, and evaluation of test results. Klucas and other authors have suggested alternative classifications in dividing software testing. He uses the separate levels of software modules as phases of testing, beginning with unit level testing and finishing with system integration testing.

One goal for the program manager is to integrate all test efforts (within regulatory and test agency guidance) into an efficient and non-duplicating product. At the inception of the software test process, the developing contractor has internal tests which are run for verification and validation of requirements. At the end of this software development, a complete system test is conducted on hardware and the software. One method of integrating the tests is to bring test agencies, such as the Operational Test and Evaluation Agency (OTEA) which has responsibility for overall systems testing, into the test process earlier. The Continuous and Comprehensive Evaluation Program is an Army Materiel Command (AMC) initiative designed to integrate various tests and test agencies into the software test process.[57]

A primary consideration in test planning and scheduling is the degree of testing performed on the software project. Hall argues one of the major problems in software testing is the amount

of software which is actually subject to testing. He contends only about one-third of all program statements (code) are exercised in the test process. Moreover, continuing to run the software test may only fractionally expand the coverage of the software functions. Clear requirements analysis and test case design can, and will, reduce the amount of software test duplication and conserve time and material resources to cover a greater percentage of the actual code and path testing.

Test Planning. Software test management requires that the program manager allocate a significant part of the test management effort to test scheduling. Formal and informal means are available to integrate the test planning process. The principal element from which to base the test schedule is the test and evaluation master plan (TEMP).[58]

Frewin states the test plan's aim is to ensure all testing activities, including the program controlling activity, understand what is expected, are manageable, and managed. These test plans are used to assist in the program's management by monitoring the test activities of the project, and scheduling and organizing project resources for testing. One essential quality of the test plan is acting as a medium for communication between the developer of the product, product tester, and other concerned activities such as trainers and evaluators. The test plan should enable all testing activities to be seen in the context of the full test schedule, rather than as independent actions.

The TEMP defines the scope, assessment criteria, evaluation techniques, resources and schedule of the testing activities of a project. At a minimum, according to Frewin, the TEMP should contain these items.

—Test items: Identify all test items both as defined by the user, or as developed during the test process. Identify items excluded from the test.
—Functions tested and those not tested.
—Non-functional testing: Examines areas like stress testing, security precautions, and access.
—Approach to testing: Specifies major activities, techniques and tools used to test each group of functions or function combinations.
—Constraints affecting test approach: Includes time, availability of items to test, resources, and personnel.
—Pass/fail criteria for items under test.
—Test deliverables: Includes test plans, test design specifications, test reports, and test input and output data.
—Testing responsibilities: Who is responsible for design and management, providing test items, and providing environmental needs for the tests.
—Scheduling of testing activities.
—Contingency plans: What to do in the event of test delays or failures.

Test Conduct. Once software tests are scheduled and resources identified, the actual test plan and test cases must be addressed and refined. Actual conduct of the software test depends on factors such as complexity, size, new or old technology, and cost. Tests may be technical, such as reliability measures using deterministic failure rate models; or broad, as in top management system configuration audits.

Deutsch explains there are two choices in combining software components for testing: phases vs. incremental, and top-down vs. bottom-up. The phased approach allows development teams to produce their products independently and perform integration and module interfaces later. The phases approach has the advantage of developmental speed, but the incremental approach is the one required by the Department of Defense. The incremental approach is done in the following steps:

—Design, code, and test one module by itself
—Add another module
—Test and debug the combination
—Repeat steps two and three until the entire software package has been tested.

Top-down testing begins at the top of the software structure and proceeds to test components at progressively lower levels. This method requires using test stubs (statements which make the program act as if it is accessing an actual block of code), according to Deutsch. Top-down testing is especially valuable in keeping the software development keyed to the overall requirements and preventing software modules to be written without clear objectives. Bottom-up testing is the testing of lower-level units of the program before moving into higher-level testing. This requires using test drivers. A driver exercises the software component by simulating the activity of the next higher level component. Bottom-up testing requires less management emphasis and more freedom to the individual analysts and programmers; however, connectivity and integration may suffer as a result. The most frequent practice of software testing is to combine top-down and bottom-up strategies. The degree that one approach is used over the other depends on the nature of the system; large complex systems may favor top-down testing while systems which rely on large modular components are suited for bottom-up testing.

A pervasive decision in the test effort is the length, extent and degree of testing. As stated, regardless of the scope and depth, no amount of testing can completely discover all possible process and path errors. This conflict between complete confidence in the software product and the ability to test to a given level of confidence has led to a field of software testing known as stress testing. The concept of total unit testing and integration for any type of input data is essentially stress testing. Hall enumerates the following characteristics which typify the conduct of stress testing:

—Trying to pass more information than the processor is designed to accommodate
—Excessive data transfer requirements
—Exceeding assigned storage area requirements
—Defining failure as any stop of the test prior to specified completion time.

Dunn and Ullman do not support the contention that stress testing is an unfair test of the software's ability. Frequently, stress testing results in a "breaking point" well below one's expectations. However, stress testing is representative of the operational environment, and should be done if possible. This type of testing may be compared to destructive testing in hardware items.

Stress testing should not be used in lieu of requirements testing. When defining test cases, the program

manager must require standards and criteria even for stress testing. This will minimize conflicts between conformance to contractual specifications and test results.

Test Outputs. As a result of the testing process, certain results should be available to the program manager. Richardson and Clarke remark that although verification proves or disproves the correctness of the code, program testing is necessary to assess quality of software. Outputs of testing include factors like run-time behavior, interfacing between modules, and data transfer.[59] Products resulting from the test effort are based on contract specifications. From a program manager's perspective, the contractor can only be accountable for the compliance of the test effort to the contract specification.[60]

Results of test efforts are only relative in terms of confidence in the software. The test manager must assume correct requirements and specifications. Although he cannot guarantee absolute correctness of software, test results indicate a high probability of compliance to test criteria. Similarly, Dunn and Ullman agree with this position, in that proofs and tests are alike since neither can eliminate the possibility of potential failures.

Cost Considerations. Various software cost estimating techniques may be used to predict or evaluate cost of software development. One of these models is the COnstructive COst MOdel (COCOMO) developed by Boehm as a parametric method of estimating software costs based on programming code. Several variations of the COCOMO are used throughout the Army Materiel Command. The basis for cost estimating is lines of programming code. The estimated size of the project is then converted into man-months (152 hours per month) and expressed in terms of dollars.

The COCOMO model is intended for small-to-medium-size projects, and has three levels of detail: basic, intermediate, and detailed. The COCOMO provides three levels or levels of analysis. The basic model is used for in-house software development and is good for an initial order of magnitude of software costs. The intermediate model uses the basic model and includes factors like hardware, personnel quality and experience, and tools. The detailed model applies the two lower level models for specific projects.

Other parametric software cost models have been developed including: Software Life Cycle Model (SLIM), FAST-E, System-3, and Price-S. The Price-S model (RCA) was developed in 1977 as the first complex and commercially available model for software cost estimating. Unlike COCOMO, the actual algorithms of estimating costs are not available due to proprietary rights. The Price-S model provides cost estimates for developmental software.[61] The actual software cost estimating model used for program costing is more than likely determined by command guidance with the objective being a standard cost estimating technique used within the organization.

> ithin the U.S. Army Communications-Electronics Command, two directorates provide valuable software and evaluation assistance . . .

Solutions and Recommendations

Within the U.S. Army Communications-Electronics Command (CECOM), two directorates provide valuable software test and evaluation assistance to program managers. The Center for Life Cycle Software Engineering (CLCSE) conducts software development monitoring and sustainment evaluation. The Product Assurance and Test Directorate (PA&T) fulfills the role of independent testing office (ITO) and coordinates and approves the IV&V testing. Together, these two agencies provide comprehensive software test and evaluation support of C-E and other program offices located at Fort Monmouth, N. J.

Based on my research conducted at CECOM, and a review of the current software testing literature, software development, and program management, six areas were identified to provide a central theme in software testing management. While not intended to be exhaustive, they are sufficient to keep a program on track and in balance throughout its development. A short summary of each topic follows.

Test Planning. This begins with an estimate of the size and extent of the software development effort. Using this as a basis, this step entails identification of required test agencies, published guidance, test cases, use of IV&V contractors, and the Test and Evaluation Master Plan.

Test Funding. This is important to address since this category becomes more critical as software changes and intial estimates are revised. Depending on cost and volume of the acquisition, software tests may account for one-fourth of total procurement costs. The method and basis of determining the test cost estimate, required hardware, development of test drivers and stubs, and validation of test results are considerations when examining test funding.

Test Scheduling. This is best done from a backward planning perspective. Most programs are hardware schedule dependent until system or software integration testing. Critical areas in scheduling are test integration with hardware, agency coordination, sequencing lower-to-higher-level tests, and critical design reviews.

Test Conduct. This is usually an iterative process which begins with informal unit and module tests and progresses toward formal system and integration testing. Ground rules must be in place before even these informal tests occur since one of the test objectives must be to reduce testing duplication. Roles of developing contractor, integrating contractor, test agencies, and IV&V testers need to be specified.

Test Control. This is primarily concerned with the criteria and activities responsible for approval of the software to move from one phase of testing to the next. Principal documents for this area are the TEMP

and software quality evaluation plan. One key issue is how to resolve disputes between test participants such as the integrating contractor and IV&V tester. Format and schedule of test reports will contribute to software test control.

Test Improvements. These consist of the review and evaluation of the test effort. Where are there inefficiencies, poor coordination and cooperation, duplication, unnecessary reporting, and excess cost and schedule constraints?

The following checklist is a compilation based on research done to support this paper. The format comprises self-check questions which address each of the six aspects described. As a minimum, they represent topics which should be considered and evaluated.

Software Project Management Testing Checklist

All questions should be answered in the affirmative except where a specific response is required.

General Questions

1. What percentage of this project is software oriented?
2. What guidance is available for managing the software test portion of this project?
3. Is the software for this project primarily new or old technology?
4. How can the extent and duration of the test be estimated?

Software Test Planning

1. Is the test and evaluation master plan (TEMP) coordinated with all the applicable test activities?
2. Does the test plan present a complete picture of all aspects of the test effort?
3. Does the TEMP address software testing as a separate portion of the project?
4. Does the independent testing office (ITO) draft or assist in the drafting of the test procedures?
5. Is integration testing done as a separate effort from that done by the developing contractor?
6. Is the emphasis of the software testing and evaluation on initial design?
7. Are contingency plans addressed in the event of test failure?

Software Test Scheduling

1. Is hardware and software integrated into the overall test schedule?
2. Is preliminary testing done as the basis for the next phase of testing?
3. Have requirements determination (test procedures) been identified before incremental testing?
4. Has incremental testing been completed prior to environmental testing?
5. Has validation testing been completed before operational testing?
6. Has validation testing been done progressively?
7. Are there sufficient resources to conduct independent verification and validation (IV&V) testing?

Software Test Conduct

1. Is this software tested by integration of modules?
2. Does the integration testing evaluate previous test results?
3. Does the integration testing use the test specifications and requirements?
4. Is the test conducted using a combined Top-down and Bottom-up approach?
5. Does the independent testing office (ITO) develop:
   a. Guidance on the conduct of the test?
   b. Feedback on problem reporting?
   c. Comprehensive test reports?
6. Is a specific set of standards or guidance used to conduct IV&V testing?
7. Is a separate IV&V contractor used for large, complex systems?
8. Are test metrics and test generators used to evaluate the software as much as possible?
9. To what degree is stress testing used to evaluate performance boundaries?

Software Test Control

1. Does the PM office have visibility into the software development testing process?
2. Does IV&V testing begin at the conclusion of integration testing?
3. Are independent tests based on results of earlier tests (minimum duplication)?
4. Is the acceptance and qualification test done by a separate agency than the developing contractor?
5. What are the software quality and quality design specifications or guidance being used?
6. Is the ITO used to conduct IV&V testing?
7. Is the software testing evaluated using:
   a. Automatic test case generators?
   b. Design walk-throughs?
   c. Reliability models?
8. Are test cases developed outside of the developing contractor's interest?
9. Is there an adversarial relationship between the developing contractor and the test agency?
10. Are test resource and cost estimations reasonable?

Conclusion

Software test management depends upon a thorough examination of the software project's requirements, scope, and complexity. From this, the program manager develops test cases representative of the technical and operational environment. A strong effort to integrate software and hardware program schedules will provide success at a future date when system integration and acceptance testing are conducted. A well-coordinated and detailed test and evaluation plan will reduce test duplication, resources, schedule conflicts, and eventually conserve funds.

Software intensive weapon systems require extensive and thorough testing to build and sustain user confidence. The program manager can significantly raise this level of confidence through well-planned and decisive software test management.

Besides the DOD STDs 2167 and 2168 (Draft), these are three excellent desktop references for the program manager on software testing:

—*Software Testing and Evaluation*, DeMillo et al, 1987.
—*Managing a Programming Project*, Metzger, 1981.
—*Software Verification and Validation*, Deutsch, 1982.

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BASELINING OF MAJOR DEFENSE ACQUISITION PROGRAMS: PAST, PRESENT, AND FUTURE

Joseph A. Ferrara

The Department of Defense (DOD) has developed a variety of management systems designed to control, in varying degrees, the critical parameters of weapons systems as they progress through the stages of the acquisition process. The critical parameters of a major program include cost, schedule, and performance. What will it cost the government to acquire the system; how long will it take to research, develop, procure, deliver, and field it; when are the critical events of the acquisition process—major milestone decisions, developmental and operational testing, contract awards—scheduled to occur? What are the planned technical and operational characteristics of the system; how will they relate to the overall effectiveness once it is deployed; what are the operating support implications and are they being adequately planned for? Finally, how effectively will the system perform its intended mission? These are examples of questions to which the above parameters are addressed. The ability to answer these questions satisfactorily enables DOD managers to work more effectively.

Major program baselining is a management technique designed to enhance program stability by adding a measure of control over critical program parameters. Baselining as a concept and practice is certainly not new, but it has generated an enormous amount of interest recently at the Pentagon and on Capitol Hill. This increased attention is due to a number of factors. The current fiscal environment, for example, is one of severe constraint, dramatically highlighted by the recent resurrection of the Gramm-Rudman-Hollings deficit-reduction legislation. (As of this writing, congressional and administration negotiators have agreed to reduce the federal deficit by more than $76 billion for fiscal years 1988 and 1989. It is unclear exactly what the ramifications of this agreement will be for defense budget authority and outlays; the FY 89 program is currently being revised.) The public and congressional consensus for higher defense spending, evident a few years ago, has eroded alarmingly. Finally, procurement brouhahas, ranging from overpriced spare parts to unforeseen and costly problems with avionics on platforms, contributed to a general focus of attention on the DOD acquisition system. In light of these sobering trends, baselining of major defense acquisition programs will continue to represent a legitimate means of bringing much-needed stability to the process and illuminating affordability issues.

The appointment of Frank Carlucci as Secretary of Defense rekindled interest in enhancing program stability. While Deputy Secretary of Defense in 1981, Mr. Carlucci

articulated a set of management principles and actions designed to increase the integrity of the acquisition process. Many of these principles came to be known as the "Carlucci Initiatives," centered around improving program stability. In fact, one of the initiatives was actually entitled *Program Stability*, but the initiatives *Realistic Budgeting*, *Economic Production Rates*, and *Multiyear Procurement* were all related to the concept of program stability as well. Baselining, as we know it, comes from the Carlucci reforms. Mr. Carlucci, in his Senate confirmation hearings, contended that a slimmer, more efficient military will be paramount in the face of fiscal constraint and that many tough decisions will have to be made, presumably on whether or not to terminate certain programs.[1]

Why should we be concerned about enhancing program stability? Program instability damages the integrity of the systems acquisition process. Destabilization of programs occurs for a number of reasons, many beyond the control of any one official, no matter the level, and certainly beyond the control of the program manager. Some destabilizing factors include fiscal constraint and attendant fluctuations in defense budget authority levels; changes in program structure or procurement profile due to technical or contractual factors; and overburdening of resource levels due to too many programs in the acquisition cycle simultaneously. Negative ramifications of program instability, among other things, include:

—Fostering defense industry unwillingness to make productivity-improving capital investments

—Increases in unit costs of defense systems

—Layoffs in the defense industry due to program delays

—Disincentive for firms (contractors, subcontractors, suppliers, and vendors) to remain in the defense business.[2]

Given the problems associated with program instability, baselining should be considered a technique to reduce destabilizing and improve management effectiveness.

This article should give a comprehensive understanding of the concept, history, and current practice of baselining and will draw some conclusions on baselining effectiveness. I will examine the background and purpose of baselining, with the military service efforts primarily; discuss baselining history, roughly since early 1986; and assess the executive and legislative initiatives implemented during that time. I will then discuss the *current* status of DOD baselining policy and implementation, examining successes of policy implementation and assessing problems encountered. Finally, several conclusions will be drawn on the future of major program baselining and its potential for enhancing program stability.

Baselining: Purpose and Definition

For this article, I define baselining as a formal agreement between essential program participants that specifies the critical parameters of a program entering full-scale development or production, to include cost, schedule, and performance. Baselining is a technique used to enhance stability and control cost growth. Once the baseline is approved, the program manager has authority to manage the program within the specified baseline parameters.

Essential program participants for a DOD-level baseline agreement are the program manager (PM), the program executive officer (PEO), the military service acquisition executive (SAE), and the defense acquisition executive (DAE).

The PM is the officer chartered to manage a major defense acquisition program and reports directly to the PEO.

The PEO is the officer in each military service reporting directly to the SAE and responsible for a defined number of major defense acquisition programs (often the programs under the PEO's purview are related functionally, such as command, control, and communications (C^3) programs or tactical aircraft programs).

The SAE is the senior acquisition executive within each military department, designated by the component head, responsible for administering acquisition programs in accordance with DOD policies and guidelines.[3]

Baselining: Military Service Experience

Air Force. No discussion of baselining policy is complete without examining the Air Force experience. The Air Force baselining system has been institutionalized since 1983, and has served as the framework upon which most subsequent baselining efforts have been constructed.

Air Force policy on acquisition program baselining is officially embodied in Air Force Regulation 800-25 (AFR 800-25), *Acquisition Program Baselining*.[4] The Air Force initiated major program baselining to enhance program stability and control cost growth for selected acquisition programs. During the late 1970s, the Air Force Systems Command (AFSC) initiated the concept of baselining as a sort of cost "contract" between the PM and the commander.[5] This relatively narrow document was expanded in the early 1980s into a full-fledged "agreement" involving all program participants, such as AFSC, Air Force Logistics Command (AFLC), Air Force Operational Test and Evaluation (AFOTEC), and Military Airlift Command (MAC). By 1984, this baselining approach had evolved into a fully institutionalized policy as AFR 800-25 was published for the first time.

The current AFR 800-25, published April 1986 and currently being revised to reflect recent changes in DOD acquisition policy, details the purpose of program baselining in the Air Force and the procedures necessary to accomplish baselining. According to AFR 800-25, "Acquisition program baselining is a management technique used to enhance stability and control cost growth for selected Air Force weapon and information systems acquisition programs."[6] Two concepts, program stability and selected programs, stand out. By stating the purpose in program stability, the Air Force implies that baselining does not merely represent a program-reporting mechanism, but that it is a "contract" between program participants in an attempt to adhere to a specified program content. The Air Force did not initially intend baselining for all acquisition

programs but, rather, for a selected few. This is an important distinction, especially in light of recent policy and legislation.

Who selects acquisition programs for baselining at the Headquarters level within the Air Force (HQ USAF)? According to AFR 800-25, this decision is arrived at consensually through the recommendations of several staff components—the Assistant Secretary of the Air Force for Acquisition (SAF AQ); Offices of Primary Responsibility (HQ USAF/OPR), presumably program offices; Directorate of Program Planning and Integration (SAF AQX) and others. The Vice Chief of Staff (CV) approves certain baselines and his deputy, the SAE, approves certain baselines, depending upon the nature of the program; i.e., Air Force priority, funding level, etc. When a program baseline is established, the CV informs the Secretary of the Air Force (SAF).

The AFR 800-25 requires a relatively large amount of program information and precise level of detail to be included in the program baseline. The Program Content section of the baseline document, for example, is divided into categories: 1) *System Definition* including configuration, government-furnished equipment (GFE), and subsystems; 2) *Performance* including operating characteristics, reliability, availability, key specifications (military, federal, etc.), and quality standards; 3) *Operations Concept* including basing concept, primary use, and initial operating capability (IOCs); 4) *System Readiness* including readiness objectives, production surge, and mobility; 5) *Integrated Logistics Support* including initial spares, replenishment spares, and technical data; 6) *Maintenance Concept* including deployability and depot maintenance; 7) *Communications, Data Automation,* and *Information Systems Resources* including equipment type, locations and network standards; 8) *Test and Evaluation* including test schedule milestones, locations, contractor role, and unusual types of testing; 9) *Training* including requirements, types, milestones, and simulators; 10) *Facilities (engineering and installation)* including construction, location, contractor role, and acceptance testing; and, finally, 11) *Schedule* including key dates and milestones.

Also, the Air Force baseline includes a section on funding. Funding information is divided into Total Program Funding, Program Acquisition Funding, and Program Support Funding, and includes all appropriated funds, budget year funding, Five Year Defense Plan (FYDP) funding and a To Complete column. Funding is given in Base-Year and Then-Year dollars.[7]

Another section of the Air Force baseline involves deferred program content. This section details program elements of an approved baseline which the program participants agree must be removed from the baseline because of fiscal constraints. These elements are then reinserted into the Planning, Programming, and Budgeting System (PPBS) to compete for resources. This deferral mechanism highlights a central feature of the Air Force baselining system, the executable and non-executable baseline. In an executable baseline, the level of approved funding is sufficient to accomplish the program content; in a non-executable baseline, the level of funding is insufficient (or one of the program participants cannot support/accomplish the program content). By making such a distinction, the baselining process gains integrity and alerts Air Force leadership to potential affordability and/or technical problems.

The Air Force baseline then is much more than merely "...a brief baseline agreement describing functional specifications, cost, schedule and other factors critical to the program's success" that David Packard envisioned for DOD-wide implementation.[8] The Air Force baseline is not brief and does not simply extract those program "critical" factors; rather, the baseline is a detailed portrait of the acquisition program, focusing on everything from the actual program definition to its manning and training requirements. Depending on the nature of the program, the baseline may include the signature of as many as nine officials, from the PM to the Secretary of the Air Force.

Navy. In 1982, the Office of the Chief of Naval Operations (OPNAV) initiated the Program Management Proposal (PMP) system as an effort to "regulate research and development and control configuration changes and modifications to ships, aircraft, missiles, systems, combat vehicles...."[9] Part of the Navy's explicit intent in establishing the PMP process was to "...avoid Research and Development programs that lead nowhere...." and "...balancing the need for new programs with modernizing existing equipments...."[10] It seems that enhancing program stability was the primary impetus in the Navy's move to implement baselining.

Technically, the PMP process is not the initial baselining effort within the Navy but represents the mechanism by which the Navy approves and processes changes to baselines. The Navy process of establishing baselines is the product of consensual staff negotiation as in the Air Force, and is ratified at the highest level. The Chief of Naval Operations (CNO) and the Commandant of the Marine Corps (CMC) establish baselines. The Navy baselining system recognizes the attendant fluctuations in a program as it progresses through major acquisition milestones and, consequently, baselines programs in this fashion. This philosophy is similar to the Air Force system, which baselines in a total program sense. Navy baselines are updated many times during the acquisition cycle.

For example, in RDT&E, when an Operational Requirement (OR) has been approved, the OR becomes the baseline. Subsequently, the baseline is updated at each approved milestone. The Navy baselining system then begins earlier in the acquisition cycle than the Air Force Milestone II system (Full-Scale Development (FSD)). The baseline is required to define program scope, definition cost, and configuration. In a sense, the Navy's baseline document is not a document, but, rather, is embodied in decisional- and planning-related documentation. Prior to Milestone II, the OR serves as the baseline. At a major program's approval point for FSD, for example, there are many forms of documentation, in the Navy and the Department

of Defense, describing certain facets of the program; in aggregate, these documents represent a detailed program description. The primary baseline documentation is the Decision Coordinating Paper (DCP), the DOD-level decisional report summarizing program accomplishments to date and describing the cost, schedule, performance, readiness and supportability parameters of the program.

Specifically, revised Navy guidance[11] now defines an approved baseline as: "The *combination* of approved program schedule, configuration, performance characteristics, acquisition strategy, and other business aspects which constitute the variables reflected in either the appropriate acquisition milestone approval for the acquisition category or as reflected in the latest approved program management proposal (PMP) action."

Changes to the baseline as a result of the PPBS process do not require submittal of a PMP; only changes occurring outside the normal resource allocation process trigger PMPs. This is an interesting deviation criterion and actually mirrors a recent policy enunciation at the Department of Defense level in DoD Directive 5000.1 regarding baselining changes and the PPBS process. The PMPs are initiated by the program manager, systems commander, or the resource sponsor and are processed in the event of approval of an OR for system improvement or an anticipated baseline change which will result in recurring, non-recurring, or support costs. No dollar threshold values are entertained; any change (read, increase) in cost requires a PMP.

The PMP process elevates proposed changes in approved programs to the Navy leadership for approval or disapproval. By elevating this decision, the purpose of the PMP system "...is to prevent cost growth and requirements creep due to existing systems or making improvements that entail 'hidden' execution costs."[12]

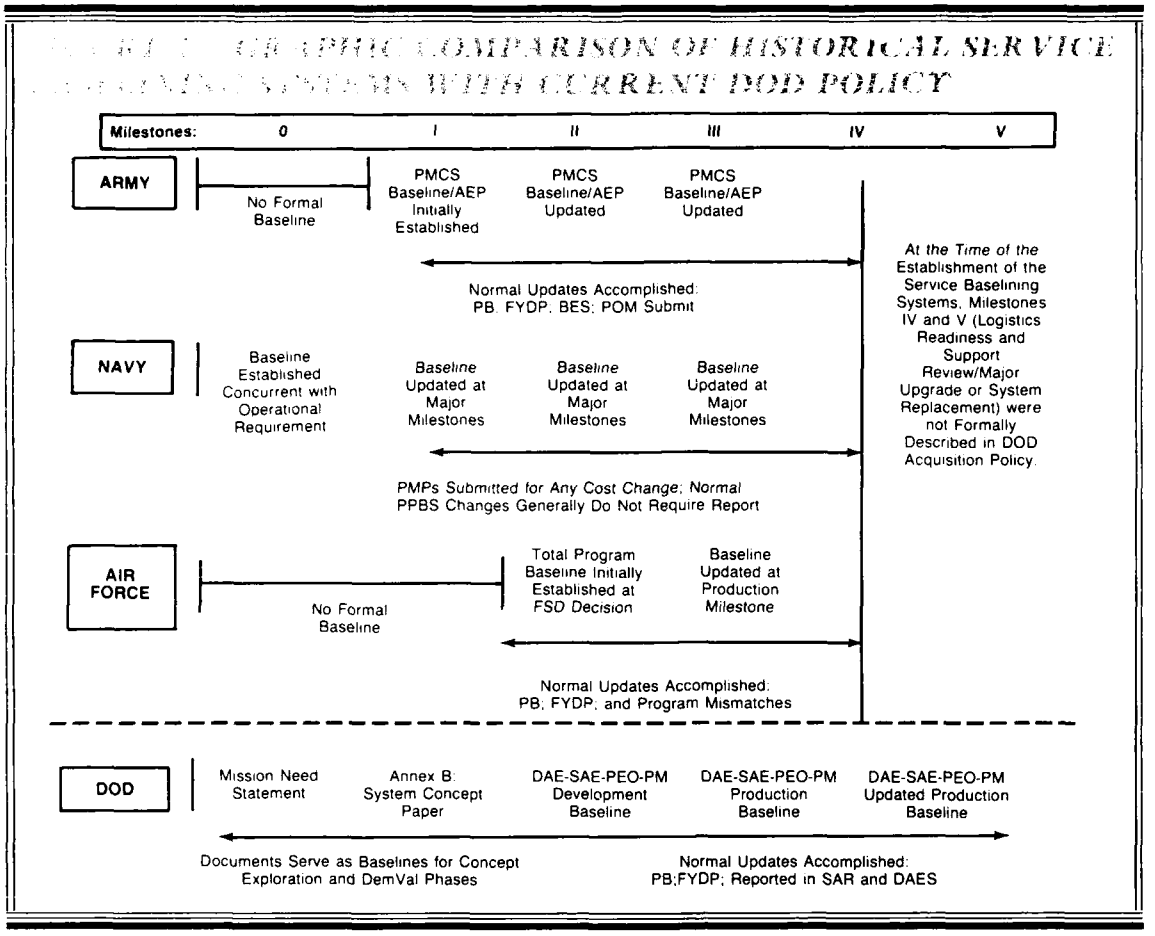
Army. Since 1981, the Army has controlled cost and managed programs through the Program Management Control System (PMCS). Recently, the Army revised its baselining procedures to accommodate the streamlined management concept advocated by the Packard Commission and to reflect changes in Department of Defense policy, reorganization and legislative mandates. First, we will review briefly the PMCS model, much of which remains similar in scope after recent revisions.

The overall objectives of the PMCS were to "provide improved management, program stability and increased cost discipline in the weapon system acquisition process at all levels."[13] In addition to this overarching objective, the PMCS provided an early warning system of potential program deviations through monthly reporting to the highest levels of Army leadership, and improved program reporting, controlled program changes, and developed a consensus supporting program requirements.[14]

Under the PMCS process, there were two types of baselines: The primary baseline was a major command (MACOM) level baseline representing agreement among program participants on major programs, signed by the PM and approved by the Commander, Army Materiel Command (AMC), and the Commander, Train-

COMPARISON OF HISTORICAL SERVICE BASELINING EFFORTS

ARMY	NAVY	AIR FORCE
PROGRAM MANAGEMENT CONTROL SYSTEM	PROGRAM MANAGEMENT PROPOSAL PROCESS	ACQUISITION PROGRAM BASELINING
AR-1000XX	SECNAVINST 5000.33A	AF REGULATION 800-25
PM;MACOMS;CS;VCS; DCSRDA	CNO;CMC;SECNAV	PM;MAJCOMS;CV;CVA
BASELINE ESTABLISHED AT MILESTONE I	BASELINE ESTABLISHED AT MILESTONES 0 TO II (PMPs Continue Throughout Program Life)	BASELINE ESTABLISHED AT MILESTONE II
MAJOR AND NON-MAJOR PROGRAMS	MAJOR AND NON-MAJOR PROGRAMS	MAJOR AND NON-MAJOR PROGRAMS
MONTHLY REPORTING AGAINST ANNUAL EXECUTION PLAN (By PM)	ANY SIZE DOLLAR CHANGE; NO FORMAL REBASELINING IF CHANGE RESULTS FROM PPBS	UPDATE YEARLY (PB; FYDP); BASELINE CHANGE LOG; ZERO GROWTH OPTION
ACTUAL BASELINE DOCUMENT	BASELINE IS THE LATEST FYDP (OR/DCP)	ACTUAL BASELINE DOCUMENT
EMPHASIS ON BOTH INITIAL ESTABLISHMENT AND SUBSEQUENT REPORTING OF BASELINE	EMPHASIS ON SUBSEQUENT REPORTING OF BASELINE; MANAGEMENT BY EXCEPTION	EMPHASIS ON BOTH INITIAL ESTABLISHMENT AND SUBSEQUENT REPORTING OF BASELINE
FORMALLY INSTITUTIONALIZED	FORMALLY INSTITUTIONALIZED	FORMALLY INSTITUTIONALIZED



ing and Doctrine Command (TRADOC); the Army Secretariat; Army Chief of Staff and Vice Chief of Staff; Army Headquarters Staff (ARSTAF); and signed by the Deputy Chief of Staff, Research, Development and Acquisition (DCSRDA). This approval scheme resembles the Air Force process of wide staff coordination and consensus-building among essential program participants. In addition to this major category of PMCS baseline, the Major Subordinate Army Commands (MSC) and the MACOMs selectively tailored the PMCS process for application to non-major systems.

The essential PMCS baseline document was the Program Directive Document (PDD), consisting of information in program description, acquisition strategy, integrated logistics support, testing, design-to-cost, reliability growth, and the Army/Office of the Secretary of Defense (OSD) funding profile, including RDT&E, procurement, MILCON and O&S costs. Usually, the initial PDD was established at Milestone I. An Annual Execution Plan (AEP) served as an appendix to the PDD and was the PM's plan for executing the approved program. The AEP incorporated the changes in the latest President's Budget and the associated Five Year Defense Plan (FYDP). Changes to the approved baseline were formalized and require DCSRDA approval. Each PM completed Monthly Program Status Reports (MPSR) indicating the success to date of the AEP.

Recent revisions to the Army process outlined above were accomplished to accommodate the program-reporting changes in Department of Defense policy. These changes retain the basic concept with incorporation of the streamlined management approach as the primary difference. These revisions include approved authority only of the PM, PEO, SAE and DAE and a focus on Army Selected Acquisition Report (SAR) programs for which baselines are being established for DOD-level approval. Also, the revised baselining concept is being applied to all programs, including extension to PEO-manager programs. On a selective basis, the concept will extend to the SAE level. In addition, the PDD has been modified to reflect the program information requirements of DoDD 5000.45, *Baselining of Selected Major Weapons Systems* and public law (Title 10, United States Code, Chapter 144, Section 2435).

For several years, each military service has controlled program instabilities and cost growth through a management mechanism. The three military service systems differ in various respects, including the degree of information detail required and the timing of the initial establishment of the baseline. However, the systems share a common purpose—to enhance management effectiveness by gaining some control over critical program parameters. Table 1 and Figure 1 summarize the similarities and differences among the military service baselining systems and compare them with the current DOD system.

Baselining: Recent History

In July 1985, President Reagan, beset by procurement scandals in the media and repeated calls for defense reform action, appointed former Deputy Secretary of Defense David Packard to

head a commission charged "...to conduct a defense management study of important dimension." The President's Blue Ribbon Commission on Defense Management or, more familiarily, the Packard Commission, studied a broad range of defense issues, including planning and budgeting, military organization and command, and government-industry accountability. Also, they explored acquisition organization and procedures and made several major recommendations to improve the acquisition process. Subsequently, many were enacted into legislation; included was the establishment of an Under Secretary of Defense for Acquisition. One recommendation which found its way into permanent codification was major program baselining.

In tandem with the work of the Packard Commission, the Congress intensified its oversight of the defense acquisition process and held numerous hearings on acquisition reform. A broad spectrum of witnesses, including former and current military service chiefs of staff and industrial executives, were called before congressional committees to testify on their perceptions of problems plaguing the acquisition process and to offer their prescriptions for improvement. The result of this unprecedented degree of congressional investigation into executive branch operations was a bonanza of legislation covering almost every aspect of the acquisition process, from competitive prototyping strategies to estimating manpower requirements for systems at the initiation of FSD. Baselining of major programs, of course, became law.

What did the Packard Commission and the Congress say about baselining? What were their respective intentions? In its final report to the President, the Packard Commission stated, "Program stability must be enhanced in two fundamental ways. First, DoD should fully institutionalize 'baselining' for major weapon systems at the initiation of FSD. Second, DoD and Congress should expand the use of multi-year procurement for high-priority systems."[15] Clearly, David Packard envisioned "fully institutionalized" baselining for enhancing program stability. To complete the endeavor, Mr. Packard contended the Congress should approve multi-year funding of the baselined program.

A careful reading of the Packard report reveals that the baselining of which the commissioners were speaking was not intended as merely a means of improving program reporting and elevating programmatic issues to departmental leadership. To the contrary, Packard et al were describing *an organizational commitment* to a particular program profile, a commitment that would be shared by congressional authorizing and appropriating committees. The distinction is critical, somewhat obscure, and at the center of current baselining dialogue. Does the baseline represent a shared commitment of program participants to preserve a particular program profile, with the attendant reductions or even terminations of lesser priority programs (i.e., non-baselined) that is implicit in this approach? Or is the baseline a mechanism by which to improve program reporting and ensure the elevation of program status to upper management? The latter philosophy reflects a "management control system." As one writer has described the purpose of these systems, "...management needs some way to assure that people in the organization are doing what they are supposed to do."[16] The former concept, however, implies a selective system of ranking and building programmatic priorities.

The Congress, relying heavily on Commission recommendations, legislated major program baselining in the Fiscal Year 1987 National Defense Authorization Act. In the legislation, the Congress required the Secretary of each military department to establish a baseline description for major defense acquisition programs before such programs entered FSD or Full-Rate Production (FRP). The passage of the Authorization Act occurred just 2 months after the department issued a baselining directive, DoDD 5000.45, *Baselining of Selected Major Weapons Systems*. The Department of Defense, in issuing the baselining directive, responded rather promptly to the Packard Commission recommendations, but not promptly enough to avoid legislation. This is not to imply that, in and of itself, legislative requirements represent an undue complication of the policy process. However, this is often the case in certain policy areas, because there are often myriad policy disconnects between the new legislation and the extant executive branch regulation that must be ferreted through and resolved. For example, the law was similar in many respects to the recently established departmental baselining policy, but, predictably, did differ significantly in a few crucial areas. Figure 2, *DOD Baselining Requirements and Public Law: A Comparison*, depicts similarities and differences.

In issuing DoDD 5000.45 (August 1986), the Department of Defense relied on the Packard recommendations as well as existing Air Force baselining policy. The directive required the establishment of baselines for all major programs as they entered FSD and production. The baseline established at FSD would contain total development costs and a unit production cost goal and become the *development baseline*. The baseline established at the production decision point would contain the average unit production cost and a total procurement cost profile and would become the *production baseline*. The establishment of two baselines, one for development and one for production, was deemed necessary because of uncertainty still associated with many program parameters, such as production and support costs, at the initiation of FSD. It was contended that requiring baselining of total production costs and applying strict deviation criteria to these parameters too early in the program's cycle would virtually ensure a baseline cost breach situation.

The DoDD 5000.45 also called for the inclusion of "important events such as initial operating capability and first deployment" and "those system performance parameters that are considered critical to the success of the system mission" and, for production baselines, a "validated estimate of the cost of the remaining program" and a "production delivery schedule." These requirements reflected concern for monitoring only program characteristics absolutely necessary for DAE management purposes. The immense detail of the Air Force system was clearly not envisioned.

Baseline Category	DOD Requirements	Legislative Requirements
COST	**For Development:** Total Development Cost and Average Unit Production Cost Goal **For Production:** Total Production Cost (Remaining Program) and Average Unit Cost	**For Development:** Total Development Cost By Fiscal Year **For Production:** Total Production Cost By Fiscal Year (NTE ICE submitted by SecDef)
SCHEDULE	**For Development:** Milestone Schedule, Including IOC; Milestone III, etc. **For Production:** Production Delivery Schedule	**For Development and Production:** Milestone Schedules
PERFORMANCE	**For Development:** Critical Performance Parameters **For Production:** Demonstrated Performance Parameters and Acceptable Deviation Limits	**For Development and Production:** Performance Goals, Technical Characteristics, and Configuration
OTHER	N/A	**For Production:** Testing, Initial Training; Initial Provisioning; Number of End-Items by Fiscal Year
BREACH PROCEDURES	**For Development:** 15% Increase in Cost Parameter; Performance Parameter Not Expected to Be Met; Schedule Parameter to Be Missed by More Than 90 Days **For Production:** Same as Above Except 5% Increase in Cost Parameter DAE Notified of Breach and Potentially a DAB (JRMB) Review is held	**For Development and Production:** Any Increase in Cost Parameter; Performance Parameter Not Expected to Be Met; Schedule Parameter to Be Missed Secretary, MilDept, convenes Review Panel and Submits Report to USD(A) within 45 Days

The directive also mandated that "major programs currently in FSD or production will be baselined within 90 days after the effective date of this directive ("90 days after" equated to November 26, 1986). This passage in DoDD 5000.45 was thoroughly misunderstood, perhaps with good reason, by the military services, none of whom submitted a baseline for approval as of the 90-day deadline. For several reasons, this statement was interpreted by the military services as contradictory guidance in the context of the entire directive. First, the directive is entitled *Baselining of Selected Major Systems* and implies that the baselining process described in the directive will be applied only to certain major programs meeting specific criteria. Yet, the directive called for baselining all major programs "within 90 days." Second, the directive states the Service Acquisition Executive (SAE) shall recommend to the DAE which major programs falling under SAE jurisdiction should be baselined. Again, this responsibility implies selectivity.

Consequently, the military service response tended to exploit the conflicting policy signals of DoDD 5000.45, primarily because the baseline breach procedures it established portended numerous Joint Requirements and Management Board (JRMB), now the Defense Acquisition Board (DAB), reviews. These reviews would be triggered if a system performance requirement was not met; a milestone was missed by more than 90 days; or costs increased by more than 15 percent for a development baseline or 5 percent for a production baseline. The performance deviation was probably perceived as the most constraining of the above margins, especially when stipulated in a development baseline, because the potential for redefining performance requirements and restructuring performance capabilities during the design and testing process was significant. This concern was exacerbated by the lack of a "goal and threshold" mechanism for articulating and measuring performance factors, at least in the development baseline phase. The DoDD 5000.45 did call for a "full set of demonstrated system performance parameters, together with *acceptable limits of variation* of these parameters" in establishing a production baseline. By the time the system is developed and tested and gains approval to begin production, technical and operational performance characteristics should be significantly more stable than they were at the inception of FSD.

The department's initial step toward institutionalizing baselining was, in effect, a false one. The military service response to issuing DoDD 5000.45 was negligible, partly because of inherent contradictions of the directive. Another reason may be the OSD and military departments adversarial relationship led many observers to conclude no one was in charge of the acquisition system. In part, this perception served as the primary catalyst for creating the Packard Commission.

Issuing DoDD 5000.45 and passing the baselining statute coincided with the arrival of Richard P. Godwin, a former executive of the Bechtel Corporation, the first person to occupy the newly created position of Under Secretary of Defense for Acquisition. Mr. Godwin arrived at the Pentagon amid great expectations from supporters on Capitol Hill and in the

Department of Defense. Mr. Godwin perceived his mandate as very clear: to wrestle management control, by bureaucratic force if need be, of the DOD acquisition system and make it more efficient and effective. Baselining of major programs figured very prominently into this effort.

Mr. Godwin viewed baselining much more broadly than the Department of Defense and the Congress. The DoDD 5000.45 and baselining statute called for the *establishment* of program baselines at FSD and production. He contended that programs "shouldn't break their budgets" and that a program should adhere to a particular baseline from its inception through the phases of the acquisition cycle. Soon after his official arrival, Mr. Godwin was apprised of the status of baselining (i.e., DoDD 5000.45 had been ineffective thus far). In a January 5, 1987, memorandum to the SAEs, Mr. Godwin chided the military services for their lack of response and requested they nominate candidates for baselining:

> The directive calls for the submission of candidate systems to be baselined within 90 days after its issuance. As of November 25, 1986 (90 days after issuance of the directive), no candidate systems had been submitted to OSD.
>
> In order to adhere to the tight budget preparation schedule the candidate systems are requested to be submitted to my office (attn: JRMB Secretary) by January 15, 1987.

The Air Force and Navy responded that the Programs designated as Enterprise Programs* would be ideal candidates for baselining. The Army responded that the Army Selected Acquisition Reports (SAR) programs constituted an appropriate set for baselining purposes.

The Defense Enterprise Program (DEP) was created by the Fiscal Year 1987 National Defense Authorization Act. It established a mechanism by which the Secretary of Defense and the Military Department Secretaries could designate certain programs as DEPs. The DEPs would have the following characteristics: 1) managed in a streamlined manner (PM-PEO-SAE); 2) program office structured to accommodate staff positions for technical staff (business management, auditing, engineering, etc.); 3) regulatory relief to be provided; and 4) eligible for Milestone Authorization by the Congress (baselines to be submitted to the Congress if request for milestone authorization is made). The following programs were designated DEPs:* **Army: *Mobile Subscriber Equipment (MSE); Tube-Launched Optically-Wire-Guided Missile (TOW II); Army Tactical Missile System (ATACMS).* **Navy**: *T-45 Jet Training System (T-45TS); TRIDENT D-5 Missile; SSN-21 Attack Submarine.* **Air Force**: *Delta II; TITAN IV Rocket; C-17 Airlift Aircraft; Short Range Attack Missile (SRAM II)).*

The initial OSD response was to concentrate effort on establishing baselines for the DEPs that had been requested for milestone authorization. Submitting baselines for these programs to the House and Senate Armed Services Committees within 90 days of the original request was required by law and, thus, deemed to be the highest priority in the baselining effort. After a detailed internal review, the Secretary decided to officially request milestone authorization for three of the DEPs, MSE, D-5 and Delta II. The military services were directed to prepare and submit baselines for these programs. According to the legislation, the baselines for these programs were to be in accordance with Section 2435 of Title 10 (Figure 2).

While this work was proceeding, the DAE considered the military service proposals regarding program candidates for baselining. The Air Force and Navy recommended baselining only the DEPs at the DAE level; the Army advised that the SAR programs (in FSD or Production) would be appropriate. The Air Force and Navy proposals were attractive from the standpoint of winnowing the scope of the DOD-wide baselining initiative to a few, high-priority major programs. This approach resembled the concept of the *stable programs list*, first articulated in 1981 as part of the implementation of the Defense Acquisition Improvement Program. This concept held that management attention should concentrate on a select list of high-priority programs, which would be preserved through the various phases of the PPBS process. The advantage of the Army approach was that it emphasized the necessity of actively managing all major programs. It was this philosophy that more closely coincided with the view in OSD and the Congress that DOD should manage its vast resources more effectively. Consequently, the DAE decided DoDD 5000.45 would be enforced for *all* major programs in FSD or Production.

On June 15, 1987, after preparation and submittal of the milestone authorization program baselines was almost complete, Mr. Godwin signed a memorandum to the military services that stated, in part:

> Until such time as program baselines are provided for all major systems in accordance with DoDD 5000.45, the program parameters (cost, schedule and technical/operational) contained in the Selected Acquisition Reports (SAR) shall comprise the program baselines for management and oversight purposes.
>
> The parameters to be considered part of the program baselines are as follows:
>
> *Schedule Milestones:* Section 9a of the SAR
>
> *Technical/Operational:* Section 10a and b
>
> *Cost:* Section 16c and Section 11c and d.
>
> Variances of 15% for R&D parameters and 5% for production and deployment parameters will be applied to the baseline values to determine when a breach of the baseline occurs.

Several significant issues emerge from this memorandum. The SAR, for example, had heretofore never been utilized as a baseline document, but rather as a reporting mechanism on program progress. The OSD primary motives were to prod the military services to establish baselines simultaneously for all major programs

in FSD or Production (the original intent of DoDD 5000.45) and erect a temporary baseline document in the interim. Such an action was deemed necessary by the inordinate delay experienced thus far in establishing baselines (by this point, it had been nearly a full year since DoDD 5000.45 was originally issued). In one move, baselines, albeit inherently temporary in nature, for over 100 major programs were suddenly created. Soon after this action was taken, Secretary Weinberger approved the baselines for the three milestone authorization programs and forwarded them to the Congress.

Baselining: Current Status and Remaining Issues

Submittal and Review Process. The military services' initial reaction to the memorandum of June 15, 1987, was muted but slowly began to filter in. Primary among objections was the SAR as a mechanism by which to establish program baselines. The SAR is a program "budget" report, submitted to the Congress annually. It provides the current status of a program across categories, including technical and operational performance characteristics, total program costs and unit costs, and schedule information. The SAR also includes other pertinent information, such as program and mission description, significant issues, significant changes since the last SAR, etc. The Congress can request a SAR at any point in the acquisition cycle, but normally a SAR is initiated for a program at the inception of FSD and is continued until the program has achieved 90 percent of its planned production.

The military services objections to the interim solution posed by the June 15 memorandum argued the following: 1) The SAR was primarily an historical document that merely updates the status of a program at budget time (i.e., submittal of the President's Budget to the Congress); 2) The SAR does not undergo the rigorous review and approval process that a program baseline does; 3) The SAR preparation does not occur in conjunction with a Milestone review; 4) The SAR is submitted to the Congress and including the baseline in it would invite additional congressional micromanagement; and 5) The SAR would prove to be a better baseline reporting document. Once again, the essential philosophical argument on the nature of a program baseline emerges—budget and program reporting versus management commitment to a specified program.

Although OSD management agreed in principle with many of these arguments, it still felt obliged to create an interim baseline until official baselines had been approved. In the aftermath of the June 15 direction, there was much dialogue and debate but still no formally established baselines. Once again, in a memorandum of August 26, 1987, the DAE directed the military services to prepare and submit baselines for approval:

> Major system baselining is required by DoDD 5000.45 and by public law. [Service compliance] is not adequate and does not respond to either departmental or legislative direction. Accordingly, it is requested that the [Services] submit baselines for all applicable programs no later than September 18, 1987. Any baseline breached must be reviewed by the Service and reported to the DAE.

The tone of this memorandum reflected the rising frustration of OSD management with the pace of the baselining effort as well as a sensitivity to effective compliance with the recommendations of the Packard Commission and the provisions of the baselining statute.

The military services are responding to the August 26 direction; baselines were submitted for all applicable programs as of January 1988 (see Table 2). The review process at the OSD level, thus far, has focused primarily on the performance section of the baselines, attempting to ensure that the operational and technical characteristics included in the baseline represent the most critical parameters for the program in question. Ascertaining whether this is the case depends on an understanding of the program's mission and the capabilities necessary to perform effectively. Automated message handling rate, for example, would be a prime performance factor for an information and communications system; however, it would be a meaningless factor for a ballistic missile. Similarly, correctly structuring the performance section of the baseline depends on program timing. Tracking a static design parameter such as weight for a missile in full-rate production would be a futile exercise; however, monitoring such a parameter for a cargo airlift aircraft program in the midst of a development effort would be well-advised.

The review process encompassed also the *Cost* and *Schedule* sections of the baseline. In cost, the review focused on: 1) agreement of costs with data reflected in official budget documentation (e.g., FYDP, Congressional Data Sheets); 2) display of costs in Then-Year dollars as well as Base-Year dollars; and 3) technical review to ensure mathematical accuracy. The second point was not an original requirement of DoDD 5000.45 or public law, but was a policy decision that the cost section of the baseline must reflect the impact of inflation and must be conversant with other management reports (e.g., SAR) that include Then-Year dollar tables.

In scheduling, the review focused on: 1) including important future schedule events; 2) management deciding what constitutes important baseline events; 3) including some historical events in the interest of providing an adequate context for decision-makers; and 4) technical review to ensure accuracy. In deciding what comprises important schedule events for baseline purposes, the focus was on program events that could potentially upset completion of a major acquisition phase or achievement of a major milestone (e.g., FSD or Initial Operational Capability). Completion of developmental and operational testing, for example, are critical dates because they reflect the success or failure of the testing program and the attendant fluctuations in the remainder of the program. The FSD and Production contract award dates are not as significant in terms of baselining because these events occur *after* major reviews, Milestone II or III approval by the

ARMY	NAVY		AIR FORCE	
ADDS	A-6E/F	PHOENIX	AMRAAM	SRAM II
AH-64	AN/BSY-1	SEA LANCE	ASAT	TACIT RAINBOW
AHIP	AN/BSY-2	SH-60B	ATARS	TITAN IV
ASAS	AN/SQQ-89	SH-60F	B-1B	TRI-TAC
ATACMS	ASPJ	SPARROW	C-5B	WIS
BFVS	AV-8B	SSN-21	C-17A	
CH-47D	C/MH-53E	AAN-688	CSRL	
COPPERHEAD	CG-47	SM-2	DMSP	
FAADS C2I	CVN 68 CLASS	T-45TS	DSCS III	
HELLFIRE	DDG-51	TOMAHAWK	DSP	
M-1 TANK	E-2C	D-5MISSILE	F-15	
MLRS	E-6A	TRIDENT SUB	F-16	
MSE	EA-6B	V-22	IR MAVERICK	
PATRIOT	F-14D		JSTARS	
SINCGARS	F/A-18		JTIDS	
STINGER	HARM		KC-135R	
TOW II	HARPOON		LANTIRN	
UH-60A	LCAC		NAVSTAR	
	LHD		OTH-B	
	LSD-41		PEACEKEEPER	
	MK-48		RAIL GARRISON	
***This list is still being revised as of this writing.**	MK-50		SFW	
	P-3C			
	PHALANX CIWS			

Defense Acquisition Board (DAB), already contained in the baseline.

The DAE will approve all military service baselines via a "policy memorandum" that formally establishes DOD-level baselines and promulgates baselining policy for the future. The first of these policy memoranda was issued on February 9, 1988, to the Air Force (Air Force baselines were the first submitted to OSD for review). This memorandum approved all Air Force baseline submittals "contingent upon the addition of certain critical information" and included guidance for the future:

> We are revising the Defense Acquisition Executive Summary (DAES) to incorporate the baselines and to track compliance with baseline parameters. I would like you to incorporate the complete program baselines into the DAES system as soon as possible. In the future, baselines will be proposed in the appropriate sections of the milestone documentation (e.g., Decision Coordinating Paper) and approved in conjunction with the milestone decision. DoDD 5000.45 will be rescinded and revised baselining guidance will be included in DoDI 5000.2.

The DAE policy memorandum is significant for several reasons. First, it affirms the importance of the baselining concept to effective management. Second, it more closely relates baseline establishment to the milestone review process and eliminates the need for a separate baseline document. Third, it establishes a process for reviewing baseline progress. Although final approval of all baselines for all FSD and Production major programs and promulgation of revised baselining guidance represent significant milestones in the program stability effort, much work will remain to be done and many issues will have to be resolved.

Remaining Issues

After major program baselines are initially established, issues still to be resolved include:

—*Baseline Administration*. Rigorous administration of baseline parameters and strict adherence to major elements of baselining policy is absolutely necessary to make the baselining effort truly meaningful (see Figure 3). A major part of rigorous enforcement involves tracking baseline breaches closely; to accomplish this, the SAR and DAES reports will be used extensively. The DAES report will be a quarterly rather than a current monthly report and will contain not only all baseline information (cost, schedule and performance), but also will serve as the mechanism by which actual baseline deviations and *potential* baseline deviations are reported to the DAE. Of course, the SAE will be expected to review baseline deviations and offer alternative courses of action for the DAE to consider.

The distinction between actual and potential baseline deviations is critical. As the PPBS process moves from the programming to the budgeting phase, many tentative decisions are made and, in many cases, subsequently unmade. A POM proposal to increase quantities for Program X may be overturned during the Program Review via the PDM and modified once again in a PBD action. Of course, once contained in the President's Budget, the proposal can again be adjusted by congressional action. Consequently, when the POM is submitted to OSD for

review and adjustment, the program manager can, at best, only assess the *potential* impacts to the baseline; these potential impacts may still be shaped by future PPBS or congressional action.

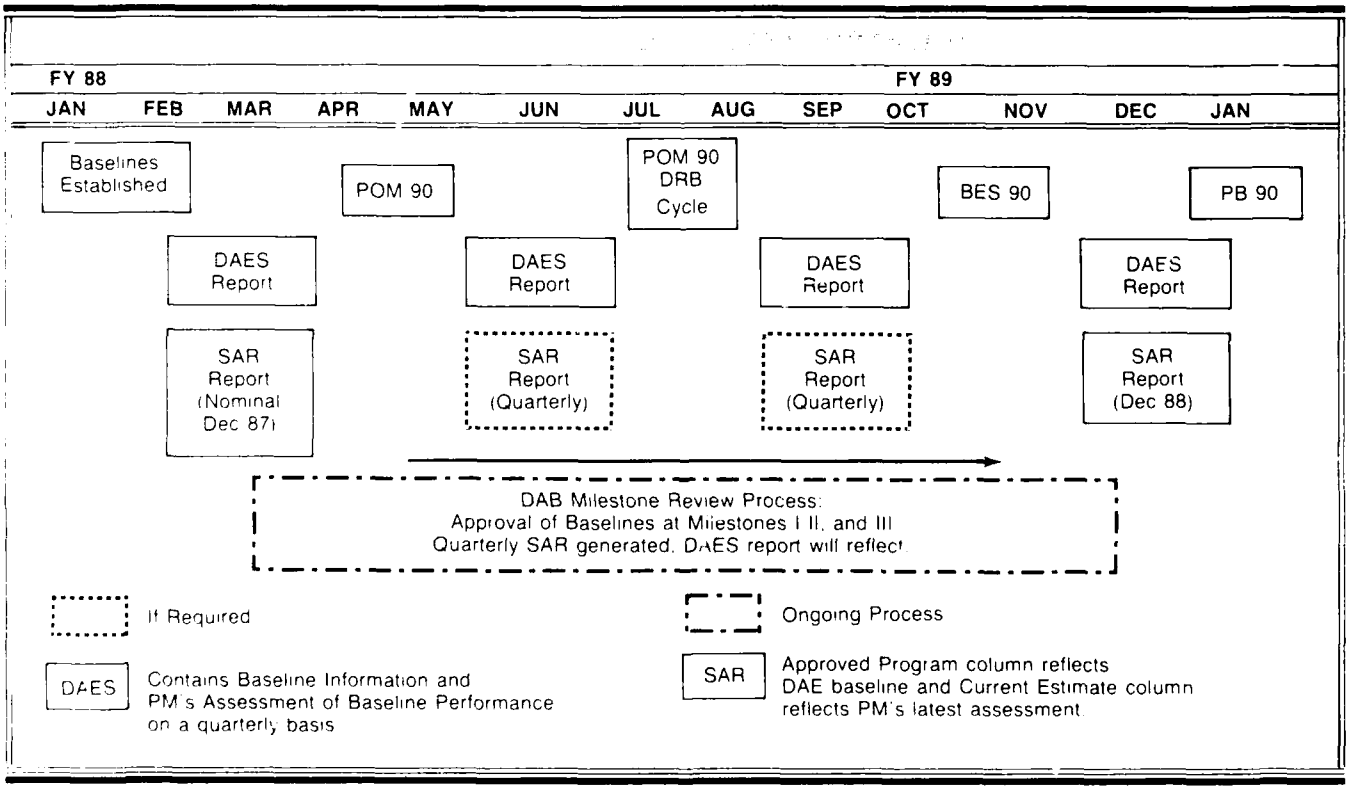
—*Baseline Breaches and Defense Acquisition Board (DAB) Review.* One major area of contention in baselining policy has been the review activity of the DAB that a baseline breach might trigger. Justifiably concerned by this possibility, the military services have been somewhat reluctant to baseline certain performance (as well as cost and schedule) parameters for fear that slippage in any of these (including "fact-of-life" breaches—those directly caused by congressional or OSD action) would automatically cause a full-scale DAB review of the program. Even if the DAB chairman were predisposed to initiate reviews for every baseline breach that occurred, it would be a physical impossibility; congressional action alone will cause myriad deviations from previous baseline levels. More realistically, the DAB chairman (and staff) will assess the significance of the deviation on a case-by-case basis and then decide if a DAB review is warranted. Substantial degradation in performance capability or severe cost growth will probably be the prime considerations in this decision. The February 9 DAE policy memorandum states, "baseline breaches will not necessarily warrant a DAB review."

—*The DOD/Legislative Harmony.* An important issue for future baselining policy is ensuring full harmony between the baselining requirements of legislation and DOD policy. The two are essentially synonymous at this point, although that was not always the case, due primarily to the administrative lag of the legislative process. As initially passed, the baselining statute (now embodied in Title 10, U.S. Code, Section 2435) conflicted with previously established DOD baselining policy in the area of deviation margins. The original version of the law allowed for no margin in cost or schedule parameters whereas DoDD 5000.45 allowed for 5 percent (production) and 15 percent (RDT&E) cost margins and a 90-day schedule margin. According to the law, the PM was to submit a deviation report:

> ...there is reasonable cause to believe that the total cost of completion of the program *will be more than* [the baseline]...and, any milestone specified in [the baseline] will not be completed as scheduled.

Subsequent amendments to the statute have incorporated the 5 percent/15 percent and 90-day margins. The DOD amended baselining policy via the DAE policy memorandum to include a 180-day schedule margin because such a margin is much more realistic and also has the advantage of matching the SAR quarterly submission schedule criterion. Once again, this change will necessitate legislative relief. Ninety-day slippages will still be reported in DAES submittals, in accordance with current legislation.

Reporting baseline deviations via DAES reports allows the military services to abide by another legislative requirement—the program deviation report. Also called for in Section 2435, this report must be submitted by the PM to the Service Secretary and the SAE. After reviewing the subject program, the Service Secretary must submit a report to the USD(A). The quarterly DAES submittal, including the PM, PEO and the SAE assessment of baseline performance, will allow the military service to report breaches and



warn of impending breaches.

Summary

This article attempts to give you a broad overview of major program baselining in the Department of Defense. Areas covered are the purpose and definition of baselining; a brief history of baselining efforts within the three military services; a discussion of recent program baselining, with an emphasis on OSD and legislative initiatives; and an examination of issues still to be addressed in the baselining effort and a review of the current status of Department of Defense baselining effort.

Baselining as a management concept and practice is certainly not a new idea within the department, but one that gained renewed emphasis, especially in the current environment of fiscal constraint. Baselining the critical parameters of a program is inextricably linked to the departmental goal of enhancing program stability and the oft-stated objective of gaining effective control of the acquisition process. Perhaps it is due to having these related but separate demands placed upon it that baselining has so often been pulled in different philosophical and practical directions. These competing objectives can be summarized succinctly: Another budget and management reporting requirement levied upon the program office merely for the sake of reporting *versus* a true and substantial management commitment (extending across all military service management levels and to OSD) to a specified program.

We have seen that the military services employed methods of baselining programs (major and non-major) for several years and the three methods differ across a range of categories. We examined the history behind the recent resurgence of baselining as a department-wide initiative and reviewed the specific recommendations of the Packard Commission and the provisions of the baselining statute. Also, we reviewed, in some detail, the policy process leading to enforced baselining for all major programs in FSD or production. Finally, the current status of the baselining effort was analyzed and some outstanding policy issues were discussed.

Conclusions

Is baselining the answer to the perennial problem of fluctuating budget authority levels and the attendant program instability it causes; or is baselining merely a buzzword, a catchy title for a less-than-substantive concept with reporting guidelines belying essential premise? These questions define the central policy debate waged within the Pentagon and on Capitol Hill for the past 18 months.

Detractors argued that baselining (as applied to more than 100 major programs spanning the technological and financial gap from radios to fighter aircraft, from hundreds of millions of dollars to tens of billions of dollars) is doomed to failure. It is contended it will not and cannot fulfill its primary mission to control costs and schedules and stabilize programs. These detractors view baselining as a true *contract* between senior-level managers and the program manager. In the detractors' opinion, once baselined, a program definition is preserved and protected from the vagaries of budget and policy processes. For such a method to be effective, it must be used sparingly and only on the highest priority programs; thus, the conundrum presented by applying the concept to more than 100 programs. Consequently, in the face of this baselining policy, detractors tend to view it as merely another reporting requirement.

Proponents, on the other hand, bemoan the lack of true management control in the DOD acquisition milestone review process and point to the short term of Richard P. Godwin as Under Secretary of Defense for Acquisition, as evidence of this trend. Baselining is seen as a means to strengthen the management effectiveness of the DAE in the performance of duties. By reviewing and approving a program baseline for every major program as it enters FSD and production, proponents contend the DAE is making the milestone review process a much more substantive examination of a program's true military worth and cost effectiveness. In addition, the DAE is laying the foundation for any necessary future reviews; by stipulating goals and thresholds for critical program parameters at the inception of FSD, the DAE is informing the acquisition community of the standard that the program is expected to meet. Proponents argue that, while attractive in the abstract, it is practically infeasible to "fence" even a few high-priority programs and that, given this reality, it makes sense to at least set the standard for program performance and thereby illuminate technical and affordability issues when the time comes for major budget decisions.

Baselining policy will undoubtedly continue to be refined in the future. Much progress has been made thus far including clarifying the relationship between departmental policy and legislative requirements and the preparation and submittal of close to 100 baseline documents. In what appears to be an era of prolonged fiscal constraint, impervious to which party wins control of the White House this November, baselining will probably continue to be accorded a high level of management attention. After initial establishment of baselines for all major programs, the true management challenge will be the effective administration of these baselines. This will include not only a well-articulated policy of baseline deviation reviews but also a routine process of reporting progress against the baseline standards. Finally, one management challenge will be adequately defining the integrity of baseline parameters, especially cost, as they relate to the PPBS process. Dealing with this challenge will highlight the longstanding debate as to which management system predominates in defense planning, the acquisition milestone review process or the PPBS resource allocation process.

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2. Acker, David D., and Schutt, Harold J., "Program Stability: An Essential Element in Improved Acquisition," *Concepts*, Summer 1982, p. 148.

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5. Official Air Force Briefing on Baselining, Colonel Richard Danhoff, USAF, former Director of Program Integration.

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(Continued from page 41)

—Diagnosing organizational problems
—To show M.B.A. students the nature of managerial work
—To enable technical people to experience managerial work
—Assessment of managerial potential.

Participation in Looking Glass can be the highlight of a student's visit with DSMC. So far, DSMC has run the simulation 12 times. The following comments from past participants are typical of those received on the critique sheets:

—"I feel I was helped by the entire workshop."
—"One of the best experiences at DSMC."
—"An excellent simulation—very realistic,"
—"One of the highlights at DSMC,"
—"Exceptionally valuable,"
—"Thoroughly fascinating."

As reflected in discussions after the conclusion of the workshop, the simulation has been challenging and fun. Participants find they have taken stock of their managerial abilities, learned more about the process of management, and how to make it work for themselves and their organizations.

Looking Glass is like a mirror. It provides a manager the opportunity to look at personal managerial performance and to be perceived by other Looking Glass managers. Reflections provide greater self understanding from which one can make decisions to change or fine tune management style. In a quest for excellence, this simulation helps participants understand what Plato meant when he said, "Know thyself."

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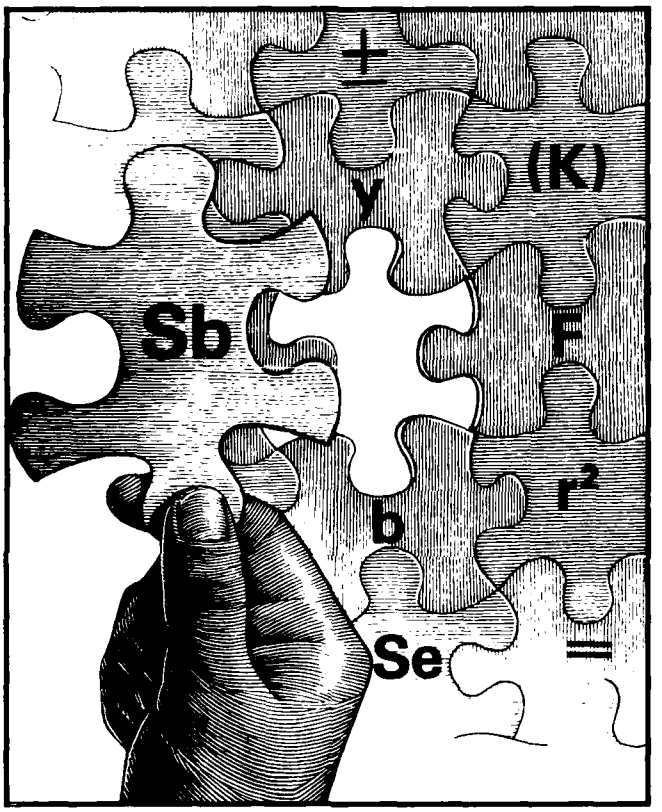
DATA MAN MANAGEMENT: A STATISTICAL PERSPECTIVE

Dr. Jack B. Re Veille *Dr. Lane B. Blunk*



The purpose of this article is to present selected statistical methods which can be applied in establishing population parameters. These parameters have application in analysis and development of sustaining and corrective actions regarding trends, recognizing and dealing with timeliness and responsiveness measurements, and obtaining optimal information from statistical *action* experiments.

Each measurement indicator presented to the appropriate audience is the result of the timely treatment of one or more established data bases or parts (files) thereof by mature, readily available statistical analysis routines. Output forms include both tables and charts or graphs.

Multivariate Methods

The analysis and interpretation of trends nearly always utilizes one or more of the statistical techniques known collectively as "multivariate methods." Thus, the application and examples presented in this article are introduced through a brief tutorial on the subject of multivariate analysis as a whole.

Observers of any quantified process—whether it is physical, financial, social, or in any other realm—tend to relate the trend being studied to a time-interval scale. In other words, we review past data and then forecast the future status of manufacturing, economic, or human performance using time units such as hours, days, quarters or years. While there is no harm in this practice, neither is it inclusive of all of the useful dimensions upon which such behavior may be based.

In fact, as is frequently the case, when time-based populations or samples are quite dissimilar in size, conclusions from analyses are severely hampered, and alternative methods of grouping should be used. For example, in a production environment chronological subgroups of equal size (e.g., 5, 10, 20, or even 100) can be identified and evaluated. In another vein, when distances operated by a vehicle are of interest, the scale of the independent variable could be miles or kilometers.

A distinction must be made between two major topics in the area of multivariate analysis; i.e., correlation and regression. Correlation analysis is limited to describing the direction and degree of association between and among variables which are considered to be mutually related rather than dependent one upon another. By definition, coefficients of correlation are limited in value such that they cannot exceed either negative or positive one, while their squares, coefficients of determination (which are defined and described below), are bounded by zero and one.

On the other hand, regression analysis is used to estimate dependent variable values based on given values of one or more independent variables. It utilizes the "least-squares"

method in minimizing the sum of the squares of the vertical distances of all the sample points from the resulting regression line, a graphic pattern which is the line of best fit to the sample points. Regression line coefficients (intercepts and slopes) are limited in value by negative and positive infinity.

Assumptions and Conventions

To optimally apply standard multivariate methods such as regression and correlation to the analysis of trends in manufacturing yields and defect/defective rates, the following assumptions must be made: (1) the "collection" of elements being tracked is a *sample* from a larger population, lot or batch; (2) the sample, thus defined, has been selected *randomly*, or at least under conditions that assure representativeness; and (3) the sample is sufficiently *large* to expect it to behave "normally" according to the statistical "Central Limit Theorem." Forms of the correlation model include, but are not limited to:

—*Simple*. This form can use only two variables.
—*Multiple*. This model is based on the relationship between a single variable and a collection of two or more other variables.
—*Partial*. This technique is used to assess the relationship between two variables, *excluding* the influence of one or more additional variables.
—*Rank*. This approach is used when the data are of the ordinal, not interval nor ratio, level of measurement. Examples include: the Spearman "rho" and Kendal "tau" methods.

Among, but not exhaustive of, the varieties of regression analysis applied to scientific, economic and social data are:

—*Simple linear*. This is a straight line relationship between two variables.
Multiple. This version makes use of two or more independent variables.
Stepwise multiple. This approach collects or eliminates independent variables in the order of their relative contribution to the estimate of the dependent variable.
Non-linear (curvilinear or polynomial). This technique establishes the relationship between two variable forms. Graphically, it is a curve rather than a straight line and, therefore, higher powers (second, third, etc.) of the independent variable are found in the model/equation.
—*Discriminant analysis*. This method uses simple or multiple regression in which the dependent variable is categorized into a small number of groups rather than measured along a scale.
—*Time series analysis*. This can take either a linear or non-linear form, but with the distinguishing feature that the independent variable is measured along a time scale or its equivalent.

A better single measure of bivariate (simple) or mutivariate association than the coefficient of correlation (r) is its square, known as the coefficient of determination (r-squared). The latter statistic indicates what proportion of the dispersion or variance in one variable is explained by the dispersion in the other variable. An "r-squared" of 0.25 (i.e., r = either +0.5 or −0.5) indicates that 25 percent of the spread in one variable is accounted for by the spread, either plus or minus, in the other; conversely, when r = ± 0.8, then r-squared = 0.64 is intepreted to mean that 64 percent is likewise explained.

Extreme Values Among Samples

The simplest and most popular method of testing a suspected extreme value uses the ratio of two ranges; i.e., the distance of the suspected outlier from one of its *near* neighbors divided by its distance from one of the *furthest* sample values. Sound technical and managerial judgment must override the performance of numbers in assessing possible extreme values.

If one or more high and/or low values is/are rejected at a chosen risk level (alpha), the appropriate descriptive measures are then conventionally recalculated, as are the test statistics concerning hypotheses; e.g., F, t, r, and the regression coefficients. However, one should not automatically eliminate an outlier since it may yield information that the other members of the sample cannot.

Interpretation

In the interpretation of trends, linear and otherwise, one must exercise great care in attempting to estimate the dependent variable by extrapolation very far beyond the range of the sample data from which the model was built. A crude, but appropriate, rule-of-thumb might be that the number of time periods or other points extrapolated beyond the sample points should not exceed one-fourth of the number of those sample members. All other factors being equal, the larger the ratio between historical and forecasted values, the more reliable the forecast.

Also, multiple regression analysis should pay heed to the existence of any *multicollinearity*; i.e., a *significant* correlation, either positive or negative, between one or more pairs of independent variables.

To aid in the interpretation of trends over time and in other multivariate analyses, a number of statistical and graphical outputs should be considered; among them:

—*Coefficient of determination* (r-squared). As noted earlier, this is the best indicator of bivariate or multivariate association. It measures the proportion of variation which can be explained by the variation in the other. In general, an r-squared greater than 0.8 is considered a good fit, from 0.5 to 0.8 a moderate fit, and 0.25 to 0.5 only fair.
—*Variance ratio* (F). This is the variance due to the regression relationship divided by the variance due to error (the composition of the sample). It indicates whether and to what extent a significant relationship exists between the dependent variable and the independent variable or set of independent variables.
—*Regression slopes/coefficients* (b), their *standard errors* (Sb), and the *ratio of "b" to "Sb"* (t). In general, the greater the value of "t," the more significant the slope; i.e., the less chance that a line of such a slope could have been obtained merely by accident while sampling.
—*Standard error of the estimate* (Se). This is the standard deviation of the distribution of the values of y for a given value of x.
—*Control limits*. These are used for estimating the dependent variable (y) and are determined using the relationship, y ± (K) (Se). It is common, but not necessarily recommended, to use

K = 3 standard errors in establishing such limits so as to be virtually certain (actualy 99.73 percent) to bracket normally distributed values of y. From a trend warning standpoint, more useful limits might be ± 1.96Se, ± 1.645Se, or ± 1.00Se. These are equivalent to 95 percent, 90 percent, and 68 percent assurance (confidence), respectively.

Precautions

Frequently, it is necessary to compare the behavior of a process or a product at two different life stages; e.g., yields for two successive tests, "before" and "after." This is to say that not only is each of the trends analyzed and interpreted, but the two patterns are compared and contrasted with each other.

Although Mark Twain is not remembered as a statistician, he once noted that if the linear drying out of the lower Mississippi River continued as it had during the last century, the river would disappear altogether in the mathematically foreseeable future. There are many such dangers of extrapolation in the real world.

The "behavior" of numbers has another serious drawback in its lack of parallelism with things physical, social and economic. Regression coefficients and the equations or models built from them are, as noted earlier, patterns or paths of best fit through existing data points.

If the physical or mental growth pattern of a child is plotted for the early years, it is likely to take on a second degree form with early acceleration slowing, but with progress still occurring, even after some years. Projecting the mathematical equation which best fits the existing points beyond the present (i.e., extrapolating the patterns to later years) would probably show downturns in the near- to mid-term future. In other words, the child would be predicted to become *smaller, less skilled* or *less developed*, and so on. Of course, that is an illogical forecast as would be its counterpart in quality-related trends such as reliability growth, manufacturing yield, and defect reduction. Sound technological and managerial judgment based on additional information must override the performance of numbers.

Not all trends can be described accurately with a straight line; neither can all regressions be fitted best unless the non-linear models are also considered. Probably the best way to test for non-linearity is to fit the regression by straight line and then by one or more curvilinear relationships. If one of the latter cases has a higher coefficient of determination, then it can be expected to be more appropriate. The specific application will dictate whether or not the non-linear model is useful. In some cases more of the variation in the dependent variable could be accounted for by the non-linear model, but it might not be practical to use in any prediction. There is frequently a trade-off between a more simplified model and a better statistical fit. Usually, the latter implies collecting more data at a cost that must be weighed against benefits.

In applying regression techniques, the first step is usually to plot the variables as a scatter diagram. A working knowledge of the series one is using is necessary and should be of value in reaching a decision. Visual inspection and judgment are vital. There is no substitute for a sound knowledge of the data and good common sense in the application of statistical methods to any problem.

Indicator Ranges

Typical ranges of data for a proposed set of management indicators tend to fit into predetermined clusters. For example, such items as manufacturing and field yields, both theoretically and occasionally in practice, are bounded by 0 and 100 percent. Rates of engineering changes, absences, return on investment, turnover, overtime, cycle times, etc., are also percentages but tend toward a limit of zero.

Labor performance factors may range from slightly less than one (i.e., more than the particular standard is actually earned) to five or more in inefficient or immature programs, organizations or production lines.

Reliability and maintainability numbers are usually reported as mean times (e.g., between failures, to first failure, to repair, etc.) on the order of hundreds of hours. Alternatively, reliability may be measured as mean miles, perhaps thousands, or as the probability of success. The last scale is limited to values of zero through one, but it is anticipated that products and processes perform toward the high end of that segment.

Scrap and rework figures, as well as many other cost and value indicators, are expressed as dollar totals. Deliveries of hardware, software, data, etc., are reported as raw frequencies and/or percent conformance to schedule. Current period as well as cumulative information is frequently prioritized by its recency to make its role more meaningful. Ratio information is also produced to meet management's needs; e.g., touch, direct, supervisory, and quality support labor. Time delays related to material procurement, handling, and disposition are found in management reports; usually expressed in time periods (hours, days, and weeks).

Conclusion

Data management can be considerably enhanced by the intelligent and practical application of statistical methodologies. This article has provided a brief overview of the vast array of quantitative and graphical techniques available for use in making better use of our extensive data bases. Interested readers are encouraged to refer to the list of references following this article.

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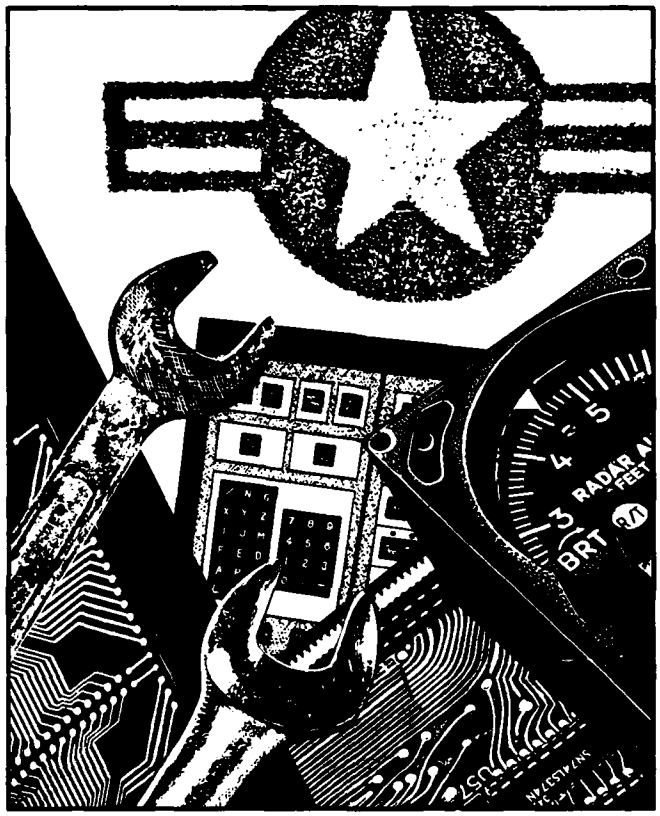
AN APPROACH TO IMPROVE ACQUISITION OF SUPPORT EQUIPMENT

Lieutenant Colonel Robert E. Schafrik, USAF • *Dr. Norma Hubele*

Dr. Dan Shunk *Mr. Leo Bernier*



For every $1 billion the Air Force spends for the acquisition of a major weapon system, $3-5 billion are typically spent during its lifetime to support it. A significant part of the logistics system is the equipment required for weapon system checkout, maintenance, and repair. This equipment ranges in complexity from relatively simple wrenches to complex computer-controlled test benches. It can be located on the flightline, in a base repair shop, or at a depot. This wide range of equipment is generally referred to as support equipment (SE).

For a major aeronautical weapon system involving many weapon platforms, literally thousands of line items of support equipment are required, generally at the three levels of maintenance mentioned above; flight line, intermediate shop or base level, and depot level.

The cost of support equipment can approach, or exceed, $1 billion during the weapon system's life cycle. The magnitude of this budget is not surprising if one considers, for example, that fighter aircraft are deployed at many bases throughout the world and have many complex subsystems (avionics, jet engines, weapons handling, etc.) which must be supported to sustain high rates of readiness.

Normally, the support equipment can be finalized only after everything else is designed, since its final configuration depends on the weapon system's final design and specific details of the maintenance approach. To avoid proliferation of individual items of equipment which perform essentially the same function, the military requires that existing support equipment be evaluated to determine if one could satisfy the requirement. The Air Force increasingly is "breaking out" the purchase of high-dollar value support equipment and items available in the commercial marketplace. This increases the management workload on the acquisition agency.

Many improvements have been made to the SE acquisition process; e.g., updating and computerizing the data base of existing SE (MIL-HDBK-300). But SE acquisition, from design to approval to contracting to manufacture, remains a labor-intensive process. Often, it operates under very real time constraints. The Air Force is developing a Support Equipment Master Plan (SEMP) as a roadmap for SE acquisition. This paper concerns a concept for a Support Equipment Decision Support System (SEDSS) which could provide automated tools to support the implementation of the SEMP. It could reduce the need for manpower-intensive activities required during the SE acquisition process by providing contractors with tools that could be used interactively during design and manufacturing planning, and by the government for assuring application of appropriate design methodology, aggregating orders of similar types of SE, etc.

The design process for a weapon system usually employs at least these four techniques to narrow the choices of design alternatives:

—Modify design constraints

—Select final design implementation from among alternatives

—Employ standard hardware components to greatest extent possible

—Describe standard hardware components by key functional characteristics.

These same ideas can be incorporated into the SEDSS. For instance, if a weapon system designer was aware early enough of implications of his design on cost and complexity of the SE, he could modify the design approach somewhat or alter functions that the SE was to accomplish, so that it could be simplified. An SE design engineer might modify specifications for an SE item if he was readily aware of the cost of each level of functionality of the SE and whether SE already existed, either slightly more capable or less capable than specified.

Issues

There are many management oriented barriers to developing a SEDSS. These include the high initial costs of developing and populating data bases, overcoming reluctance of designers to have more constraints added to their menu, establishing a suitable way to measure the extent of SE reuse, measuring productivity increase due to application of an SEDSS, and so on. Answers to these issues are influenced to a large extent by the technical solutions to the SEDSS. Central to the SEDSS concept are readily accessible and usable data bases. Thus, management and organization of these data bases are the most significant issues to be addressed.

The establishment of a complete library, to serve all users, containing all SE with all of its pertinent characteristics extending beyond what is currently available in MIL-HDBK-300, "Technical Information File of Support Equipment," would be a substantial undertaking. It may not be well advised for some time. A complex cataloging and retrieval system would be necessary to serve all users. It would be costly to develop and would require a long development cycle. A better approach is to narrow the domain sufficiently so that data bases do not become large and unwieldly, but large enough to incorporate a meaningful suite of SE.

Such a library could be implemented at different levels. A Level 1 library may be used at a particular location within a specific domain. A Level 2 library could encompass several locations, perhaps still belonging to the same organization, within the same domain. A Level 3 library might include several Level 2 libraries and, thus, have a broadened domain, and so on. In this way, the library system, (i.e., data bases) would be constructed incrementally while still providing near-term benefits. This approach requires a top-down architecture of the library so that various levels could be readily integrated later.

Populating the library entails application of well-defined guidelines to select data elements for the library. This process inevitably requires tradeoffs. For instance, large and more complex items of SE have a greater reuse payoff than smaller and less complex ones, but the domain of the application narrows appreciably and, thus, the chance of reuse is reduced. Some are too specialized, too large, or too small. Developing the boundaries of the SE before the data bases are designed is a significant issue.

Component descriptions are necessary to encode the key information represented by the SE. These descriptors must be complete enough so that the library search will not identify a large number of SE items which are not pertinent, but will not require an excessively long descriptor list either. A complete description must include information at all levels of abstraction available, from requirements and specifications at the highest level to engineering drawings and detailed cost information at the lowest level. Users of the system should not have to spend excessive time inspecting and evaluating a candidate item of SE.

A standard vocabulary should be established to describe various SE elements. An approach utilizing the group technology philosophy has worked well in manufacturing. For instance, a machined part can be described by a series of digits.

A library scheme is the cornerstone of SE reuse. The classification approach is the crucial factor in the effectiveness of the library. Data retrieval systems are naturally deterministic. On the other hand, document retrieval systems, based on abstract descriptions, tend to be probabilistic since the user cannot be assured that a given document will satisfy a request until it is examined. The SE retrieval falls somewhere between those two extremes. If the desired SE is described specifically, the retrieval process approaches the deterministic end of the spectrum; for instance, "retrieve all rigid boroscopes 10 inches in length." But if the features are described more abstractly, the retrieval process approaches the probabilistic end of the spectrum; for example, "retrieve all boroscopes capable of inspecting a gear about 10 inches inside a gear box, and which can sustain some amount of impact loading."

A probabilistic search increases the chance that a usable item of SE will be retrieved so long as the search attributes are relevant to the user's request and are available as coded attributes of the items in the collections. However, the user must be able to easily understand and evaluate the retrieved SE. An SE library should be capable of providing the user with different levels of documentation matched to the user's interest.

Once an item is selected, the user could either use the item as is or modify it to suit the new application. Modification could involve specification of the item, and physical changes to the SE.

From the above discussion, these components are necessary to provide an automated system geared to the use of existing SE:

—Library of SE with pointers to detailed documentation, such as engineering drawings, specifications, etc., which reside in a data base.

—Classification scheme that provides framework for placing items in the library, and for building queries and conducting SE retrieval searches.

—Decision support systems which facilitate user access to library information, and assist in selection process. The system should guide user through the classification scheme to choose the most appropriate terms for the query. The system should apply a logical set of rules to rank order the retrieved items of SE.

Decision Support Systems

Decision Support Systems (DSS) provide computer based support for decision-makers dealing with structured and semi-structured problems at organizational levels in all phases of design, manufacturing, scheduling, deployment, and follow-on support. Decision processes predictable and well understood are referred to as structured. These processes are easily automated and historically have been the major focus on computerized applications. Design analysis and status reports are typical examples of structured decision processes.

Intuitive decision processes are referred to as unstructured. They are naturally difficult to characterize and cannot be completely described because they are not well understood in advance. Those decision processes which follow logical rules but which cannot be completely defined are called semi-structured. Cost/design feature trade studies and detailed job shop scheduling in manufacturing are examples of semi-structured decision processes.

Computers are effective in supporting structured decision processes, whereas human interaction with the computer is essential in dealing with semi-structured decision processes. Two essential features of a DSS are extendability and user friendliness. These are important for the following reasons:

—The DSS must be capable of being developed and tested incrementally once the overall system architecture is defined; i.e., top-down architecture with bottoms-up implementation.

—The DSS must be capable of being adapted to many different aerospace environments since users will include a number of system program offices, depots, and the aerospace industry.

—The DSS must support a number of users, ranging from SE managers, to design engineers, to manufacturing engineers, cost estimators, etc.

—User friendliness is essential because the DSS will never be used to its potential, regardless of its capability, if users find it difficult to understand and to use.

Development Cycle

A rigorous development process must be followed to assure a computer-based system meets needs of users, in a way that makes the system fairly easy to use and maintain. The life cycle of a system can be considered to be composed of these phases:

—Needs analysis
—Requirements definition
—Preliminary design
—Detailed design
—Construction and verification testing
—Integration and validation testing
—Implementation and user acceptance
—Maintenance and support.

Proceeding step-by-step through the life cycle will help ensure the completed system performs as expected. The process can be lengthy and expensive. Software development costs can be minimized and risks reduced by building a rapid prototype system which uses software modules easily adapted from existing software already in use in other applications, such as Computer Aided Design and Computer Aided Manufacturing (CAD/CAM). Such an approach requires building a comprehensive top-down architecture, not only to assure that the users' requirements are being adequately supported but to allow for the efficient adaptation of existing software. The Needs Analysis and Requirements Definition phases are particularly important.

Architecture

A crucial element in developing a useful DSS lies in a properly constructed architecture. The system architecture becomes the framework which explicitly defines fundamental relationships between elements of the system, such as: functional interfaces, identification of common, shared, and discrete information; and the dynamic interaction of resources. Large software systems absolutely require the understanding and management of complexity. An architecture not only helps the user develop requirements, but can assist system designers in addressing such issues as:

—How should the large system be broken into modules?

—What information should be exchanged among modules?

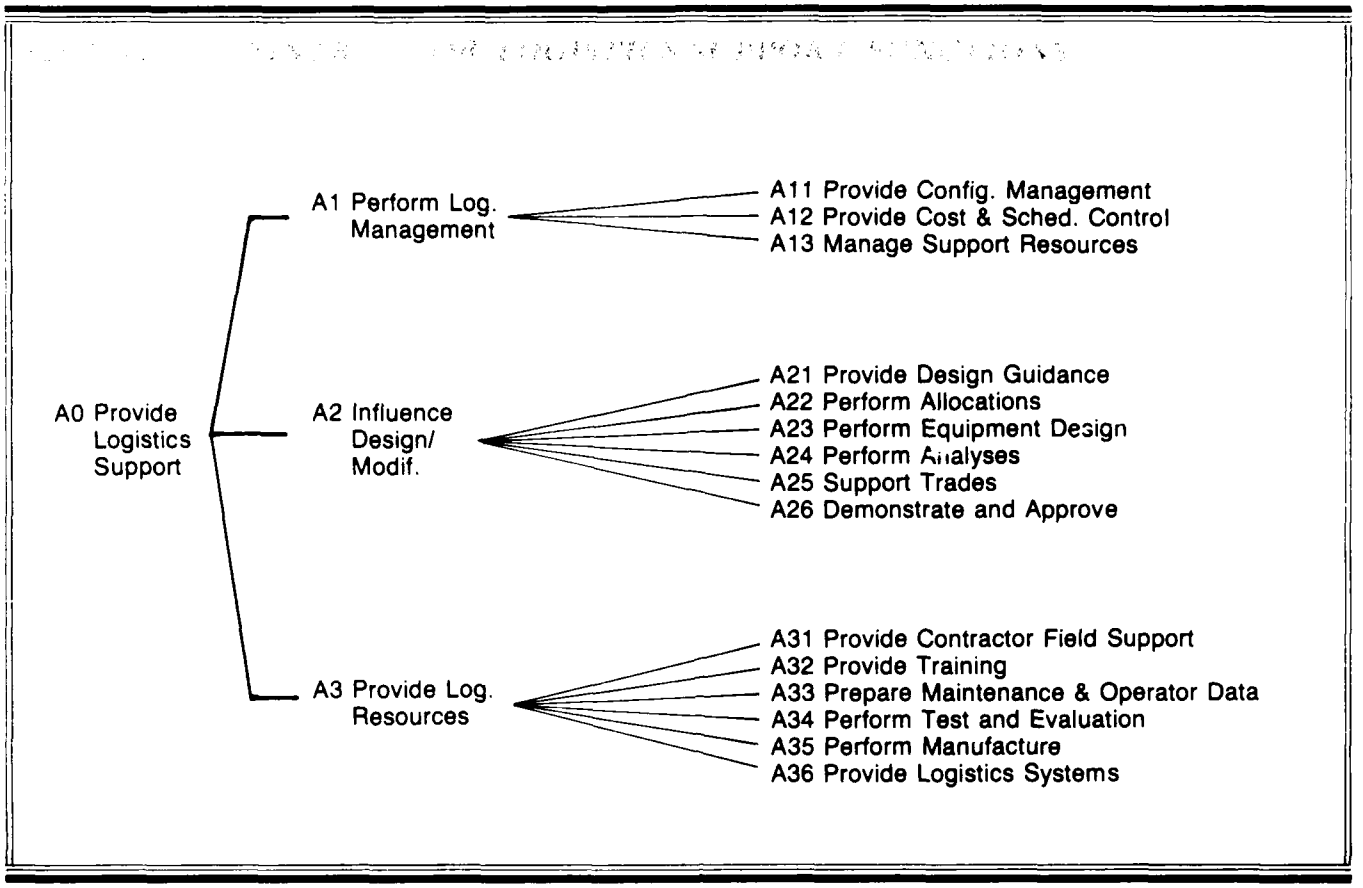
—Can an existing software module be slightly modified to serve in the new application?

Interface definition, ambiguity resolution, management visibility, and constancy of assumptions are essential for the design of efficient software systems.

Our experiences indicate the Air Force ICAM (Integrated Computer Aided Manufacturing) Definition (IDEF) methodologies are useful in defining the system architecture. The first tool, IDEFO, is known as the Functional Model. It is essentially composed of a set of modeling principals, information gathering procedures, and graphic notations. Graphic notations include a Node Tree which depicts the hierarchical relationship between functions, and Input/Output-type diagrams which display relationships between functions on the Node Tree. It is a robust tool and has been used successfully for many applications in addition to manufacturing, such as by the Department of Defense study group on Computer Aided Logistics Support (CALS).

The second systems engineering tool is IDEF1, the Information Model. This model captures the classification and relationships between information used by the functions described in the IDEFO model. It consists of entity classes (real and conceptual objects and data), attribute classes (properties or characteristics possessed by an entity class), and the relationship between two or more classes. Extensive use has been made of IDEF1 in the development of data bases.

The IDEF2, the Dynamics Model, captures the behavior of functions interacting with the information over a period of time so that meaningful measures of performance can be obtained. This simulation capability



facilitates the construct of large, integrated computer-based systems.

These IDEF models can represent the logical architecture of the system being modeled. They provide an efficient framework in which the information gathered during the Needs Analysis phase of the program can be organized and analyzed.

Needs Analysis

Extracting the functional specification from the user is often a major challenge. The user rarely knows exact requirements. A fundamental problem of requirements definition is capturing a "view" of the requirements and transposing it to a medium that can be clearly communciated and effectively analyzed. A primary goal of requirements analysis is creation and documentation of an understanding of the requirements by all participants. Data from the development of large scale computer systems indicate that analysis and design errors are, by far, the more costly and crucial types of errors; these typically are not detected until late in the life cycle when the cost to fix them can be as much as 100 times the cost of fixing them during the requirements analysis phase. It has been estimated that for some large systems, the correction of fundamental design errors over the life cycle accounts for as much as 50 percent of the life-cycle cost. The IDEFO, together with rapid prototyping of the system, can enhance the user's ability to communicate requirements to the developer.

The proper introduction of support equipment into the Air Force inventory requires careful interaction between the contractor and the government during two interrelated processes: the Integrated Logistics System (ILS) and the Support Equipment Recommendation Data (SERD) procedure. The ILS is the process of integrating support considerations into system design, developing and acquiring support elements, and providing required support during the system operational phase. The SERD process, actually a subset of ILS, is a formal procedure by which the Department of Defense reviews contractor recommendations for SE and determines types and quantities of equipment to be purchased.

Contractors provide three important functions during the SE acquisition life cycle:

—Management of support equipment acquisition process

—Technical interaction with weapon system designers

—Provision of logistics resources.

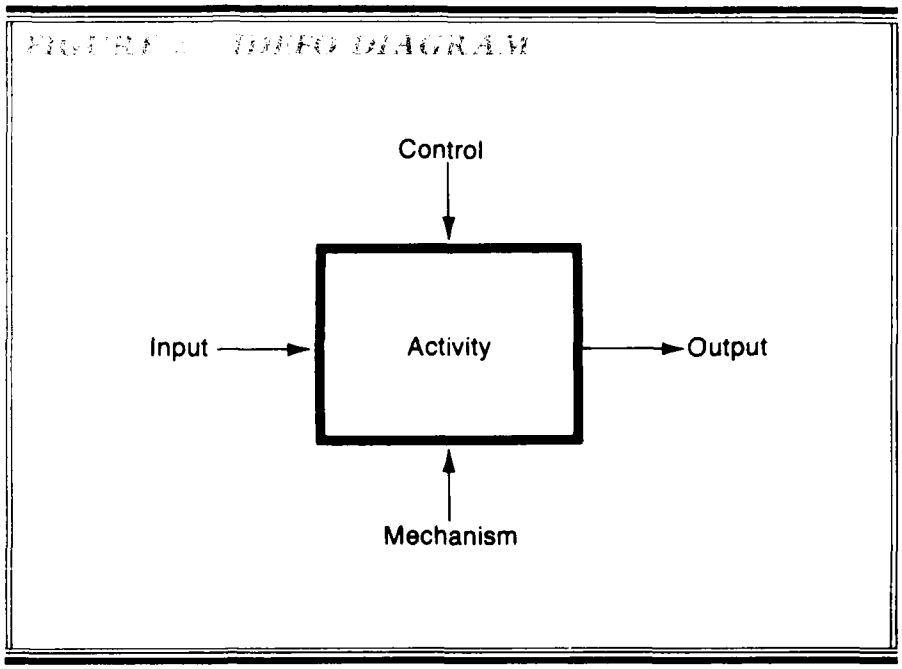
Each of these activities can be further broken into subactivities. Figure 1 is a node tree depicting the activity hierarchy for the contractor's role. It is depicted in one of the IDEFO formats. An IDEFO model should start with a declaration of the purpose of the model, the explicit viewpoint taken (e.g., user perspective, system developer point of view, etc.), and context of model. This minimizes ambiguities and facilitates reconciliation of different perceptions. As shown in Figure 1, the principal activity being modeled is labeled AO. It can be further broken down, or decomposed, into as many as six activities, A1 through A6. Likewise, A1 can be decomposed into A11 to A16; A11 can be broken down into A111 to A116, etc. Of course, an activity need not be decomposed into 6 activities if fewer activities are sufficient. An activity is described by an action verb with an object.

Now, each activity generally has information input into it, with output

from it. The activity, or function, changes the input information into the output information. The graphical depiction of the interrelationship of activities, inputs, and outputs constitute another level of the IDEFO diagram, such as shown in Figure 2. By convention, the Inputs are shown entering the activity box from the left, and the output exiting the box to the right. Also, every activity must have a control which serves as the executive. Controls are the rules, performance criteria, and evaluation data which direct an activity in the accomplishment of its mission. Controls are shown entering the activity box from the top.

Activities can accomplish their mission through the application of resources. If it is useful to indicate the mechanisms on the IDEFO model, they are shown entering the activity box from the bottom. For example, a mechanism could be a particular software package.

An important feature of IDEFO diagrams is that they gradually introduce greater and greater levels of detail through graphical representation. This enhances communication by providing a well-bounded topic in an easily understandable format.

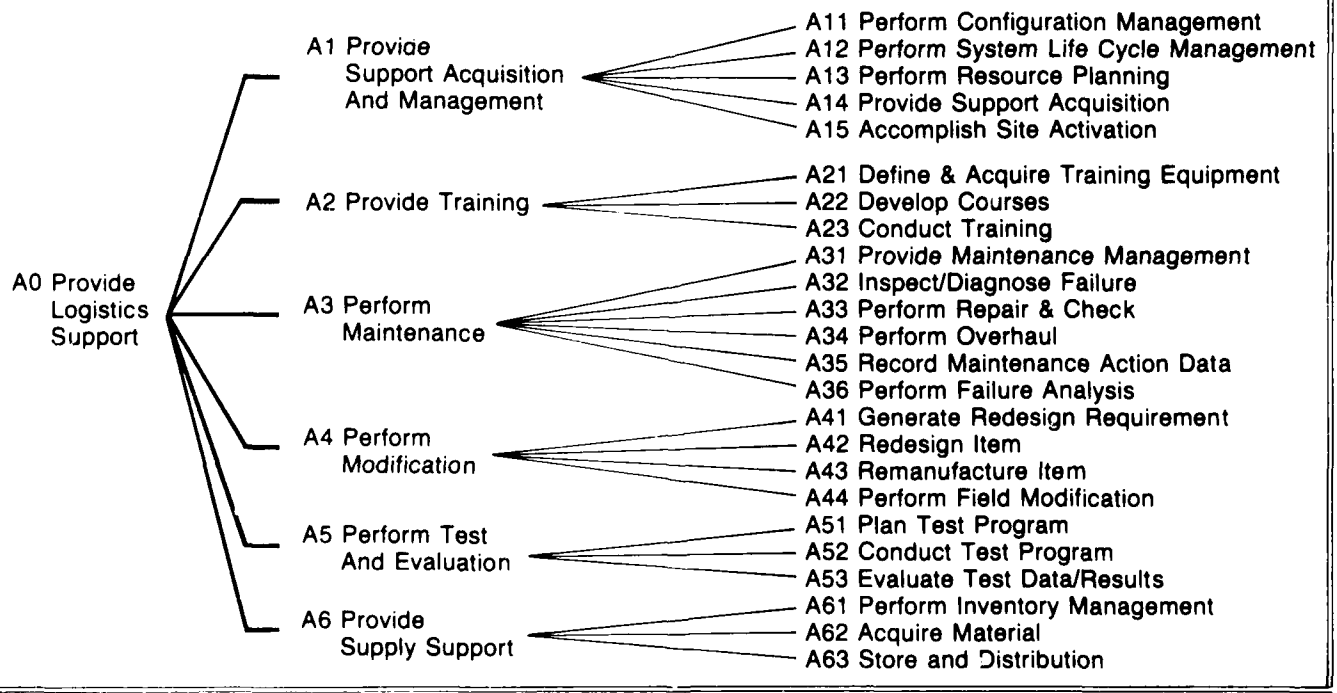


Government personnel perform some activities that parallel those of the contractor, and some which are unique. A node tree for DOD Logistics Support Functions is shown in Figure 3.

A structured model of the activities performed by the contractors and government decision-makers can be the basis to define key decision points where a Support Equipment Decision Support System can be useful. It can provide the blueprint for the construct of such a system.

Proposed System Architecture

The SEDSS can be viewed as comprising three subsystems. The Data Base Management System (DBMS) provides for management of data structures that will be required. Organization of the data bases will be discussed in detail in the next section.



The Model Base Management System (MBMS) provides the analysis and interpretation of the data in accordance with the problem posed by the decision-maker. The MBMS would be tailored for specific users, such as the SE designer, manufacturing planner, and SE manager. The MBMS could include SE design retrieval to a user-defined specification, application of multi-attribute utility theory to rank order equipment features, preliminary cost estimates based on cost element drivers, status tracking of ordered equipment, and so on. The MBMS would be constructed to provide feasible alternatives for a problem faced by a decision-maker.

The third component of the SEDSS is the interface with the user, the Dialog Generation and Management System (DGMS). This system, tailored to specific user requirements, presents the SEDSS outputs to the decision-maker, and acquires and transmits user inputs to the DBMS and MBMS. Possible dialog formats would include menus, spreadsheets, graphs, tables, etc.

The proposed SEDSS would be distributed geographically. Data bases would not reside at a central repository, but would be linked through a communications network that was transparent to the user. The MBMS and DGMS would be com- posed of modules to satisfy requirements of specific decision-makers. The use of top-down architecture, combined with rapidly building and demonstrating a prototype system to a user, can ensure the result is what the decision-maker requires. The natural modularity of the architecture readily lends itself to incremental implementation.

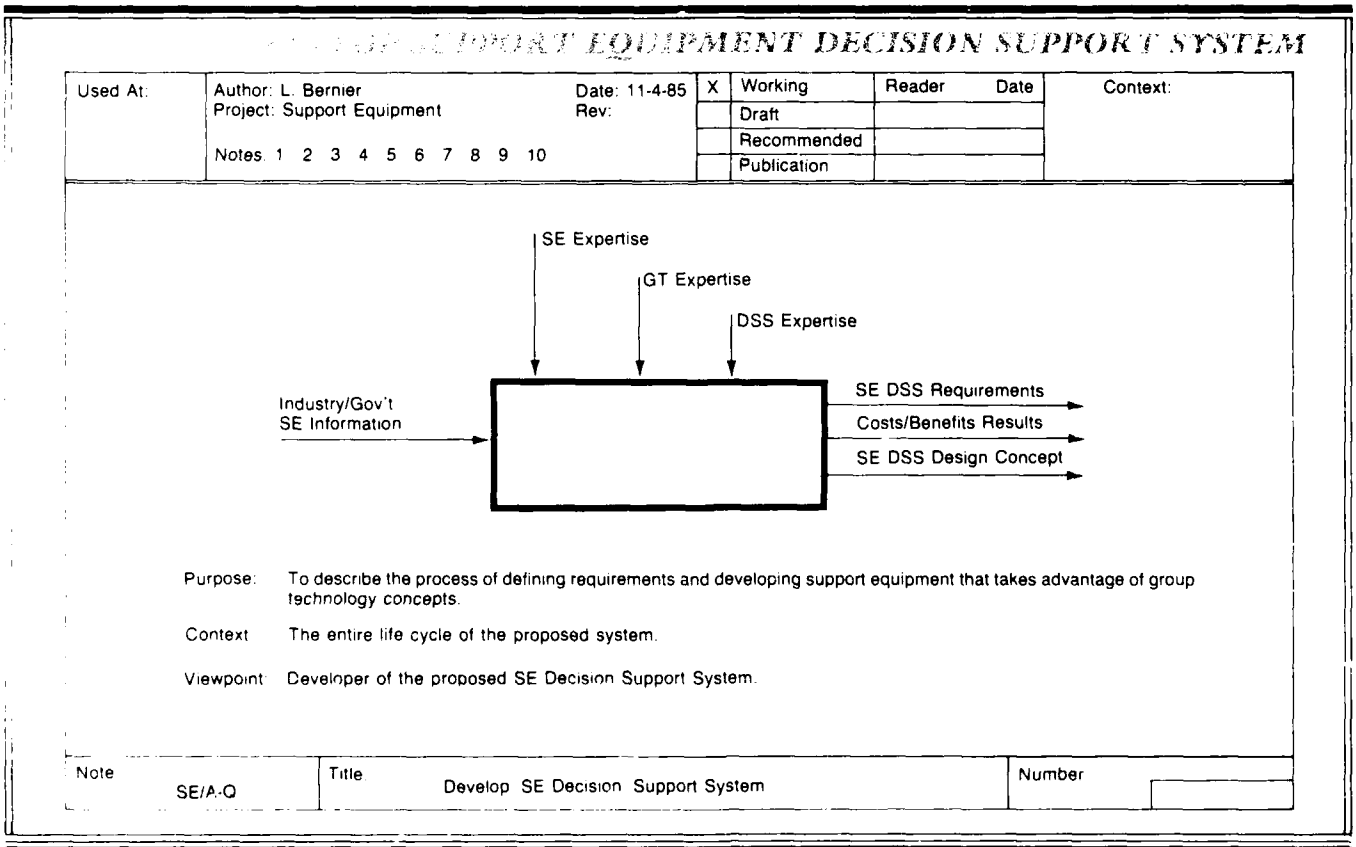
A high-level IDEFO diagram of this process is shown in Figure 4. Further decomposition of this diagram, if done in conjunction with developers and users, would provide a coherent view of what the SEDSS should do and how to achieve it. This attitudinal solidarity among the many government and industry users of SEDSS will be critical to its success.

Ideally, the system would be independent of the type of computer equipment and operating system at the user's facility. This would allow users to select disparate communication networks. The system would be user friendly, requiring minimum computer literacy. The system would be menu-driven with multiple forms of output.

Proposed Classification and Data Base Scheme

Fundamentally, solving the SE information puzzle requires the right information to be identified, organized, and made available so that it is readily usable by the decision-maker. For example, an SE designer needs information from many weapon systems to discover whether existing SE can be used on the current project to avoid designing a duplication to an existing design; or, whether a modification to an existing design is reasonable. An SE manufacturing manager can use detailed information about SE characteristics to plan an efficient manufacturing process rather than make repeated, costly small-batch runs.

Group technology (GT) can be used to organize this information in relational data bases, text files, and



graphic data bases so that users can easily retrieve and apply relevant analysis tools.

Once data are organized, they can be loaded into a base where a Group Technology Support System (GTSS) can be used to perform basic functions of creating, modifying, accessing, and deleting information in the data base.

Classification, used in the GT context, relies on the basic principle of developing the system from the user's point-of-view. Since there are many users whose needs must be met for the SEDSS, broad categories of information are suggested to capture the depth and breadth of the required information. As discussed, both enumerative and faceted classification approaches should be considered. Figure 5 depicts data files currently existing for most aeronautical weapon systems that affect support equipment, and which are candidates to be included in the data base.

The proposed classification scheme centers around the principal attributes of the SE. The scheme's purpose is to provide a consistent communication tool for identifying SE. The communication tool would differ from user to user; i.e., a design engineer requires different information in a different form than that needed by a manufacturing engineer or a purchasing agent. Supplemental attributes required by different users should be stored in the data base so that each user would receive only the information needed in the most useful form.

To provide a data system that is flexible and expandable for both volume and application of information, SE classes already used in MIL-STD-846B should be used to iden-

ENGINEERING	MANUFACTURING	LOGISTICS
Reference Data/Methods Explicit Historical Design Data Design Handbooks and Guides Design/Analysis/Test Methods Customer Operations and Inventories Supportability Design Data/ Methods Data Handling Methods Manufacturing Methods/ Facilities Test Facilities *Computational Facilities* Design Development Design Development Plans Mission Analysis Results System/Subsystem/Component Specifications External Geometry (Loft) Aerodynamic Analysis Results Propulsion Analysis Results Structural/Design/Analysis Results System/Subsystem/Design/Analysis Results Development Test Results Product Definition Production Design Plan Individual Job Analysis Job Assignments Engineering Drawings Change Definition/Control	Reference Data/Methods Explicit Historical Manufacturing Data Planning Manuals Process Specifications Job Instructions Tool Design Standards Manufacturing Work Breakdown Structure Facility Inventories Inspection Manuals Product Definition Engineering Drawings Composite Drawings Major Assembly Sequence Charts Tool Designs Production Facilitating Operation Sheets Set-Up Instructions Set-Up Drawings Tool Orders Standard Tool Requests Parts Lists Composite Lay-Up Instructions Product On Operations Manufacturing Orders Production Routing Documents Production Assembly Documents Quality Documents (Parts and Tooling) Engineering Change Notices Manufacturing Change Notices Spare Parts Requests	Reference Data/Methods Explicit Historical Logistics Data Government Furnished Field Data Maintenance Data Collection System, AFR 66-1 and Supply Data, AFR 67-1 Visibility and Management of Operating and Support Costs, VAMOSC Air Vehicle Status Management System, AFM 65-110 Air Force Planning Factors, AFD 173-13 USAF Recoverable Consumption Items Requirements System, D04 *Aircraft Battle Damage Repair Data* Lessons Learned Documents Weapon Systems Environment/Use/Support Projection Reports Government Facilities, Parts and Support/ Test Equipment Inventories Logistics Related Government Standards/ Specifications National Stock Numbers Government Furnished Simulation Models Private Simulation Models Measures of Effectiveness and Related Algorithms Design Support Design Evaluation Methods Specific Supportability Data/Methods Supportability Factor Allocation Methods Reliability Testing Procedures Maintenance Demonstration Procedures Failure Mode and Hazard Analyses Procedures Product Definition Engineering Drawings Replaceable Unit Identification Lists Reparable Item Identification Lists Reliability Test Results Maintenance Analyses Results Fault Tree Analyses Results Failure Modes/Effects Analyses Results Hazard Analyses Results Customer Operating Support Maintenance Manuals Battle Damage Repair Handbook Provisioning Recommendations *Training Recommendations* Support Equipment Recommendations Breakout Procurement Packages Contractor Support Plan Field Operation Tracking Field Service Reports Contractor Support Performance Reports

tify *function* as the major attribute to subdivide all SE. A proposed classification scheme is shown in Figure 6. Performance characteristics should be subclasses of information. Depending on the function of the SE, the proposed system would further classify an item by part characteristics and provide broad categories of information, such as supportability data.

A schematic of the integrated distributed data bases is shown in Figure 7. As can be seen, eventually the total data base would comprise numerous data bases including industrial and government data bases like the Logistics Support Analysis Requirements (LSAR) and Lessons Learned data bases, housed in different locations. Initially, different data bases may be housed in different locations within the same facility but, as the system is expanded, data bases certainly would be geographically dispersed. The key point is that the user would have access to the system's information at the individual work station. For all practical purposes the fact that the data bases are distributed should be transparent to users; that is, a user should not need to know where the data is stored because tasks should be able to be performed if data were available locally.

The system designer would rely heavily on advanced computer communication technology. The system data base would consist of four types of data bases linked together: GT, graphic, relational, and text. These

FIGURE 6. TENTATIVE CLASSIFICATION SCHEME

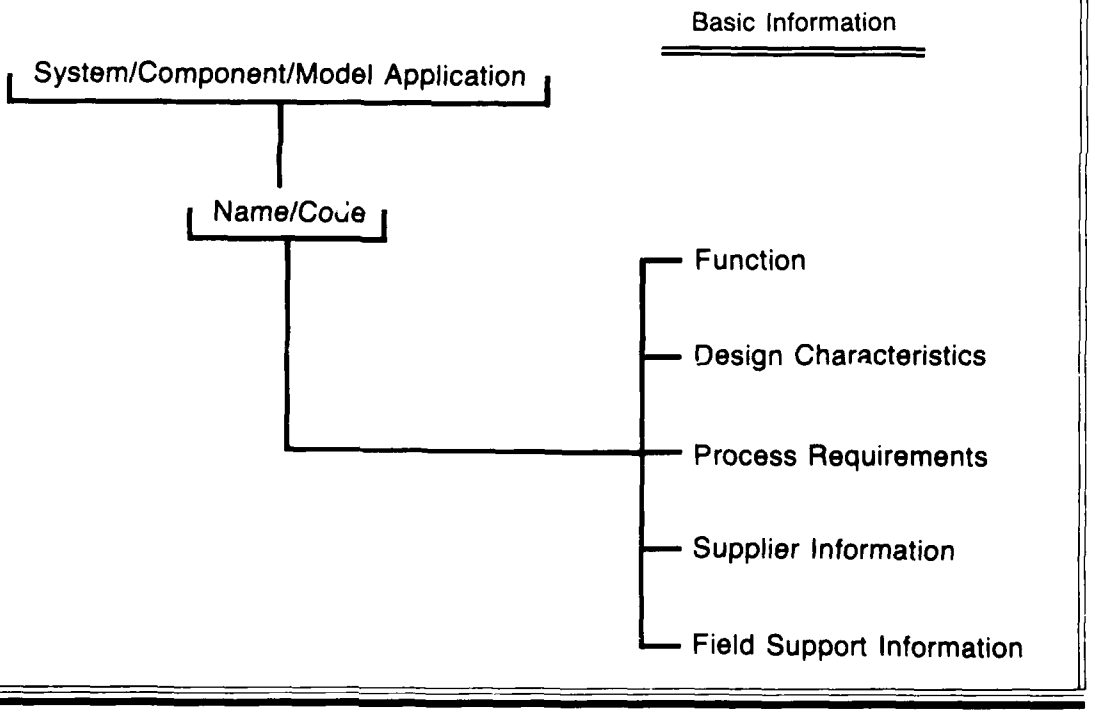


FIGURE 7 NETWORKING CONCEPT

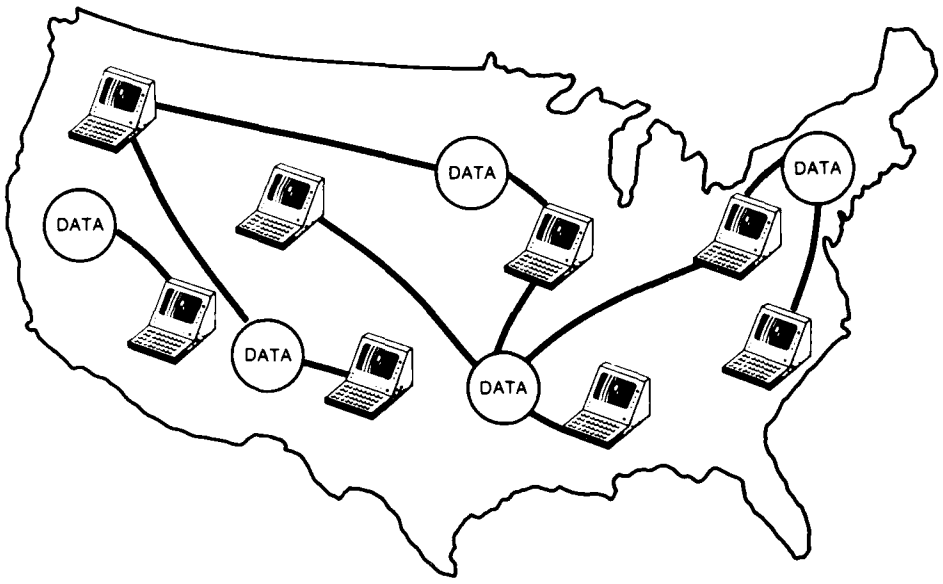
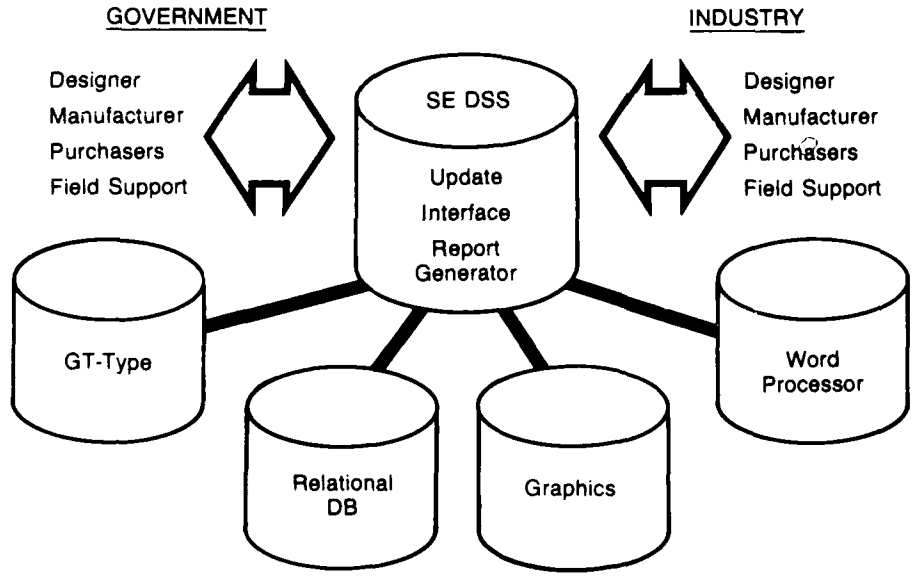


FIGURE 8 DISTRIBUTED SYSTEM CONCEPT



data bases would be heterogenous within themselves (each may comprise other data bases linked together) and among themselves (different types of data bases may be located on different systems). Some of these data bases may have to be built from the bottom up, while others could be readily adapted from existing data bases. Figure 8 is a schematic of this concept.

The communications link would have to ensure data integrity and reliable delivery of information in a timely fashion. The communication network would have to link each user to every other user to optimize information utility, and it would have to be reliable with a rapid response. It should be able to accept read and write access to make retrieving and updating

of information easy. A security system for accessing information would have to be employed since some of the data may be company proprietary. A central, controlling query processing site would not be required since each site would be capable of performing all operations.

Conclusion

Substantial savings can result from streamlining the SE acquisition process. A preliminary investigation indicated the following area of potential benefit for a SEDSS:

—Parts range in commonality of function from between 5 to 80 percent, depending on the type of equipment.

—Design time can be reduced 25 percent.

—Manufacturing operations are common for 20 to 80 percent of the parts produced.

—The SE purchasing time can be reduced 20 percent.

A Support Equipment Decision Support System can substantially improve productivity of the SE acquisition process. Development of the SEDSS must be oriented toward supporting the users' decision-making requirements. It should follow a well-structured approacn, making full use of the vast array of systems engineering tools and techniques. The system should be planned with a comprehensive top-down architecture, but be capable of being implemented bottoms up as a series of enhancements to the SEDSS. It should optimize the application of computers for tasks in which computers are best suited, such as repetitive computations and data searching, and allow human decision-makers the freedom to employ creativity and logical analysis. The construction of a prototype system to demonstrate the various SEDSS capabilities would provide valuable information for system design refinement.

Examples of how the system could be used follow.

Design engineers could search a data base for items of equipment which could perform a desired function subject to a list of constraints. Designers could effectively identify cost drivers in the design, and perform design/cost trade studies using historical cost information keyed to cost driver elements in the design.

Manufacturing and industrial engineers could use the data base to standardize tools and equipment, thereby reducing number of items manufactured. The make-buy decision could be made more effectively. Flexible manufacturing work cells and work centers, specializing in families of equipment, could be developed. These could all be manual labor and be totally automated or be semi-automated.

Program management would be able to reduce its considerable oversight of the SE process without sacrificing confidence or integrity in the process. Cost comparison of SE performing similar functions could readily be made across weapons systems. A formal and easily accessed corporate memory for SE could be established within the Department of Defense.

A significant issue is the implementation and maintenance cost of the proposed system. The next phase of the investigation should address the question: Given that the SEDSS is technically feasible, which elements of it are worthwhile? This question can be answered best by building and evaluating a prototype system.

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